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Coated Stainless Steel Gas

Coefficients on the Temperature

Highlights

The Configuration of Solar Sail

Fluid Dynamics and Experimental

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Computational Fluid Dynamics and Experimental Analysis of a Coated Stainless Steel Gas Turbine Blade

By Leandro Augusto de Souza, Elisângela Martins Leal,
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Abstract- This Work Aims to Analyze, Through Computational Fluid Dynamics (Cfd) With the Concept of Conjugate Heat Transfer (Cht), the Effect of the Thermal Barrier Coating and the Cooling System on an Austenitic Stainless Steel Blade in Order to Evaluate the Temperature Behavior of the Material. Although this Steel Has a Lower Cost Compared To Super alloys, It has Similar Properties, Such as the Thermal Expansion Coefficient, Chemical Affinity and Melting Point. this Evaluation used Ansys® Cfx Software to Solve the Numerical Problem. the System is Validated by Comparing the Computational Results to an Experiment. Gas Turbine Blades have a Low Weight and an Elevated cost. this cost came Mainly from Both the Material used and the Sophisticated Coating and cooling Method. Thermal Barrier Coatings Associated to a Cooling System are Employed on Gas Turbine Blades to Increase the Lifetime of the Blade and the gas Turbine Performance.

Keywords: gas turbine; blade; computational fluid dynamics (CFD); stainless steel; conjugate heat transfer (CHT); thermal barrier coating (TBC).

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Computational Fluid Dynamics and Experimental Analysis of a Coated Stainless Steel Gas Turbine Blade

Leandro Augusto de Souza ^α, Elisângela Martins Leal ^σ Adilson Rodrigues da Costa ^ρ
& Milton Sergio Ernandes d Lima ^ω

Abstract- This work Aims to analyze, through computational fluid dynamics (Cfd) with the concept of conjugate heat transfer (Cht), the effect of the Thermal Barrier coating and the cooling system on an Austenitic Stainless steel blade in order to Evaluate the Temperature Behavior of the Material. Although this Steel has a Lower cost compared to Super ALLOYS, it has Similar Properties, Such as the Thermal Expansion Coefficient, chemical Affinity and Melting point. this Evaluation used Ansys® Cfx Software to Solve the Numerical Problem. the System is Validated by Comparing the computational Results to an Experiment. Gas Turbine Blades have a low weight and an Elevated cost. this cost came Mainly from both the Material used and the Sophisticated coating and cooling Method. Thermal Barrier Coatings Associated to a cooling System are Employed on gas Turbine Blades to Increase the Lifetime of the Blade and the gas Turbine Performance. the study Indicates that the Thermal Barrier coating and the cooling System were Efficient At Reducing the Temperature of the Metallic Substrate By 160°C. this can Indicated that Stainless steel Blades can be used in gas turbines where the Metallic Temperature limit was not be reached.

Keywords: gas turbine; blade; computational fluid dynamics (CFD); stainless steel; conjugate heat transfer (CHT); thermal barrier coating (TBC).

I. INTRODUCTION

Nowadays, gas turbines are used for power generation, mechanical drive, aircraft and marine propulsion [1-3]. In this sense, the gas turbine performance must be improved. Increase of 1% in turbine efficiency can mean millions of dollars in savings for the electric power producer, thus providing electricity to its customers at a lower cost [4].

From the thermodynamics viewpoint, the gas turbine performance can be improved mainly in two different ways, increasing both the turbine inlet temperature and the efficiency of the gas turbine

components. The turbine inlet temperature is related to the blade material [5, 6] and the limiting factor has been associated with the working temperature of the blade material.

The increase in the turbine inlet temperature means the request of using super alloys associated with a sophisticated thermal barrier coating and advanced cooling methods. Many research centers are looking to develop new materials, new thermal barrier coatings and more efficient cooling systems in order to increase the efficiency of gas turbines [7]. Figure 1 shows the cooling system used in this research work for the experimental study.

In addition, the gas turbine blade operates in a harsh environment, where the components are subjected to corrosion and oxidation, centrifugal forces, high gas pressure, high gas velocity, high turbine inlet temperature and thermal and mechanical cycling, including fatigue and creep. All these issues are related to the most common failures in the turbine blades [8].

In this context, the thermal barrier coatings (TBCs) are used not only to increase the turbine inlet temperature but also to extend the turbine blade lifetime [9]. TBCs have a complex multilayer structure, which usually consists of four layers: top coat (TC), thermally grown oxide (TGO), bond coat (BC) and metallic substrate. TGO is formed between TC and BC due to reaction of oxygen and the aluminum present in BC [10]. Figure 1 shows this multilayer structure.

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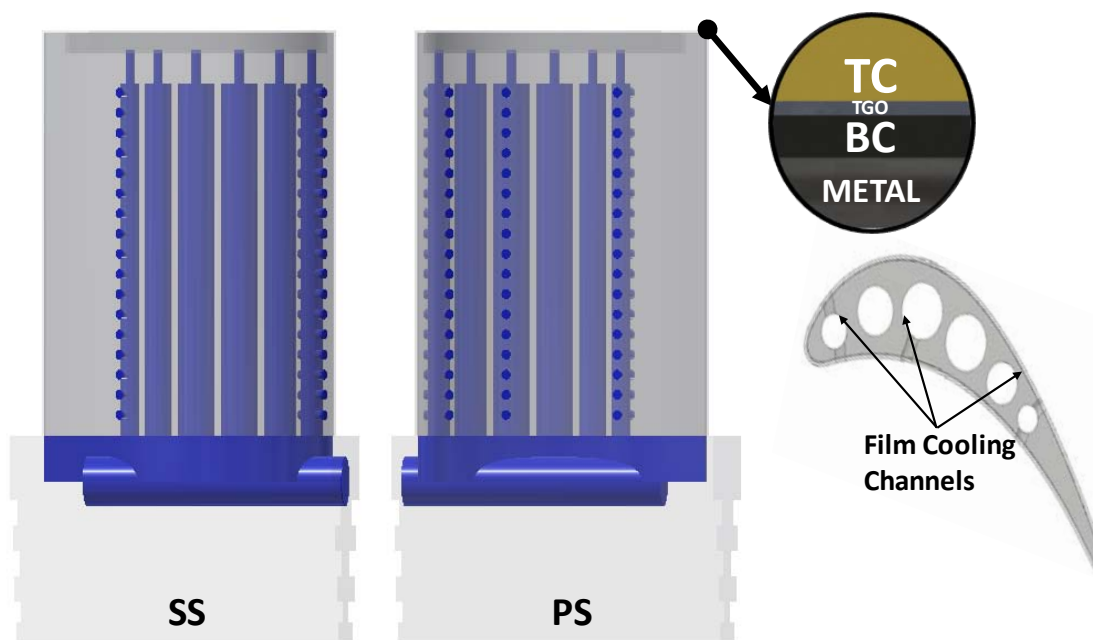


Figure 1: Blade Cooling System and Thermal Barrier Coating Layers.

The cooling system uses the compressor bypass air, which is at a relatively lower temperature than the gases from the combustion chamber. This air flows through the internal passages in the blade or through the skin and ejects into the hot gas mainstream to protect the blade surface from the hot mainstream gases. This process creates a thin film of the coolant fluid (called film cooling). Figure 1 also shows the coolant fluid path inside the blade [11].

Therefore, the metallic substrate is kept below the allowable temperature by using the cooling system and the thermal barrier coating [12]. In consideration of the commercial importance, the heat balance between the coated turbine blade, the cooling system, and a given intake temperature has been subject of many computational simulations.

The simulation of a turbine blade is a complex 3-D problem, which requires a multidisciplinary approach, including fluid dynamics and structural analysis. For example, in the cooled turbines, the blade temperature can be calculated simulating the internal coolant fluid, external hot gas and metal conduction simultaneously by the conjugate heat transfer (CHT) method. The CHT method produce a more accurate approximation to the convective heat transfer, and thus the temperature could be predicted more accurately. This problem can be solved by determining the flow of the fluid around the blade, the fluid-solid interaction and the turbine blade response to thermo-mechanical loading [13-15].

The restrict conditions for the static analysis occur when the parameters such as speed and temperature are in a steady state, the turbine is in full operation, and has a certain equilibrium, where there are

no variations with time. However, from this analysis it is not possible to state its behavior at the start and the shutoff of the engine, or when there are variations in the time of some parameter [30].

Several researchers have applied the conjugate heat transfer on turbine systems. Bohn et al. [16,17] made conjugated calculation in a turbo machinery and investigate leading edge film cooling. Bohn et al. [18] shows that the conjugated calculation gives a more accurate temperature distribution and the predicted life span of the component is more plausible.

This work aims to analyze through computational fluid dynamics (CFD) with the concept of conjugate heat transfer (CHT), the effect of the thermal barrier coating of an austenitic stainless steel gas turbine blade. Although this steel has a lower cost compared to super alloys, it has similar properties, such as the thermal expansion coefficient, chemical affinity and melting point [19-21]. Thus, the stainless steel AISI 304 and AISI 316 can be used as a blade alternative substrate. An experiment has been performed where the turbine blade was placed in a furnace, simulating the gas turbine work environment in order to validate the results of the simulation.

II. METHODOLOGY

a) Materials

The metallic substrate used in this work consisted of the stainless steel AISI 316. The stainless steel blade was shaped by machining, and the final dimensions are shown in Figure 2. The TBC consisted of a layer of Ni Cr AlY as the bond coat and an yttria-stabilized zirconia (YSZ) as the top coat. All coatings were deposited using combustion thermal spraying.

b) Computational domain and numerical model

The shape of the rotor blade was based on a GT-100 gas turbine design [22]. The blade has six coolant passages, a constant cross section, to allow film cooling. The blade has 85 holes on the pressure and suction surfaces. The construction details are shown in

Figure 3. In this paper, multiple layers were added over the metallic substrate, i.e. the bond coat NiCrAlY was added upon the metallic substrate and the top coat YSZ was added upon the NiCrAlY. The thicknesses of the BC and TC were 100 μm and 500 μm , respectively, in accordance with Clarke et al. [23].

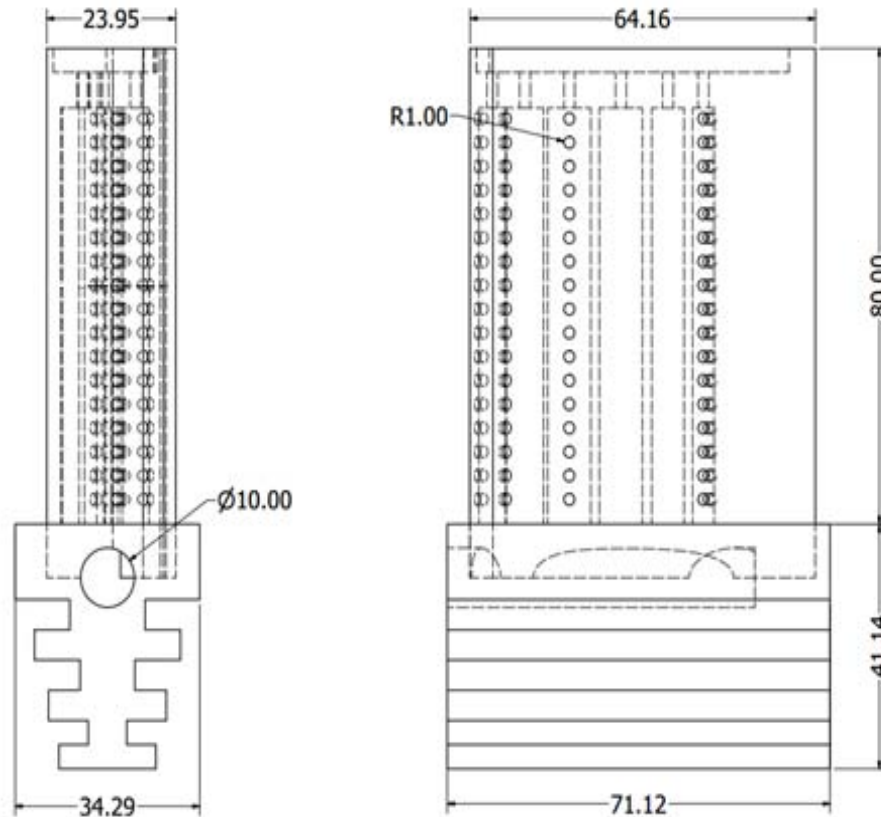


Figure 2: Blade main dimensions (mm).



Figure 3: Rotor blade with film cooling channels.

The section of the 3D computational multi-block grid mesh of the gas turbine blade is shown in Figure 4. This figure shows the elements of the solid domain, where the orange layer is the top coat, the green layer is the bond coat and the gray part is the stainless steel. The fluid domain is also shown in Fig. 4. The computational domain is comprised of the fluid regions around and inside the blade and the solid material domain of the TBC and the metallic substrate. Both tetrahedral and hexahedron cells are applied at the interface between the external fluid/YSZ and internal fluid/substrate. The grids of the interface between the solid domain and the fluid domain surface must be the same, and to improve the viscous boundary layer, the y^+ was close to one [24]. The total number of cells is 7,292,331, including 3,611,007 cells in the fluid domain and 3,681,304 cells in the solids domains (metallic substrate and the thermal barrier coating).

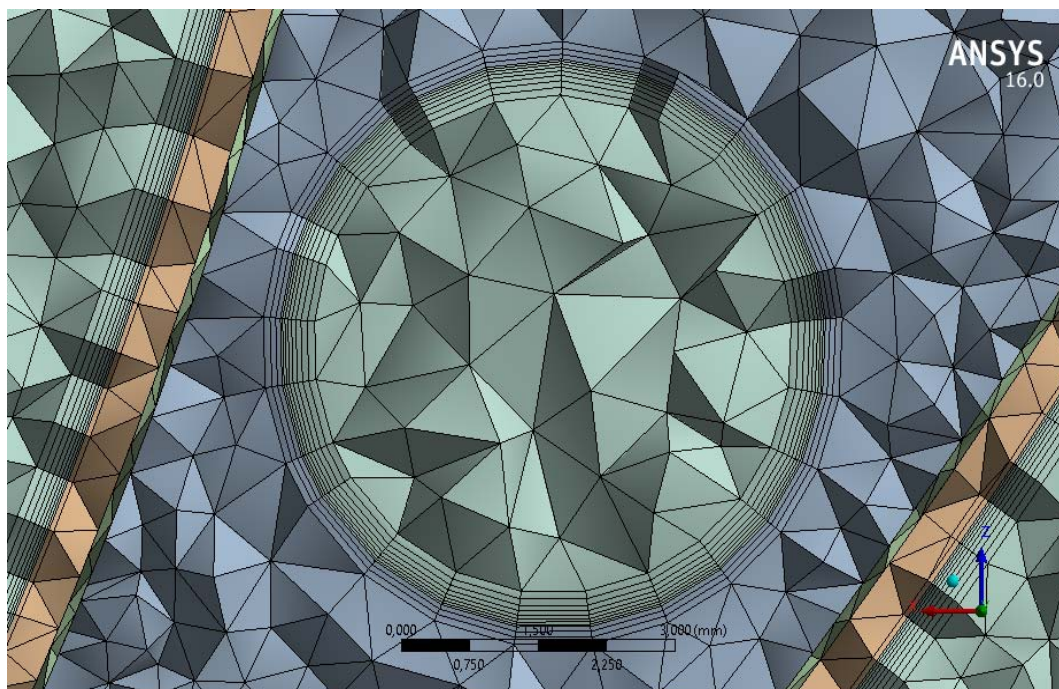


Figure 4: Representation of the 3D mesh section with the solid and fluid domain.

The numerical analyses were performed using the commercial software ANSYS CFX V.16.0, based on the finite volume method, and applying the CHT method. A steady-state analysis was fulfilled using shear stress transport turbulence model, also known as SST k-omega model, considering boundary transition and the perfect gas law was used as the equation of state [25].

c) *Governing equations – CFD Problem*

The governing equations for the computational fluid dynamics are based on Navier-Stokes equations. In this sense, three transport equations are used to solve the problem [26]. The mass conservation is:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho U) = 0 \tag{1}$$

The momentum conservation is [26]:

$$\frac{\partial(\rho U)}{\partial t} + \nabla(\rho U \times U) = -\nabla p + \nabla \tau + S_M \tag{2}$$

In addition, the energy conservation is [26]:

$$\frac{\partial(\rho h_{tot})}{\partial t} - \frac{\partial p}{\partial t} + \nabla(\rho U h_{tot}) = \nabla(\lambda \nabla T) + \nabla(U \cdot \tau) + U \cdot S_M + S_E \tag{3}$$

The conjugate heat transfer analysis made a heat balance between the convection in fluids (external

and internal fluid) and the conduction in solids. The convection and the conduction equations are [25]:

Convection:

$$\frac{\partial f}{\partial t} + \nabla \nabla(f) = 0 \tag{4}$$

Conduction:

$$\frac{\partial T}{\partial t} = \text{div}(\alpha \nabla T) \tag{5}$$

The conjugate heat transfer also uses the energy conservation equation (equation 3) for fluid and solid domains in the same matrix. Then, the interfaces between fluids and solids can be treated in an implicit way by discretizing the energy flux. Therefore, the

continuity of the temperature distribution between every interface is respect at each iteration [25].

d) *Boundary conditions – CFD Problem*

The inlet mass flow for the external fluid was fixed as 0.5kg/s. The angular velocity of the blade was

3,600rpm. The inlet temperature of the coolant fluid was set at 127 ° C, the inlet mass flow of the coolant fluid was set as 4% of the inlet mass flow of the external fluid, i.e. 0.002kg/s. Four values were used for the turbine inlet temperature: 900°C, 1000°C, 1100°C and 1200°C. The

inlet temperature profile was used to emulate a real combustor outlet profile, as known as, the Radial Temperature Distortion Factor (RTDF), as can be seen in Figure 5 [25].

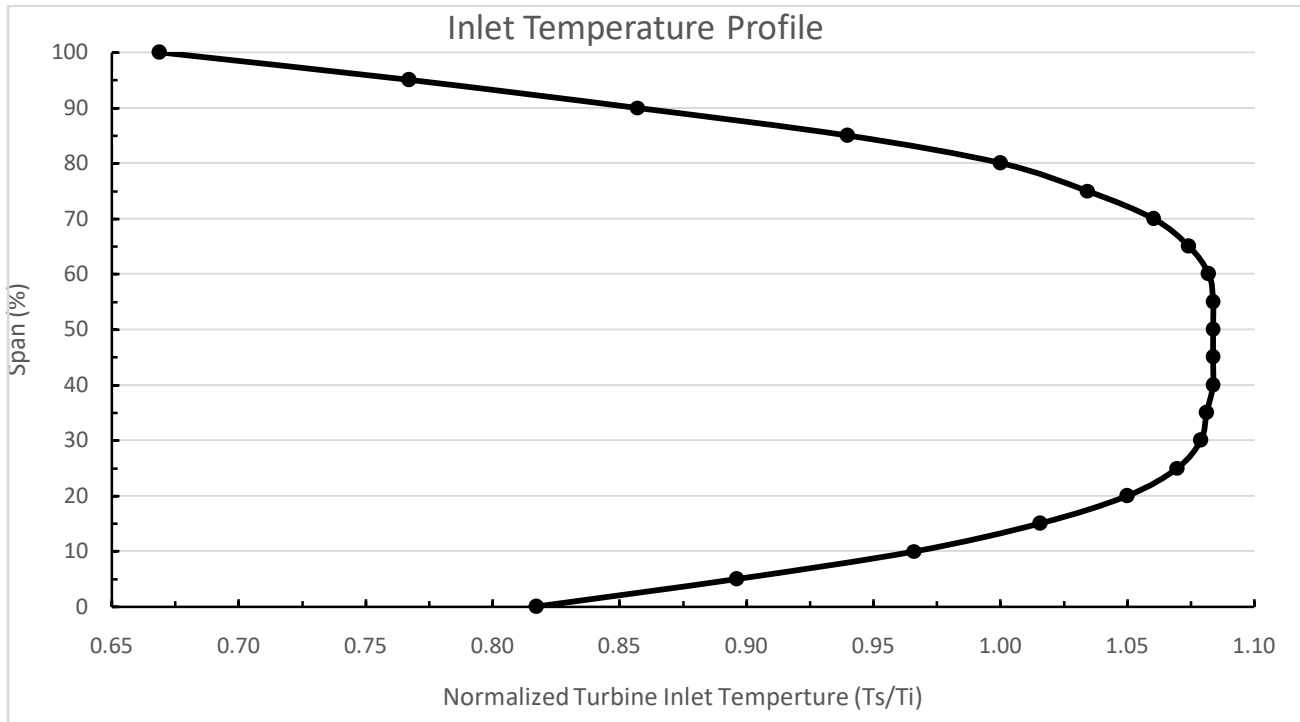


Figure 5: Turbine Inlet Temperature Profile.

The thickness of the bond coat and the top coat were set as 100µm and 500µm. The interface between the solid layers is assumed to be perfect and without

contact thermal resistance. Table 1 shows the material thermal properties.

Table 1: Material Properties used for the Thermal Analysis [24,27]

Material	Temperature (°C)	Thermal Conductivity (W/m.K)	Specific Heat (J/kg.K)	Specific Mass (kg/m³)	Thermal expansion coefficient (10 ⁻⁶ /°C)
Ytria-stabilized Zirconia	25-100	1.05	483	5,650	9.68
	400	--	--	--	--
	800	--	--	--	9.88
	1000	--	--	--	10.34
NiCrAlY	25-100	4.30	501	7,320	--
	400	6.40	592	--	12.50
	800	10.20	781	--	14.30
	1000	16.10	764	--	16.00
Stainless Steel AISI 316	25-100	16.3	500	8,000	17.5
	400	--	--	--	17.5
	800	--	--	--	--
	1000	--	--	--	--

The solver was performed to a single blade, and periodic conditions were applied to the lateral limitations of the fluid domain. Nevertheless, the results from this solver could be applied to several blades composing the rotor stage of the turbine.

e) *Governing Equations – Static Structural Problem*
 For the static structural analysis, the governing equations are based on the equilibrium equations [26]:

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} + f_x = 0 \tag{6}$$

$$\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} + f_y = 0 \tag{7}$$

$$\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \sigma_z}{\partial z} + f_z = 0 \tag{8}$$

On the 3D-Hook's Law [26]:

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{yz} \\ \tau_{xz} \\ \tau_{xy} \end{bmatrix} = \frac{E}{(1 + \nu)(1 - 2\nu)} \begin{bmatrix} 1 - \nu & \nu & \nu & 0 & 0 & 0 \\ \nu & 1 - \nu & \nu & 0 & 0 & 0 \\ \nu & \nu & 1 - \nu & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 - 2\nu & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 - 2\nu & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 - 2\nu \end{bmatrix} \begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \epsilon_z \\ \gamma_{yz} \\ \gamma_{xz} \\ \gamma_{xy} \end{bmatrix} \tag{9}$$

And on the strain-displacement relations [26]:

$$\epsilon_x = \frac{\partial u}{\partial x} \tag{10}$$

$$\epsilon_y = \frac{\partial v}{\partial y} \tag{11}$$

$$\epsilon_z = \frac{\partial w}{\partial z} \tag{12}$$

$$\gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \tag{13}$$

$$\gamma_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \tag{14}$$

$$\gamma_{zx} = \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z} \tag{15}$$

The static structural analysis was supplied by

Therefore, there are 15 equations (from equation (6) to equation (15), equation (9) has six equations in a matrix form) and 15 unknowns, which must be evaluated.

f) *Boundary Conditions – Static Structural Problem*

The static structural analysis was supplied by the computational fluid dynamics solution. The forces created by the fluid will be the input parameters, and the material properties, as shown in Table 2, would be applied for each material.

Table 2: Material Properties for Structural Analysis [27-29]

Material	Temperature T (°C)	Elastic Modulus E (GPa)	Poisson Coefficient ν
Yttria-stabilized Zirconia (YSZ)	25 - 100	222	0.25
	400 - 1500	180	--
NiCrAlY	25 - 100	231 – 226.5	0.30
	800	117	--
Stainless Steel AISI 316	25 - 100	193	0.30
	--	--	--

The base of the blade was supposed to be rigid, since it is fixed to the disc, and it is imposed a given rotation of the shaft of 3600 rpm.

g) *Experimental Procedure and validation of the numerical method*

The experiments were performed in a furnace powered by combustion gases from LPG (Liquefied

Petroleum Gas) firing. The burning was made by a blowtorch. In this set-up, the blowtorch was placed in a position that only the combustion gases pass through the blade. In order to keep the heat inside the furnace, the space between the blowtorch and the leading edge of the blade was covered by refractory bricks. A schematic draw of the furnace is show in Figure 6.

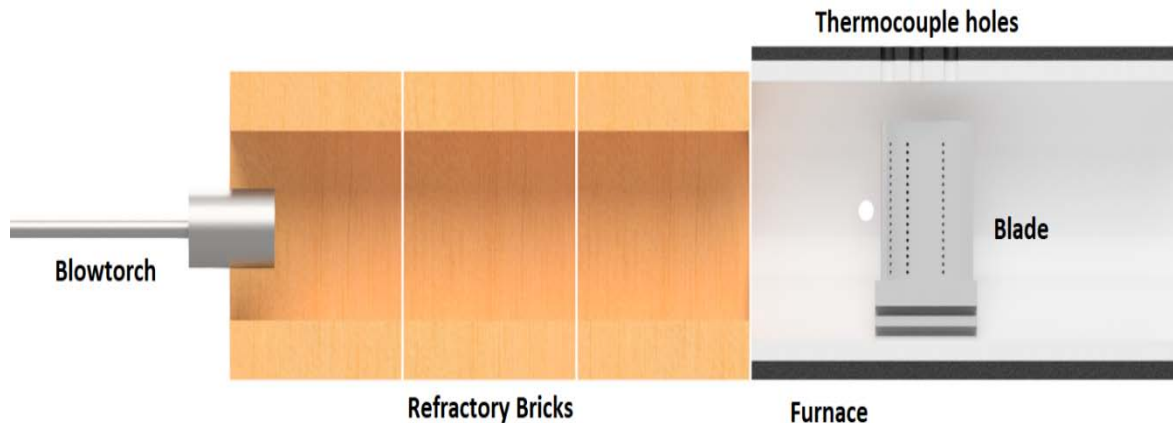


Figure 6: Schematic draw of the furnace.

The inlet temperature was measured by a thermocouple close to the leading edge of the blade. Moreover, the internal temperature was measured by three thermocouples that were inside in three cooling channels. One thermocouple was inside the channel close to the leading edge, another thermocouple was inside the channel close to the middle of the blade and another one into the channel close to the trailing edge.

In order to record the temperature, the thermocouples were coupled to a Eurotherm 2132 system.

The validation of the simulation was based on the comparison between the values found in the experiment and in the simulation. Table 3 shows the errors between the simulation temperature and the experimental temperature at leading edge, intermediate region and the trailing edge.

Table 3: Errors for each turbine inlet temperature

Turbine Inlet Temperature (°C)	Error in Leading Edge (%)	Error in Blade Center (%)	Error in Trailing Edge (%)
900	6	8	9
1000	3	4	4
1100	7	5	3
1200	5	4	6

The simulation has a good fit to the experiment showing an adequate degree of accuracy with the reality predicted by the experiment. The maximum error occurred in the trailing edge at 900°C.

on the stainless steel blade for the simulation and the furnace experimental will be evaluated.

III. RESULTS AND DISCUSSION

a) Thermodynamics – Furnace

In the following paragraphs, the main aspects regarding the influence of each turbine inlet temperature

Table 4 shows the gas turbine blade internal temperatures of the wall close to the leading edge, to the blade center and to the trailing edge.

Table 4: Measured blade internal temperatures

Turbine Inlet Temperature (°C)	Temperature Leading Edge (°C)	Temperature Blade Center (°C)	Temperature in Trailing Edge (°C)
900	598	538	623
1000	687	601	701
1100	782	753	811
1200	875	816	884

The differences between the turbine inlet temperature and the measured temperatures are shown in Figure 7. This figure shows that blade center has high temperature difference because the cooling system effect is high at the blade center.

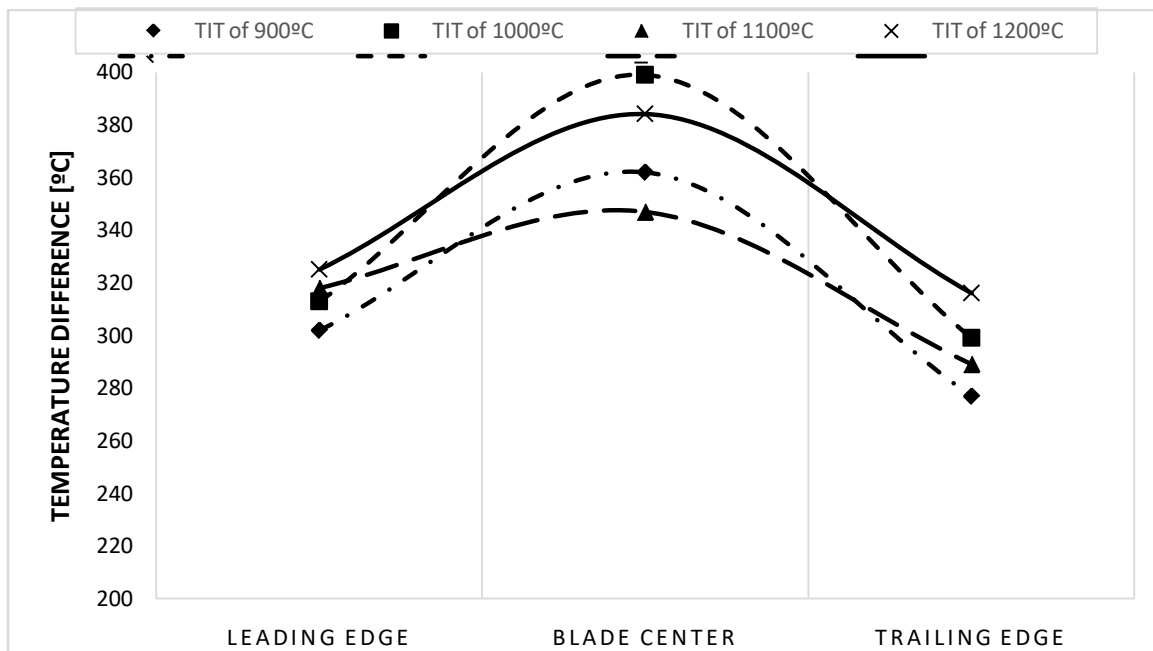


Figure 7: Temperature difference between the turbine inlet temperature (TIT) and the internal temperature

Figure 7 shows that the coating and the cooling system was able to reduce approximately 315°C on the cooling channels close to the leading edge, decrease approximately 373°C on the blade center and reduce 295°C on the trailing edge. Thus, the cooling system has great influence over the blade center and low significance over the trailing edge.

b) External Aerodynamics

The surface oil flow of each turbine inlet temperature are similar to each other. Then, the surface oil flow of the blade in the pressure and suction side, is

shown in Fig.8. The stagnation line is close to the leading edge. Then, the flow is separated, part goes to the suction side and other part goes to pressure side, generated by the horseshoe vortex (green arrows) that appears next to the leading edge. The Figure 8 also shows tip leakage flow (blue arrows) starts from the tip region of the blade pressure side. At the tip region of the suction side, the cooling air triggers a secondary vortex that grows toward the mid-span of trailing edge because of the influence of the cooling air.

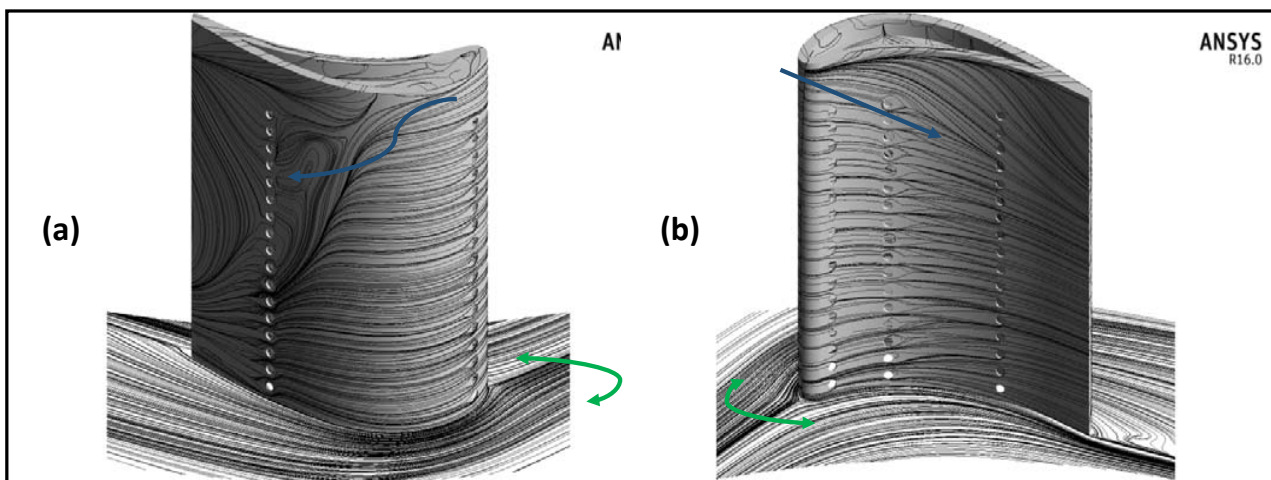


Figure 8: Surface oil flow (a) suction side and (b) pressure side.

The velocity distribution of the external and internal flow at a cross section of the blade at 50% of the height is shown in Figure9. This figure shows the

velocity distribution for the four mentioned turbine inlet temperatures.

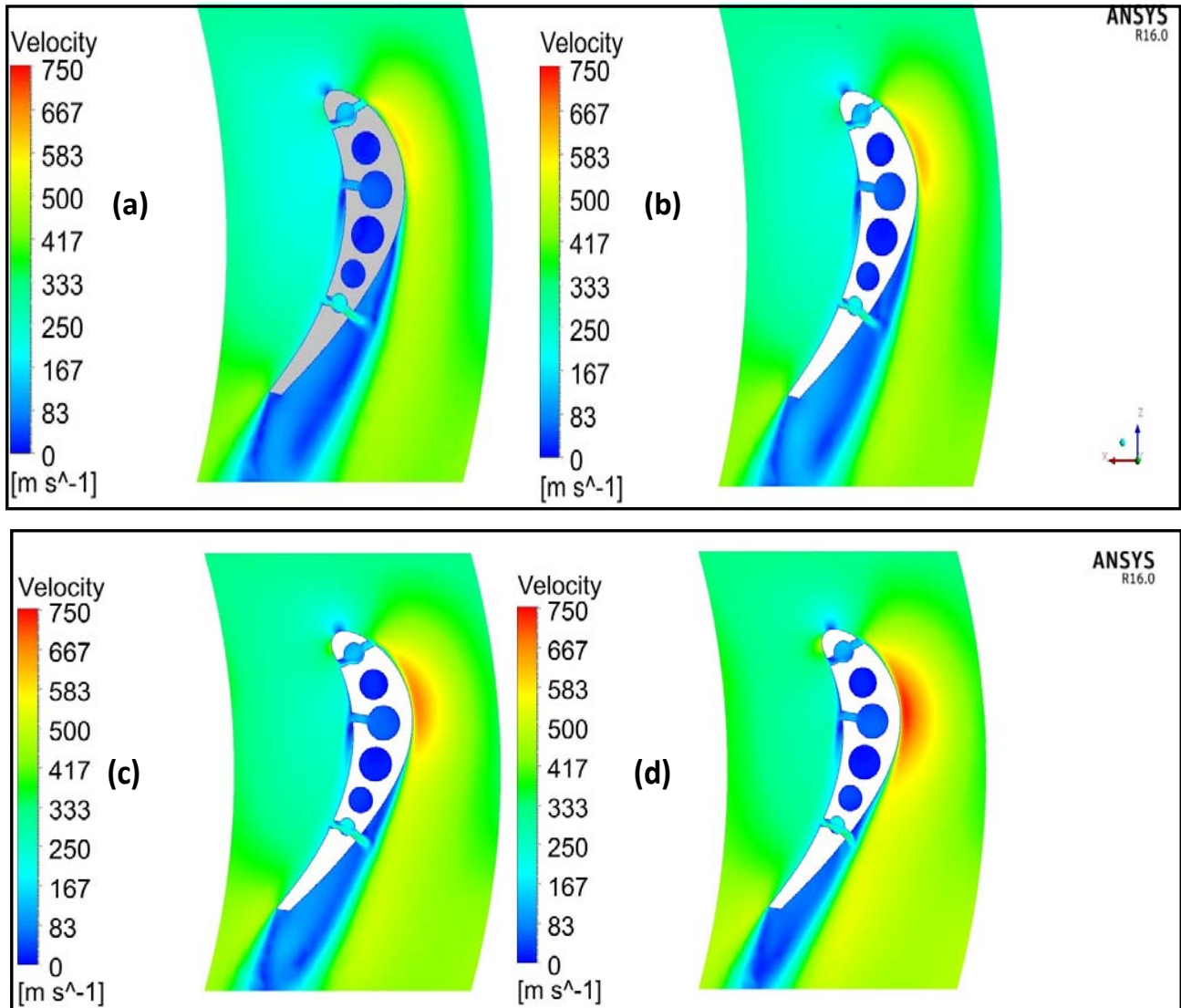


Figure 9: Velocity distribution at mid-span of the blade (a) TIT 900°C; (b) TIT 1000°C;(c) TIT 1100°C; and (d) TIT 1200°C

The Figure 9 range was fixed to compare the velocity of each turbine inlet temperature. The rise in temperature increases the gas flow velocity distribution. Then, it can be concluded that the temperature directly influences the velocity due the kinetic energy increase.

Table 6 show the maximum and minimum flow velocity (external and internal) for each gas turbine inlet temperature. Comparing the Figure 9 and Table 6, the

maximum external flow velocity occurs on the suction side, and the minimum external flow velocity on the pressure side close to the film cooling. Concerning the internal air cooling, the minimum occurs at the cooling channel without the film cooling channels, and the maximum is reached at the boundary between the external and the internal fluids.

Table 5: Minimum and maximum velocity of the fluid

Turbine Inlet Temperature (°C)	Minimum velocity (m/s)	Maximum velocity (m/s)
900	External: 120 Internal: 24	External: 586 Internal: 282
1000	External: 168 Internal: 24	External: 617 Internal: 310
1100	External: 310 Internal: 24	External: 696 Internal: 354
1200	External: 343 Internal: 24	External: 749 Internal: 378

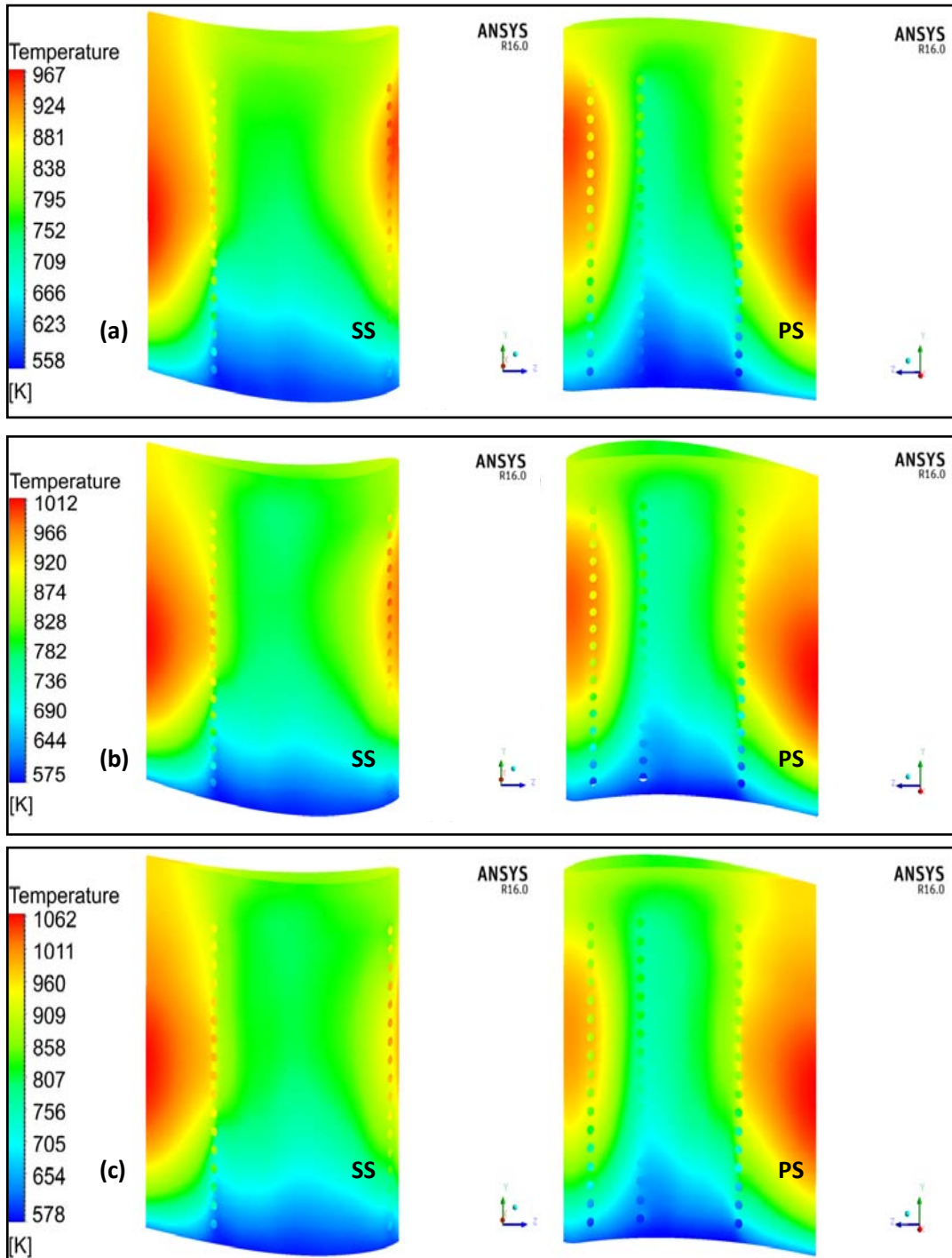
c) *Thermodynamics - CFD*

Every solution was converged between 800-1000 interactions with 45-55 hours of computation. The residuals of u-momentum, v-momentum and w-momentum were of order of 10^{-4} and the residual of the mass was the order of 10^{-5} .

The conjugate heat transfer obtained the blade temperature distribution. The temperature distribution of the substrate at the suction side and pressure side are shown in Figure 10. This figure shows the temperature distribution- for each turbine inlet temperature. In

addition, Figure 11 shows the temperature distribution for the blade at each span.

These figures show that the temperature distribution indicates that the suction side (SS) temperature is lower than the pressure side (PS) because the flow on the suction side was accelerated. As a result of the turbine inlet temperature profile, the gas temperature was higher at the blade mid-span, then the temperature was higher at the inlet blade mid-span. There is a lower temperature region at the root, where the coolant fluid is colder.



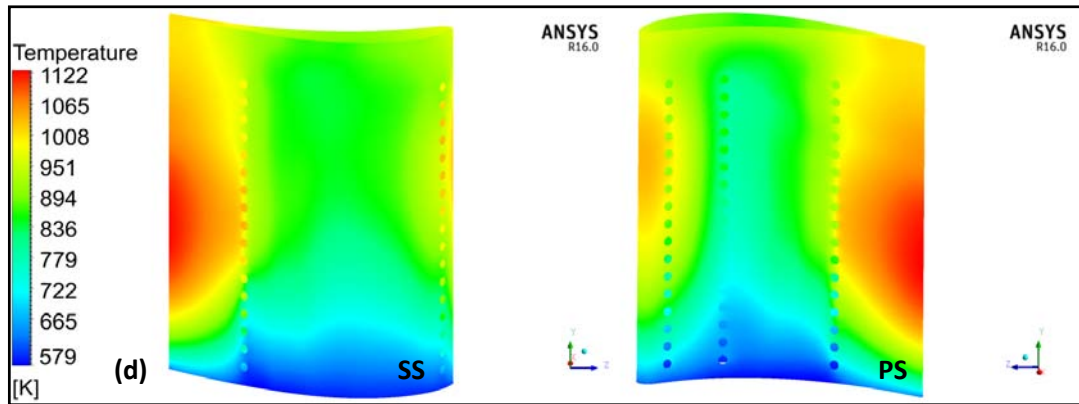
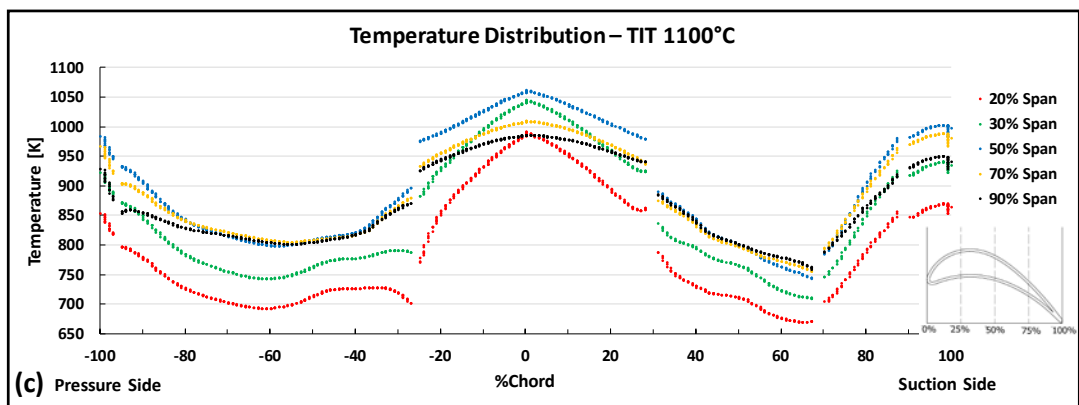
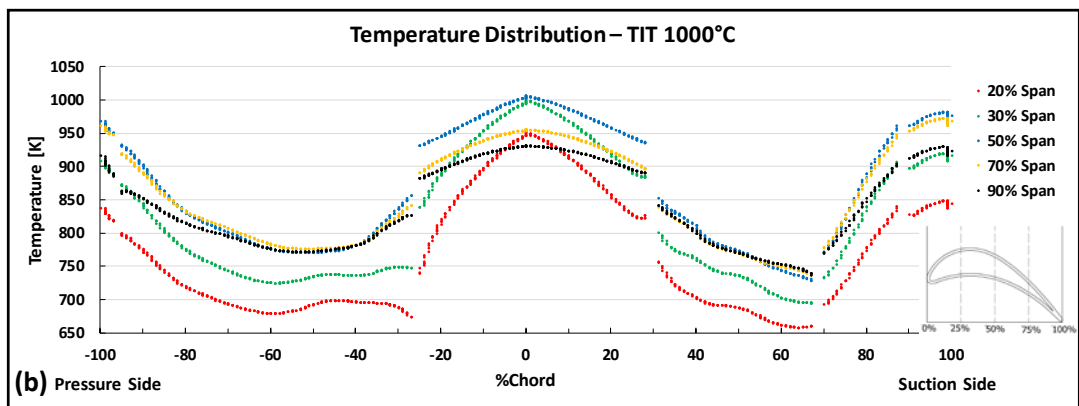
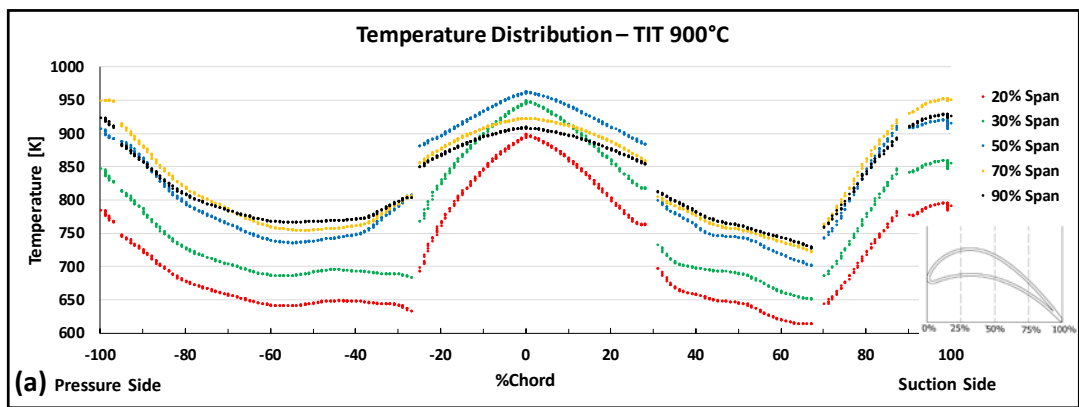


Figure 10: Temperature distribution on the substrate for (a) TIT 900°C; (b) TIT 1000°C; (c) TIT 1100°C; and (d) TIT 1200°C



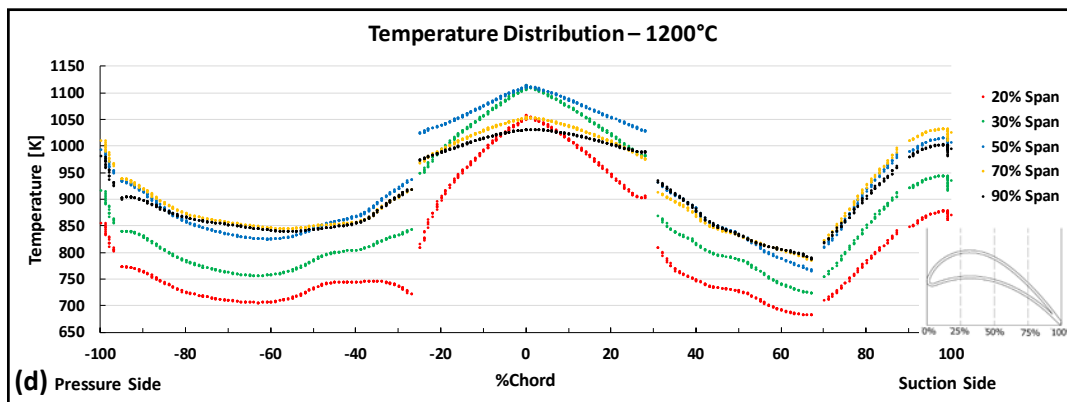


Figure 11: Temperature distribution for the blade at each span for (a) TIT 900°C; (b) TIT 1000°C; (c) TIT 1100°C; and (d) TIT 1200°C

The temperature distribution of the blade can be captured in Figures 10 and 11. From Figure 10, it can be seen clearly that hot spots exist at the leading edge and the trailing edge of the blade. Hot spot at the leading edge of the blade is observed at the mid-span (50% span) where the temperature of the gas flow is highest due to the turbine inlet temperature profile. The trailing edge hot spot is observed at 70% span of the blade where the cooling system is inefficient, and where the flow is converged due to tip leakage flow mentioned above. The gas flow vortices affect the temperature distribution on the blade suction side and pressure side.

Then, the temperature increases gradually in a perpendicular direction to the blade rotation axis, the

temperature drops sharply at blade center next to the root, indeed at this region the cooling has higher effectiveness. However, the cooling system is more effective at the TIT of 900°C. The thermal load on the suction side and on the pressure side declines gradually toward the mid span and rises gradually on the way to the trailing edge of the blade. In spite of that, the temperature reaches a maximum close to the leading edge at the mid-span while the minimum is next to the blade middle root. Table 5 shows the maximum temperature for each turbine inlet temperature and for each solid material.

Table 6: Maximum temperature for the solid materials

Turbine Inlet Temperature (°C)	Maximum temperature of AISI 316 (°C)	Maximum temperature of NiCrAlY (°C)	Maximum temperature of YSZ (°C)
900	694	737	739
1000	739	810	838
1100	789	856	919
1200	849	936	1036

The operating temperature of the AISI 316 austenitic stainless steel is 925°C for a constant temperature situation and 870°C for a variable temperature situation. The Table 5 and the experimental results of the furnace and the simulation, one can verify that the blade did not reach the temperature limit of operation for a constant temperature situation at the turbine inlet temperature of 900, 1000, 1100 and 1200°C. And the metallic substrate did not reach the temperature limit for a variable temperature situation. The thermal barrier coating and the cooling system reduces significantly the metal temperature.

d) Static Structural Analysis

Static structural analyses can be solved by the determination of the fluid-structural interaction and the turbine blade response due to mechanical loading

provided by the fluid. In other words, the inlet parameters were

Obtained by fluid-solid interaction. It is used the pressure and temperature distribution given by the numerical solution through the dynamic computational method. The behavior of the fluid over the blade may be imported and this solution becomes the contour conditions of the structural analysis. The stresses distribution is shown in Figure 12.

From Figure 12, it can be seen that the highest values of von Mises stress occur close to the base of the blade, in the region of the coating, with values of 333.92 MPa, 333.58 MPa, 334.32 MPa and 327.33 MPa, at temperatures of 900°C, 1000°C, 1100°C and 1200°C, respectively. The maximum deformation is located at the blade top and the deformation has the tendency to elongate and twist the blade. Therefore, this region can

be more susceptible to thermo-mechanical fatigue and coating cracking, causing coating failure.

IV. CONCLUSIONS

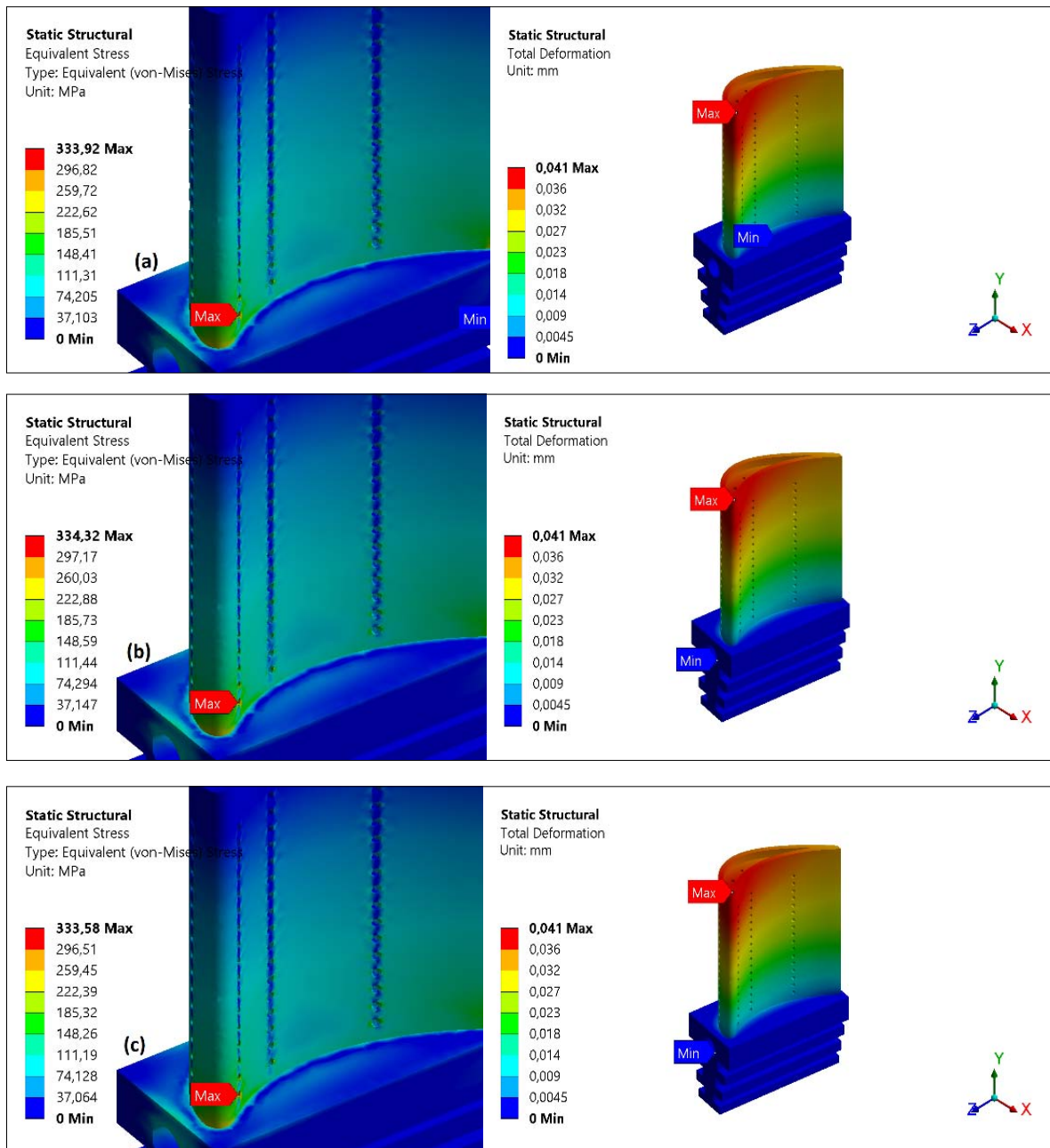
Simulation and experiment were conducted in order to predict the turbine blade temperature distribution. The aim was to verify the stainless steel temperature and behavior under cooling and the thermal barrier coating effect on the thermal insulation.

From the experimental results of the furnace and the simulation, it can be concluded that the blade did not reach the temperature limit of operation for a constant and variable temperature situation at every turbine inlet temperature.

The effect of the thermal barrier coating, with the cooling system, is to decrease the temperature of the steel by approximately 160°C for each turbine inlet temperature. The cooling effect was very high at the regions close to blade center and close to the blade root.

The structural analysis shows that the blade got a tendency to develop a coating crack in the region close to the base. The stresses at the blade develop a deformation that elongate and twist the blade.

The stainless steel blade withstands the temperature distribution and the stress load applied. In conclusion, the austenitic stainless steel can be used as a turbine blade.



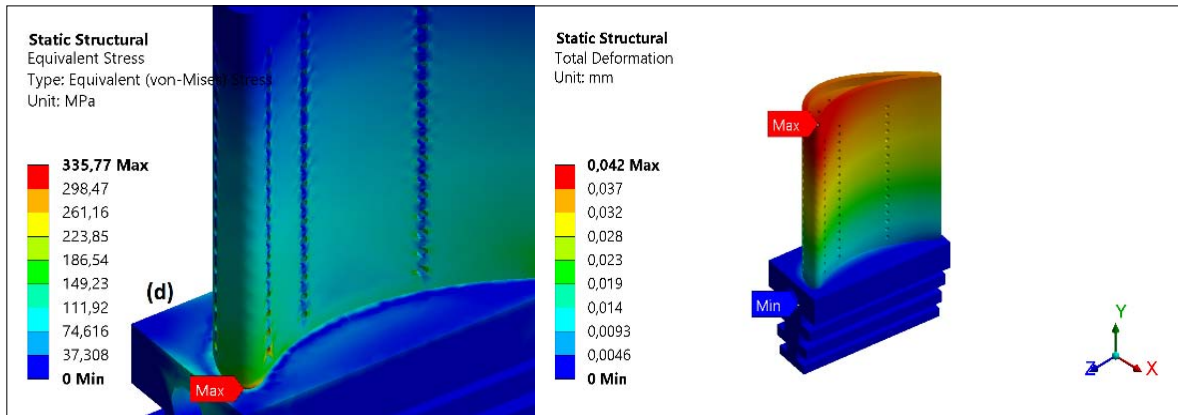


Figure 12: Stress and deformation distribution on the blade at TIT of (a) 900°C; (b) 1000°C; (c) 1100°C; and (d) 1200°C

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Nomenclature

ρ	Specific Mass (kg/m ³)
t	Time (s)
U, V, W	Velocity vectors in the x-direction, y-direction, z-direction(m/s)
p	Stagnation pressure(Pa)
τ	Shear stress (Pa)
S_M	Momentum source (N.m)
h	Stagnation enthalpy (J/kg)
λ	Thermal conductivity (W/m.K)
S_E	Energy source (J)
T	Temperature (K)
c	Specific heat at constant pressure (J/mol.K)
α	Thermal expansion coefficient (1/°C)
σ	Normal stress(Pa)
f	Force(N)
E	Elastic modulus(Pa)
ν	Poisson coefficient (-)
ϵ	Normal strain (-)
γ	Shear strain (-)
<i>Subscripts</i>	
tot	Total
s	Solid
i	xversor
j	yversor
k	zversor

Abbreviations

<i>TBC</i>	Thermal barrier coating
<i>TC</i>	Top coat
<i>TGO</i>	Thermally grown oxide
<i>BC</i>	Bond coat
<i>CHT</i>	Conjugate heat transfer
<i>CFD</i>	Computational fluid dynamics
<i>YSZ</i>	Ytria-stabilized zirconia
<i>GT</i>	Gas turbine
<i>SST</i>	Shear stress transport
<i>LPG</i>	Liquefied petroleum gas
<i>TIT</i>	Turbine inlet temperature
<i>SS</i>	Suction Side
<i>PS</i>	Pressure Side

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Influence of Temperature with its Geometric and Failure Morphology Defects on the Mechanical Properties of Graphene: Molecular Dynamics Simulation (MDs)

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Abstract- This paper addressed that graphene is a regular monolayer of carbon atoms settled in a 2D-hexagonal lattice; which is listed among the strongest material ever measured with strength exceeding more than hundred times of steel. However, the strength of graphene is critically influenced by temperature, geometric & vacancy defects (VD). Defects are at all believed to worsen the mechanical toughness and reduce the strength of graphene sheet. They are revealed that stiffness and strength are the key factors in determining solidity and life span of any technological devices. Molecular dynamics-based atomistic modeling was performed to predict and quantify the effect of non-bonded interactions on the failure morphology of vacancy affected sheets of graphene. The defective sheet of graphene containing vacancy defect was simulated in conjunction with the non-bonded interactions experienced due to the presence of a pristine sheet of graphene.

Keywords: *graphene, vacancy defects, fracture strength, molecular dynamics simulation, failure morphology.*

GJRE-A Classification: FOR Code: 091399



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Influence of Temperature with its Geometric and Failure Morphology Defects on the Mechanical Properties of Graphene: Molecular Dynamics Simulation (MDs)

Muse Degefe Chewaka Liban ^α & Dr. Prabhu Paramasivam ^σ

Abstract- This paper addressed that graphene is a regular monolayer of carbon atoms settled in a 2D- hexagonal lattice; which is listed among the strongest material ever measured with strength exceeding more than hundred times of steel. However, the strength of graphene is critically influenced by temperature, geometric & vacancy defects (VD). Defects are at all believed to worsen the mechanical toughness and reduce the strength of graphene sheet. They are revealed that stiffness and strength are the key factors in determining solidity and life span of any technological devices. Molecular dynamics-based atomistic modeling was performed to predict and quantify the effect of non-bonded interactions on the failure morphology of vacancy affected sheets of graphene. The defective sheet of graphene containing vacancy defect was simulated in conjunction with the non-bonded interactions experienced due to the presence of a pristine sheet of graphene. In this study, the author also revealed that mechanical properties and failure morphology of single and bi-layer graphene sheets under the influence of single, double, and multi-vacancy defects. It was concluded based on atomistic simulations that non-bonded interactions as well as stiffness of a pristine graphene sheet has a significant impact on the failure morphology of the defective graphene sheet. Non-bonded interactions, in conjunction with defects, can be further used for modifying the brittle nature of graphene to ductile.

Keywords: graphene, vacancy defects, fracture strength, molecular dynamics simulation, failure morphology.

1. INTRODUCTION

Graphene is an outstanding material which has a number of multifunctional properties that repeatedly gross it into the title of “wonder material” which is a road map on the way to guide the community toward the development of products [1]. The remarkable mechanical behavior and properties of graphene-based material's has concerned with important study concern in recent years, in line for to their encouraging forecasts, now adaptable divisions for example micromechanics [2], microelectronics [3], and thermal [4] application with desired mechanical

properties, and electrical conductivities [2-4]. The trial and hypothetical revision of graphene, two-dimensional (2D), is a tremendously growing field of today's condensed matter research. The causes for this massive methodical attention were diverse; on the other hand, one might highlight some key inspirations. Keeping given of the science-based interest generated via graphene and its promising upcoming contribution toward electronic engineering and sensing applications, so a group of research effort is steadfastly hooked on considering the configuration and properties of graphene in this paper. Outstanding toward its excellent mechanical behavior, thermal and electrical conductivities of graphene could also use for more conventional purposes as compared with carbon nanotubes, which was quit restricted to aerospace industries and graphene is also known to have very-high stiffness in addition strength until now an extensive scatter have been witnessed in the mechanical properties [1-4]. In this effort, we present molecular dynamics model simulation for the initiation of defects and the influence of different defects (vacancy defects) and pristine one on mechanical strength of graphene sheets were observed and, the fracture strength was predicted from the numerical simulation and the properties of graphene in table 1 and investigated young's modulus displayed in table 2 below.

Table 1: Properties for a Single Sheet of Graphene [1].

Property	Value
Young's modulus [1]	1.0TPa
Rupture strength [1]	130GPa
Tensile strength [2]	100GPa
Thermal conductivity [3-4]	5000w/mK
Shear modulus [5-6]	280GPa
Longitudinal sound velocity [5,7-9]	20km/s
Melting temperature [5,10]	4900K
Specific surface area [11]	2630m ² /g
Optical transmittance [12]	97.70%
High electron mobility [13]	250,000cm ² /Vs

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Table 2: Young's modulus of pristine and defective graphene found by different research

Studied by	Conditions/ Types of Defects	Methods Adopted	Young's Modulus (TPa)	Poisson's Ratio
Jiang et al. ¹⁴	T = 100-500 K	Molecular Dynamics	0.95 - 1.1	0.17
Shen et al. ¹⁵	T = 300-700 K	Molecular Dynamics	0.905	
Lee et al. ¹⁶	Pristine graphene	Experiment	1 ± 0.1	
Tsai et al. ¹⁷	NPT ensemble	Molecular Dynamics	0.912	0.261
Sakhaee-Pour ¹⁸	Pristine graphene	Finite Element Method	1.025	
Georgantzinou et al. ¹⁹	Pristine graphene	Finite Element Method	1.367	
Kvashnin et al. ²⁰	Vacancy defects	Molecular Mechanics	1.08	
Neek-Amal et al. ²¹	randomly distributed vacancy defects	STW defects	0.501 ± 0.032	
Shokrieh et al. ²²	Pristine graphene	Continuum Mechanics	1.04	
R.Ansary et al. ²³	STW defects	Molecular Dynamics	60% reduction	
Muse Degefe & Avinash Parashar et al. ²⁴	Vacancy bi-layer graphene T=300K	Molecular Dynamics	0.91	

II. MODELING AND METHODOLOGY

a) Molecular Dynamics based Simulation

Molecular dynamics-based simulations were performed to study the effect of non-bonded interactions on the mechanical behavior and failure morphology of defective graphene sheet. The success of any molecular dynamics-based simulations entirely depends on the interatomic potentials chosen for simulating the atomic interactions. A Significant amount of advancement in conjunction with computational techniques has already been made by the researchers

$$E^{AIREBO} = \frac{1}{2} \sum_i \sum_{j \neq i} \left[E_{ij}^{REBO} + E_{ij}^{LJ} + \sum_{k \neq i, j} \sum_{l \neq i, j, k} E_{kij}^{ltors} \right] \quad (1)$$

Here, i, j, k, and l refers to individual atoms, E is the total potential energy of the system estimated with the help of AIBO potential. To perform this study, a graphene sheet consisting of 800 atoms was generated in the simulation box. The dimensions of a single sheet of graphene was kept fixed at A=46.599Å and B=49.19Å (as shown in Fig.1) along the zig-zag and arm chair direction respectively. In-plane periodic boundary conditions were imposed on the simulation performed at such a low temperature of 1K. Stress-strain response was estimated in this study with the help of the virial stress component [26, 27], which can be

$$\sigma_{ij}^{\alpha} = \frac{1}{V} \left(\frac{1}{2} m^{\alpha} v_i^{\alpha} v_j^{\alpha} + \sum_{\beta=1, n} r_{\alpha\beta}^j f_{\alpha\beta}^i \right); \quad (2)$$

Here, i and j denote indices in Cartesian coordinates system; α and β are the atomic indices; m^{α} and v^{α} are mass and velocity of atom α ; $r_{\alpha\beta}$ is the

in developing potentials for capturing the realistic properties for the range of materials. In this study, AIBO (adaptive intermolecular reactive bond order) potential was used to compute the interatomic forces between carbon atoms in graphene. Simulations were performed with a single cutoff distance of 1.95Å as proposed in the work of [25]. AIREBO potential consists of a summation of pair potential REBO (E_{ij}^{REBO}), non-bonded Lennard Jones potential (E_{ij}^{LJ}) and torsional component between carbon atoms (E_{ijk}^{tors}), also described with the help of mathematical expressions in equation (1).

box. The interlayer spacing between the sheets of graphene in bilayer graphene was kept constant at 3.45Å. During the simulations, the NPT (isothermal-isobaric) ensemble in conjunction with an integration time step of 1fs was enforced. After achieving a minimum energy configuration of graphene, atoms at a temperature of 1K, tensile loading was applied at a strain rate of 0.005ps⁻¹. To avoid thermal effects on the failure mechanism of graphene, simulations were calculated with the help of mathematical expression given in equation (2).

distance between α and β atoms and V is the surrounding volume of atom α .

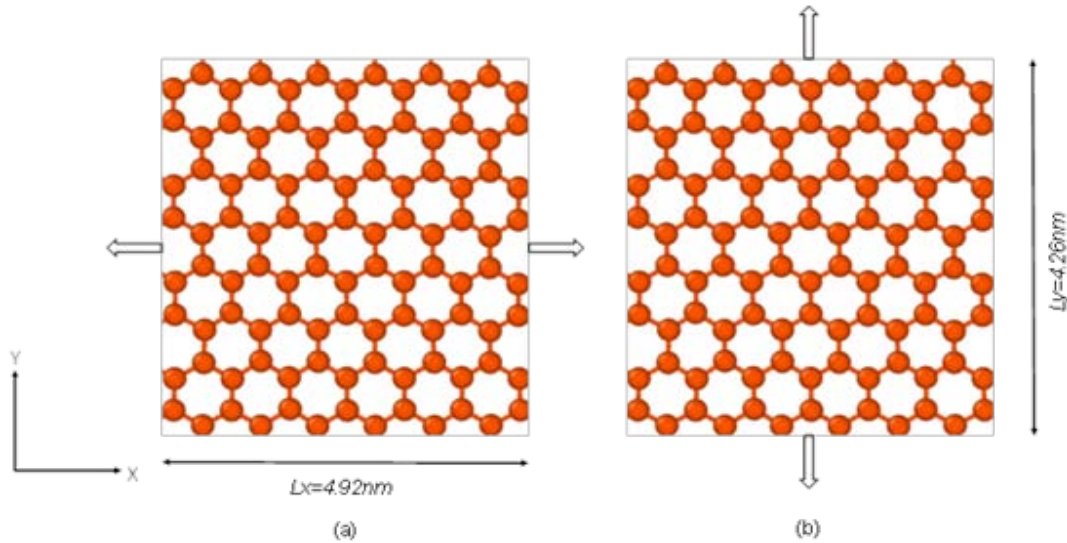


Figure 1: Single graphene sheet: same tension alongside; (a) Zigzag direction and, (b) armchair direction; Simulation models of single graphene sheet where the dimension is given by L_x and L_y : uniaxial tension along.

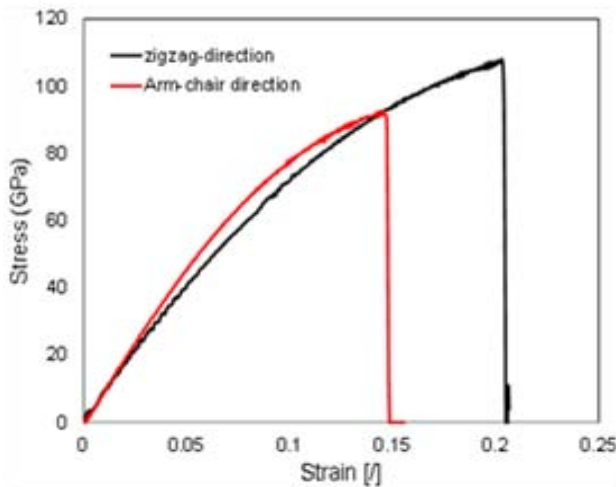


Figure 2: Snapshots on the way to confirm the mathematical method, the fracture strength of a pristine graphene sheet was initially calculated. Stress-strain bends of pristine graphene sheet under same tension along the zigzag way (black color) and armchair way (red color) at 300K.

Now the direction of validating the mathematical method, the rupture stress of pure graphene sheet was initially designed. The Consequence of minimal stress-strain bend next to the temperature of 300 K, subjected to tension load alongside both armchair and zigzag directions shown above Fig.1, was revealed, that fracture stress beside the armchair and the zigzag way are calculated as 91 and 106 GPa, separately. In Cauchy stress; the rupture stiffness was 100GPa and 126 GPa, and the rupture strain is 0.13 and 0.22 correspondingly. These results were promising new examination, i.e., $\sigma_f \approx 130 \text{ GPa}$ and $\epsilon_f \approx 0.25$ [28] as well as previous numerical simulation [29], verifying

dynamism and exactness of our mathematical approach.

Also, graphene can be subjected to a higher temperature at the production stage as well as when graphene-based devices operate at the higher temperature. As we discussed above Chemical vapor deposition (CVD) is one of the most commonly used methods of graphene manufacture; that products graphene at a temperature of around 800 K. Therefore, understanding the temperature behavior of graphene helps to fabricate best excellence graphene founded devices. Studying the effect of high temperature on mechanical properties of a substantial armchair and zigzag is presented. In the temperature range of 200K, 300K, and 450K, the breakage stress with a vacancy was evaluated subjected to load; along with armchair and zigzag way. Modeling was held at a temperature of 200K, 300K, and 450K as shown in Fig.3. (a), and (b) Shows the fracture strength σ_f for the graphene sheets without defect at temperatures of 200 K, 300 K, and 450 K.

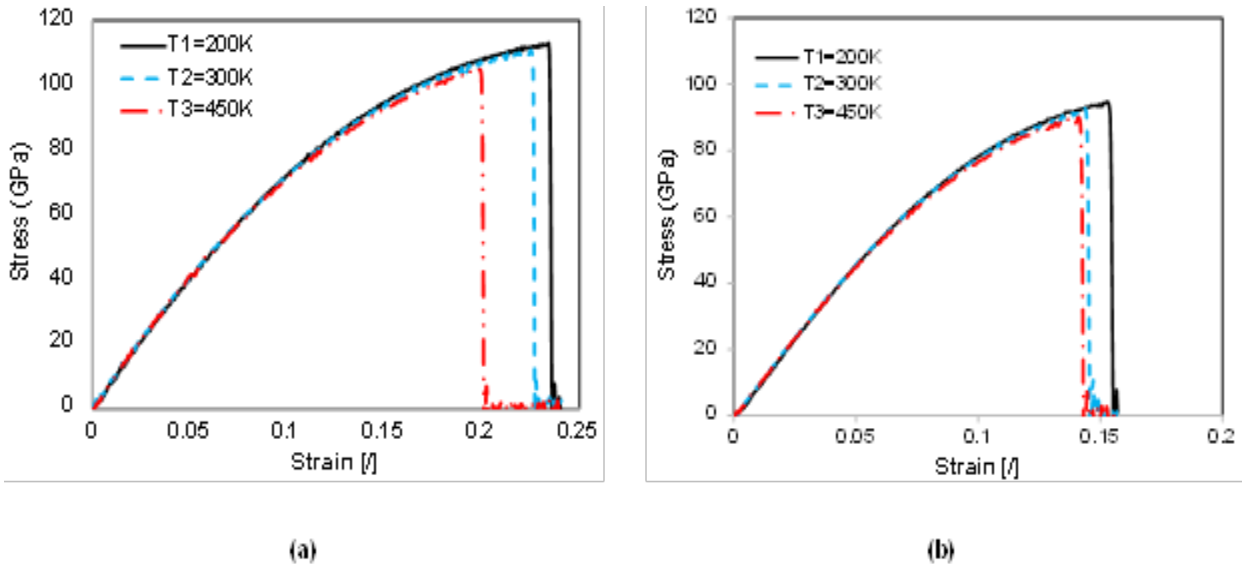


Figure 3: Stress versus strain curves; (a) Zigzag direction graphene sheets at different temperatures, (b) Armchair direction graphene sheets at different temperatures.

III. RESULTS AND DISCUSSION

Molecular dynamics-based simulations were performed to capture the failure morphology of pristine graphene either as a single or in bi-layer sheet configuration. These simulations were performed with the help of three models to study the effects of non-bonded interactions on the mechanical behavior of pristine graphene. Stress and strain response estimated along the zig-zag and arm chair directions of pristine

single sheet graphene were plotted in Fig.4. It can be observed from Fig.4 that the mechanical properties of pristine graphene along with the zig-zag and arm chair directions are quite different because of edge defects. In direction to get a better insight on the failure mechanism of the pristine form of graphene under the influence of tensile loading, snapshots of the simulation box were taken at the time of initiation of the failure as provided in Fig.4.

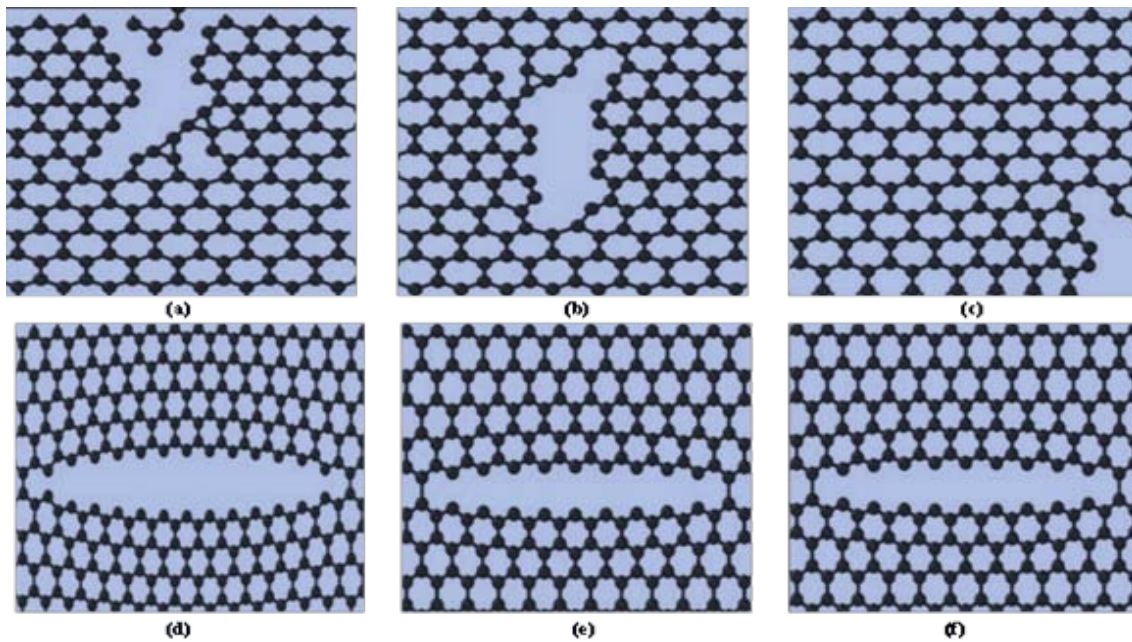


Figure 4: Failure morphology of pristine single and bilayer sheets (a & d) along zig-zag and arm chair directions respectively (b & e) along zig-zag and arm chair directions with non-bonded interactions between bi-layer configuration of graphene containing one defective and another pristine sheet (c & f) along zig-zag and arm chair directions with (bi-layer configuration of graphene containing one defective and another pristine that without non-bonded interactions) [24].

It is observed that the failure morphology of graphene sheet inferred from the snapshots provided in Fig.4 is almost independent of the non-bonded interactions. A brittle nature of failure can be observed in zig-zag as well as arm chair directions of graphene sheets under the influence of tensile loading.

Stress and strain response estimated along with the zig-zag and arm chair directions of pristine single sheet graphene & bi-layer with (LJ-On) & (LJ-Off) were plotted in Fig.5 below. It can be observed from Fig.5 that the mechanical properties of pristine graphene single & bi-layer along the zig zag and arm chair direction.

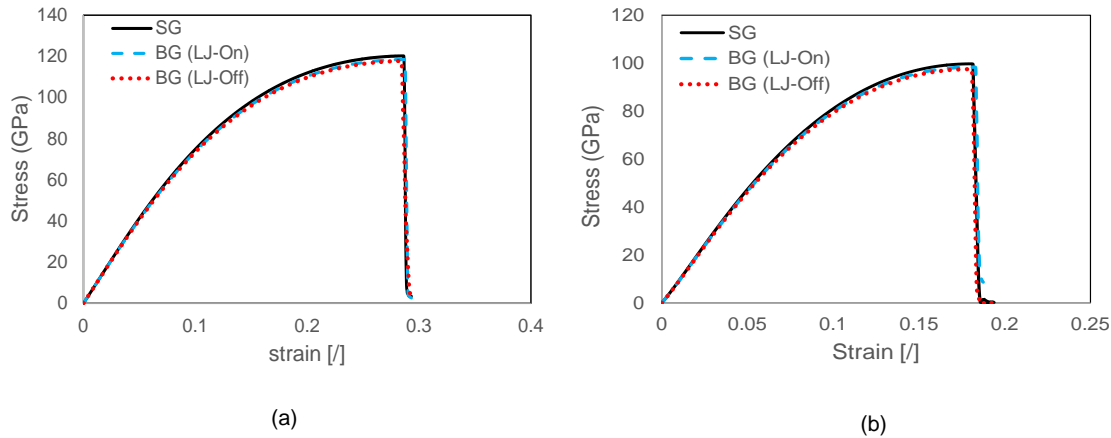
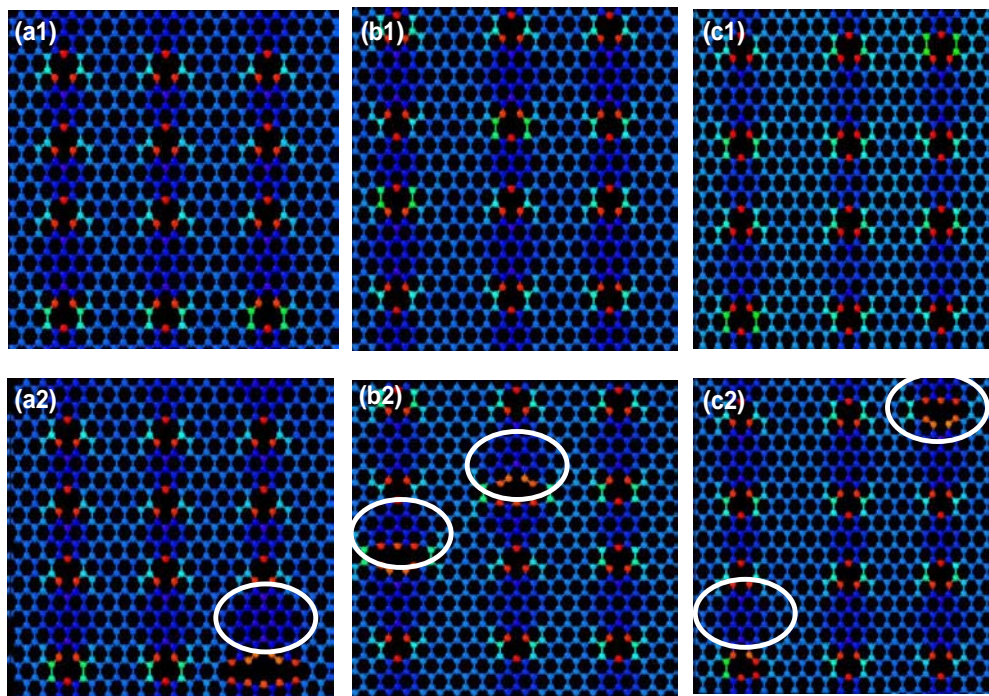


Figure 5: Stress-strain curves of pristine graphene under (a) zigzag and (b) armchair direction; where SG (single graphene sheet), BG (LJ-On) (bilayer graphene sheet with non-bonded interactions) and BG (LJ-Off) (bilayer graphene without non-bonded interactions) [24].

It can be inferred from Fig.6 that non-bonded interactions as well as stiffness of pristine graphene have an impact on the failure morphology of defective graphene sheet containing single vacancy defects. Snapshots of the simulation box provided in Fig.6 (c3) for defective graphene sheet accompanied by a pristine sheet of graphene connected with non-bonded

interactions show that the failure initiates at two different regions subsequently and helps in achieving higher failure strength. This initiation of failure at two different defects helps in distributing the energy among these points, which can be attributed to the higher failure strength for defective graphene sheets in bilayer configuration connected with non-bonded interactions.



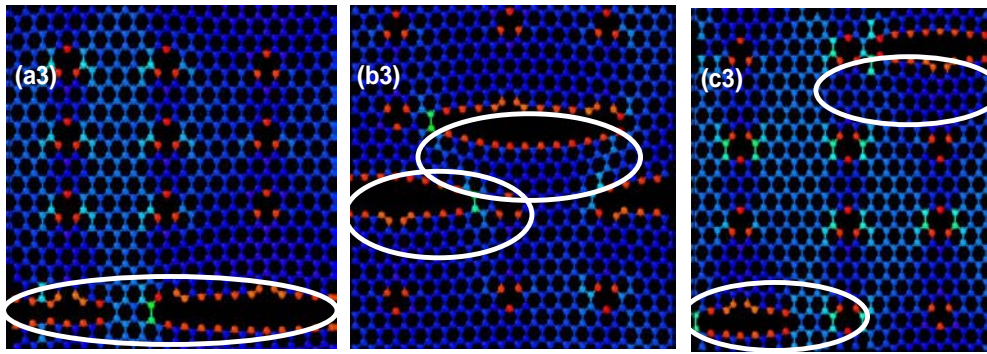


Figure 6: Failure morphology of defective graphene with varying concentration of single vacancy defects in arm-chair direction (a1) initiation of failure in isolated single defective sheet of graphene at 0.5% single vacancy defects (a2) initiation of failure in isolated single defective sheet of graphene at 1.0% single vacancy defects (a3) initiation of failure in isolated single defective sheet of graphene at 1.5% single vacancy defects (b1) initiation of failure in defective sheet of graphene in bilayer sheets connected with non-bonded interactions at 0.5% single vacancy defects (b2) initiation of failure in defective sheet of graphene in bilayer sheets connected with non-bonded interactions at 1.0% single vacancy defects (b3) initiation of failure in defective sheet of graphene in bilayer sheets connected with non-bonded interactions at 1.5% single vacancy defects (c1) initiation of failure in defective sheet of graphene in bilayer sheets without non-bonded interactions at 0.5% single vacancy defects (c2) initiation of failure in defective sheet of graphene in bilayer sheets without non-bonded interactions at 1.0% single vacancy defects (c3) initiation of failure in defective sheet of graphene in bilayer sheets without non-bonded interactions at 1.5% single vacancy defects.

In the way to investigate the reasons behind the improvement in the fracture strength and strain of defective graphene in bilayer configuration of graphene, snapshots at the time of initiation of failure are provided in Fig.7. It can be observed in Fig.6 (b3 and c3) that at the higher concentration of single vacancy defects failure triggers from the vacancies at two separate locations. Distribution of loading with the help of non-bonded interactions as well as pristine graphene sheet accompanied the defective graphene can be attributed to the higher strength of defective graphene in bi-layer sheets of graphene. This subsection of the molecular dynamics based simulation helps in concluding that at higher percentage of single vacancy defects, bilayer sheets of graphene shows higher strength and strain values for the failure of defective graphene sheet. Improvement in the strength of defective sheet was observed in the presence of another pristine graphene connected with non-bonded interactions, but no transition from brittle behavior was observed in any of the failure morphology.

a) Result of single, double and multiple vacancy defects

Failure morphology of the single graphene with uniformly distributed vacancies during strain failure vs vacancy defect ratio was displayed in Fig.7. A very instance concentrated stress occurred near unperfected; at that moment breakages happen to open from were vacancy defect started then growth in the direction of nearby defects where fracture starts

randomly from the defect of vacancies exist. We now turn to analyze the mechanical properties at the failure point for defective graphene. It should be noted that the ultimate strength is the maximum stress in the stress-strain curves, while the fracture strain is determined from the spontaneous large drop of the total energy increment curves. Without defect, the ultimate tensile strength is 91GPa and 106 GPa intended for armchair and zigzag graphene separately.

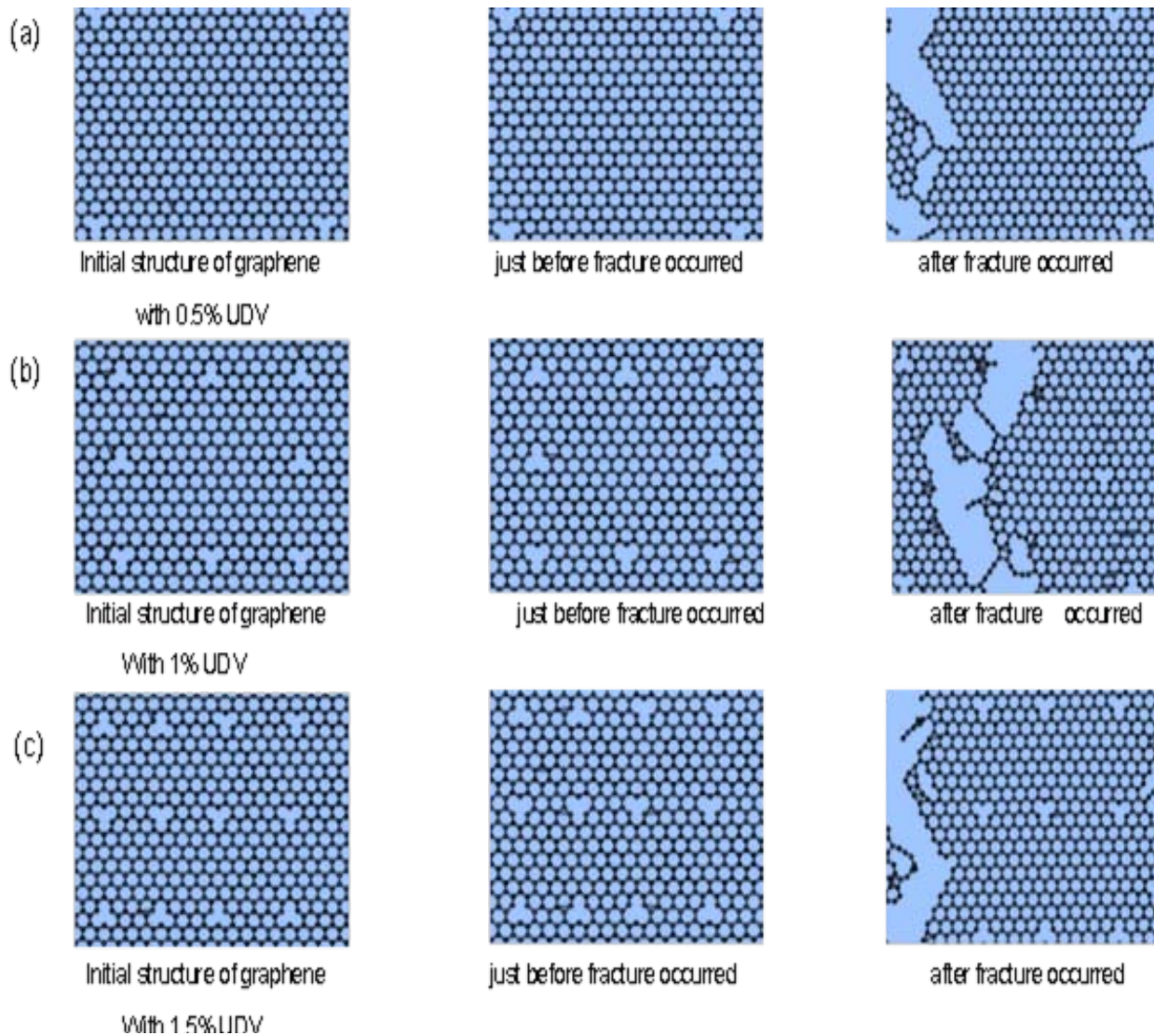


Figure 7: Steps of breakage development in graphene having evenly concentrated vacancies; the vacancy defect ratio was (a) 0.5%, (b) 1%, (c) 1.5%, where, UDV refers to uniformly distributed vacancy defect ratios.

On behalf of through evenly concentrated defects, the correlation among stress, strains besides defects are revealed below Fig.8. (a) & (b). Obviously, the stress decreases with the increase in vacancy defect, and the strain failure decreases with increase vacancy defect. On or after this we decided that in contrast, stiffness to some extent drops by the rising in vacancy Fig. 8 (b) defect; because lack of an atom implies vacancy defect that graphene is more sensitive to vacancy where carbon bond breakage is happens at the time.

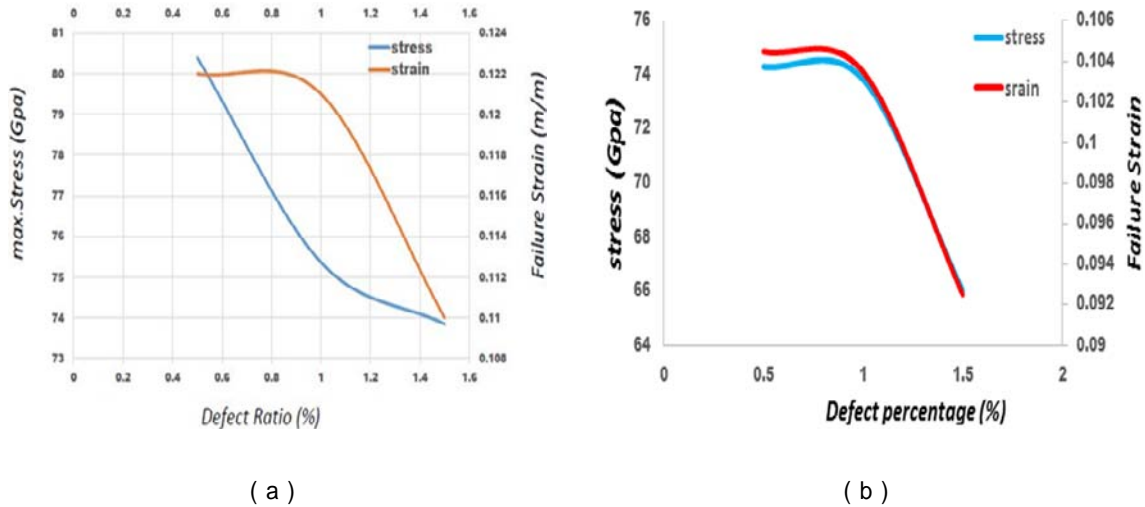


Figure 8: (a) Breakage strong point of unperfected graphene sheet on stress and strain against the number of vacancy defect ratio in Zigzag direction where both lines remain the outcomes of quantized fracture mechanics (QFM). (b) Breakage strong point of an unperfected graphene sheet on stress and strain against the number of vacancy defect ratio in Armchair direction where both lines remain the outcomes of quantized fracture mechanics (QFM).

This study revealed that fracture stress in zig zag direction with different single, double, and multiple vacancy defects are much better in Pristine single graphene than bilayer di-vacancy, single bilayer vacancy

(dangling bond because of odd vacancy defect) and multi-vacancy defect in bilayer single graphene defects are also shown in this bar graph below Fig.9.

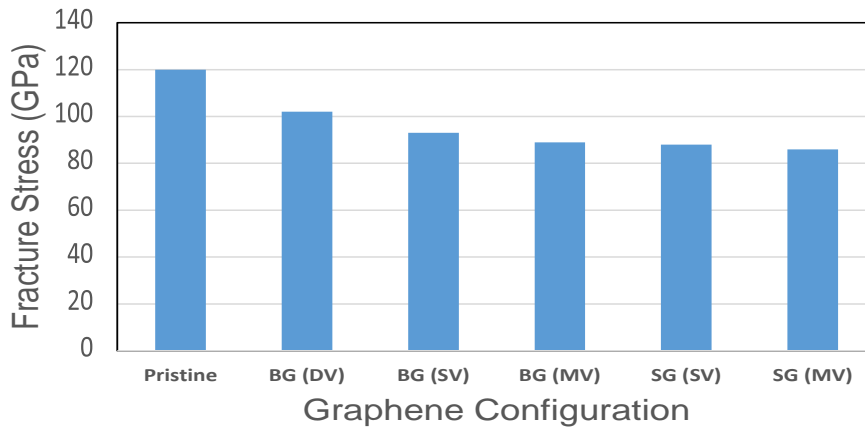


Figure 9: Fracture stress in zig zag direction with different single, double and multiple vacancy defects. Here, the pristine, BG, SG, refers to pristine single graphene sheet, bilayer graphene, and single graphene respectively; Whereas, SV, DV and MV refer to single, di- and multi-vacancy defects.

IV. CONCLUSIONS

Molecular dynamics-based simulations were performed to predict the effect of non-bonded interactions on the mechanical behavior and failure morphology of defective graphene sheet. Simulations were performed with an isolated defective sheet of graphene or defective sheet of graphene accompanied by a pristine sheet of graphene. Atomistic modeling with single as well as bilayer configuration of graphene was performed with different defect concentrations as well as geometries of vacancy defects such as single, double, and multiple vacancy defects. Di-vacancy defects have

predicted higher strength in zig-zag configuration, whereas lower strength in arm chair configuration while compared with the single vacancy defects. A Shift in the failure morphology of graphene along the arm chair direction was observed in bi-layer configuration of defective graphene containing di-vacancy defects. It can be concluded that non-bonded interaction helps in achieving a uniform distribution of load around the defects which triggers the failure simultaneously from different regions & initiating of failure simultaneously from two different points help in achieving a higher strength.

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Finned Electric Motor with Prescribed Heat Flux and Influence of the Internal and External Heat Convection Coefficients on the Temperature of the Core

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Abstract- One of a major objective is to analyze the effect of internal and external convection coefficients in the heat transfer generated by electric motors and characterize intervals of feasible values, in practical terms, for these coefficients. Another objective is to determine the motor core temperature, considering the environmental and operational conditions of the motor installation and the heat flux Q_0 (fixed) in the fins. To achieve the objectives were developed analytical solutions for determining the temperature variations in the fins, performance and electric motor efficiency, considering heat flow constant at the base of the fins and the possible variations in temperature of surround media. The heat flux at the base of the fins, in this case, is the minimum necessary for satisfactory electric motor performance and the core temperature is within the safety range stipulated by the manufacturer. The obtained results characterize a range of possible values for the inner and outer heat transfer coefficients.

Keywords: *finned electric motor; constant heat flow; efficiency; efficacy.*

GJRE-A Classification: FOR Code: 091399



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Abstract- One of a major objective is to analyze the effect of internal and external convection coefficients in the heat transfer generated by electric motors and characterize intervals of feasible values, in practical terms, for these coefficients. Another objective is to determine the motor core temperature, considering the environmental and operational conditions of the motor installation and the heat flux Q_0 (fixed) in the fins. To achieve the objectives were developed analytical solutions for determining the temperature variations in the fins, performance and electric motor efficiency, considering heat flow constant at the base of the fins and the possible variations in temperature of surround media. The heat flux at the base of the fins, in this case, is the minimum necessary for satisfactory electric motor performance and the core temperature is within the safety range stipulated by the manufacturer. The obtained results characterize a range of possible values for the inner and outer heat transfer coefficients. These values guarantee the lowest value for the heat transfer rate required for efficient heat removal at the given environmental temperature.

Keywords: *finned electric motor; constant heat flow; efficiency; efficacy.*

I. INTRODUCTION

The electric motor is responsible for the transformation of electric energy into mechanical energy, which is the main end-use of electric energy in industries in general, and its wide use in this sector is due to its simple construction and wide versatility in applying loads.

Factors that allow electric motors to lose up to 4% of their performance over their lifetime are improper installations, lack of regular maintenance, cleanliness and quality lubrication (Cardoso et. Al., 2009). Therefore, overheating the electric motor and consequently burning it is a problem for maintenance personnel, since heat produced by the electric motor must be dissipated efficiently, avoiding overheating and consequent burning. The high temperatures of the installation environment and the inefficient heat dissipation

generated by the difference in net power supplied by the motor and power absorbed in the line is the main cause of overheating (Santos, Rafael Simões, 2011).

Fins or the extended surfaces are extensively used in engineering applications to increase the heat transfer efficiency of surfaces, and are of vital importance in the design of heat exchange devices in different fields of applications in order to provide an enhanced heat transfer effect through an increase in the total heat exchange area (Campo, A.; Kundu, B., 2017), (Incropera, Frank P. Et Al., 2008), (Santos, T. A. M., 2017). Once the temperature distribution through the fin is known, the heat transfer rate and the efficiency can be readily determined.

In electric motors, it is common to use extended surfaces, which increase the exchange area as a mechanism for heat transfer optimization. In fact, an important industrial application of fins occurs in electric motors and are of vital importance in the industry as they are used in machines of all types, including, for example, computer ventilation and other electronic equipment. A well-dimensioned finned ventilation system can contribute to energy savings.

The heat dissipation is directly associated with efficient ventilation, the temperature difference between the engine housing surface and the medium (in this case, the air surrounding the engine), the total heat exchange area of the engine housing and of extended surfaces (fins). Important feature is the geometry of the fins, as they have a great influence on the area available for exchange and, in order to heat transfer as good as possible, the construction material of these fins must have high thermal conductivity, such as aluminum and copper (Duarte, Denise Freire; Novais, Ariane Silva; Nogueira, Élcio, 2012), (Novais, Ariane; Chagas, R. D. F.; Nogueira, Élcio, 2014), (Marcus Vinicius Ferreira Soares, 2015), (Voigdlener, Thiago, 2004).

Ventilation depends directly on the internal and external convection heat transfer to which the motor is subjected. This dependence is because the heat exchange occurs between a moving fluid (air) and the motor surface (housing), which are at different temperatures. The air moves due to the internal and

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external convection process causing a random molecular displacement on the surface. According to Ordenes (2008), the convection coefficient is a proportionality constant that considers several factors, including surface geometry and the nature of the flow.

Novais and Comitra (2014) showed that one of the factors that contribute to burning is the thermal resistance that exists between the housing and the motor core. According to Moreira (2012), besides the convection acting in the region outside the motor housing, and its respective convection coefficient, there is also the convection in the internal region and the resistance associated with the conduction process that occurs in the air layer, between the core and the motor housing.

The contact interface between the motor wall and its insulation is promoted by a mechanical union that generates a thermal resistance due to imperfect contact, resulting from small roughness and undulation. In this region, conduction occurs at the contact points and conduction through the trapped fluids in the interstices of roughness and undulation. However, it is important to note that some motors do not use this contact interface between the motor wall and its insulation, being air the only element that serves as thermal resistance between the motor core and the housing.

Thus, we have to determine two convection coefficients, one of them referring to the external region and the other to the internal part of the motor housing, the latter is also dependent on the microscopic imperfections on the surfaces and the contact pressure of the materials, the fluid contained in the interstices, of the applied oxide film and the metallic shim involved.

This latter convection coefficient is undoubtedly the most complex of the two processes and the most difficult to obtain experimentally.

Although the internal resistance is crucial for the correct motor thermal sizing, the usual theoretical models still consider the temperature at the fin base attached to the motor housing equal to the motor core temperature.

In Table 1 below, some physical and geometrical characteristics of the engine.

Table 1: Engine Data

Power	1 cv
Number of Poles	4
Motor Outer Diameter	139,60 mm
Engine Width	130,13 mm
Number of Fins	32
Fin Base Width	5,84 mm
Fin Height	17,00 mm
Maximum Ambient Temperature	40 °C

II. THEORETICAL ANALYSIS

Analytical solutions for temperature profiles were developed considering constant heat flux in the fins, and constant thermo physical properties. Variations were also simulated between the motor housing construction materials: cast iron and aluminum.

In this context we have the Ordinary Differential Equation (E.D.O.) of the rectangular profile fin, described by the equation below:

$$\frac{d^2T(r)}{dr^2} = \frac{h \cdot A_l}{k \cdot V} [T(r) - T_\infty] \quad 01$$

at where: $A_l = P_b \cdot L$ $e V = A_b \cdot L$

$$\frac{d^2T(r)}{dr^2} = \frac{h \cdot P_b}{k \cdot A_b} [T(r) - T_\infty] \quad 02$$

$$\theta(r) = T(r) - T_\infty \quad 03$$

$$\frac{d^2\theta(r)}{dr^2} = \frac{h \cdot P_b}{k \cdot A_b} \theta(r) \quad 04$$

making $m^2 = \frac{h \cdot P_b}{k \cdot A_b}$ and substituting in equation (3) we have:

$$\frac{d^2\theta(r)}{dr^2} = m^2 \cdot \theta(r) \quad 05$$

$$asm^2 = \frac{h \cdot P_b}{k \cdot A_b} \rightarrow m = \sqrt{\frac{h \cdot P_b}{k \cdot A_b}}$$

Whose E.D.O general solution is:

$$\theta(r) = C_1 \cdot \cosh(mr) + C_2 \cdot \sinh(mr) \quad 06$$

1st boundary condition: $r = 0$

$$-k \cdot \frac{d\theta}{dr} = Q_0 \quad 07$$

2nd boundary condition: $r = L$

$$-k \cdot \frac{d\theta}{dr} = h_2 \cdot \theta_L \quad 08$$

At where

$$\theta_L = \theta(L) = T(L) - T_\infty \quad 09$$

$$\frac{d\theta}{dr} = C_1 \cdot m \cdot \sinh(mL) + C_2 \cdot m \cdot \cosh(mL) \quad 10$$

From the first boundary condition ($r = 0$), we must:

$$-k \cdot [C_1 \cdot m \cdot \sinh(m \cdot 0) + C_2 \cdot m \cdot \cosh(m \cdot 0)] = Q_0 \quad 11$$

as $\sinh(0) = 0$ e $\cosh(0) = 1$, we have:

$$-k \cdot [C_2 \cdot m] = Q_0 \quad 12$$

$$C_2 = -\frac{Q_0}{k \cdot m} \quad 13$$

From the 2nd boundary condition ($r = L$), we must:

$$-k \cdot [C_1 \cdot m \cdot \sinh(mL) + C_2 \cdot m \cdot \cosh(mL)] = h_2 \cdot [C_1 \cdot \cosh(mL) + C_2 \cdot \sinh(mL)] \quad 14$$

$$-\frac{k}{h_2} \cdot C_1 \cdot m \cdot \sinh(mL) - \frac{k}{h_2} C_2 \cdot m \cdot \cosh(mL) = C_1 \cdot \cosh(mL) + C_2 \cdot \sinh(mL) \quad 15$$

$$-C_1 \left[\frac{k \cdot m}{h_2} \cdot \sinh(mL) + \cosh(mL) \right] = C_2 \left[\frac{k \cdot m}{h_2} \cdot \cosh(mL) + \sinh(mL) \right] \quad 16$$

$$C_1 = -C_2 \cdot \frac{\left[\frac{k \cdot m}{h_2} \cdot \cosh(mL) + \sinh(mL) \right]}{\left[\frac{k \cdot m}{h_2} \cdot \sinh(mL) + \cosh(mL) \right]} \quad 17$$

$$C_1 = \frac{Q_0}{k \cdot m} \cdot \frac{\left[\frac{k \cdot m}{h_2} \cdot \cosh(mL) + \sinh(mL) \right]}{\left[\frac{k \cdot m}{h_2} \cdot \sinh(mL) + \cosh(mL) \right]} \quad 18$$

$$Q_0 = 0,25 \cdot \left[\frac{\left(\frac{750}{32} \right)}{A} \right] \quad 19$$

Q_0 is the flow prescribed on the fins and A is the area of the fin. Note that 750 W is the engine power. The calculated value of Q_0 for the motor studied is 7709.7 W / m².

To determine the motor core temperature, we have:

$$\dot{q} = \frac{T_M - T_b}{\frac{1}{h_1 A} + \frac{\ln(D_2/D_1)}{2\pi KL}} \quad 20$$

$$A = \pi \cdot D_1 \cdot L \quad \text{e} \quad D_1 = D_2 - 2 \cdot E_0$$

$E_0 =$ Motor wall thickness

$$\frac{\dot{q}}{A} = \frac{T_M - T_b}{\frac{1}{h_1} + \frac{A \cdot \ln(D_2/D_1)}{2\pi KL}} \quad 21$$

$$\frac{\dot{q}}{A} = Q_0 = \frac{T_M - T_b}{\frac{1}{h_1} + \frac{D_1 \cdot \ln(D_2/D_1)}{2K}} \quad 22$$

$$Q_0 \cdot \left[\frac{1}{h_1} + \frac{D_1 \cdot \ln(D_2/D_1)}{2K} \right] = T_M - T_b \quad 23$$

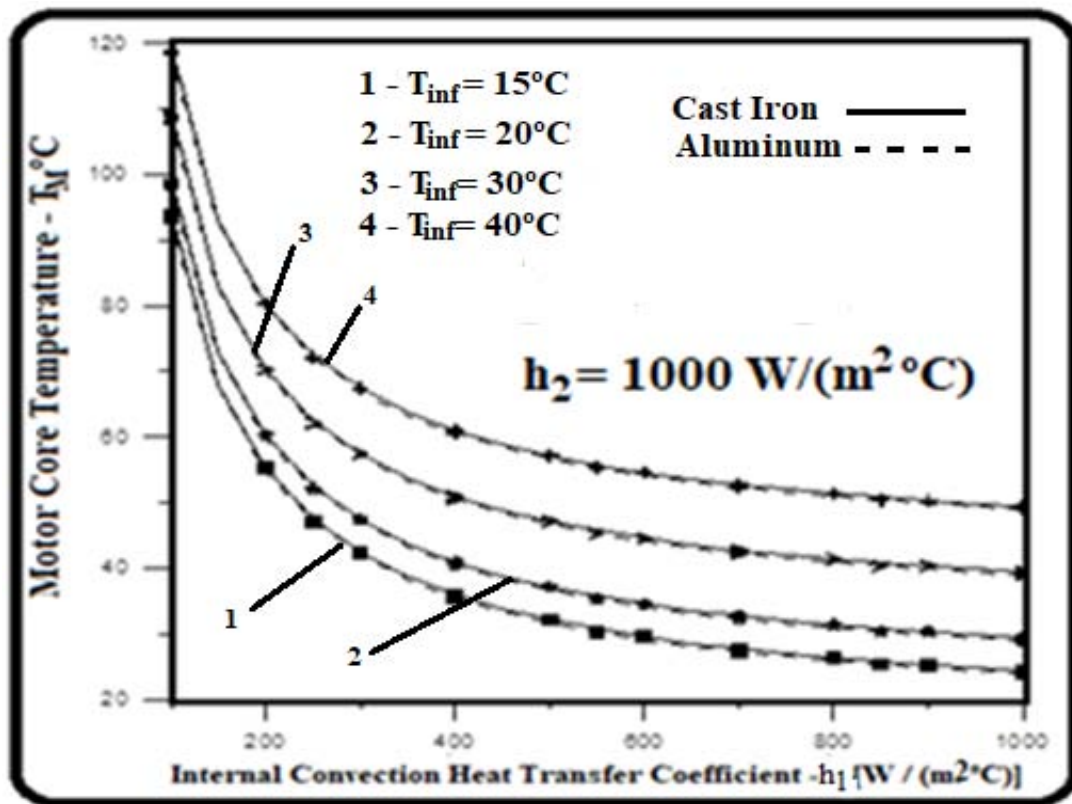
$$T_M = T_b + Q_0 \cdot \left[\frac{1}{h_1} + \frac{D_1 \cdot \ln(D_2/D_1)}{2K} \right] \quad 24$$

where T_b is the temperature at the base of the fin, which depends on the operating conditions, i.e. external temperature T_∞ and external convection coefficient h_2 .

III. RESULTS AND DISCUSSION

The Table 2 shows the numerical values for motor core temperature with $h_2 = 1000 \text{ W} / (\text{m}^2 \cdot \text{°C})$ and h_1 e T_∞ as variables.

We analyzed the temperatures ambient strictly below 45 °C for cast iron and aluminum materials. The data in Table 2 and Figure 1, related to the internal and external heat transfer coefficients, show that under the best possible condition [$h_2 = 1000 \text{ W} / (\text{m}^2 \cdot \text{°C})$], there is no considerable difference between the analyzed materials.



Authors

Figure1: Motor Core Temperature - $h_1 \times T_M$

Table 2: Motor Core Temperature (T_M) versus Internal Convection Coefficient (h_1) $h_2 = 1000 \text{ W}/(\text{m}^2 \text{ }^\circ\text{C})$

h1 W/(m ² °C)	$T_\infty = 15$		$T_\infty = 20$		$T_\infty = 30$		$T_\infty = 40$	
	Iron Cast	Al	Iron Cast	Al	Iron Cast	Al	Iron Cast	Al
100	93,86	93,40	98,86	98,40	108,86	108,40	118,86	118,40
150	68,16	67,70	73,16	72,70	83,16	82,70	93,16	92,70
200	55,31	54,85	60,31	59,85	70,31	69,85	80,31	79,85
250	47,60	47,14	52,60	52,14	62,60	62,14	72,60	72,14
300	42,46	42,00	47,46	47,00	57,46	57,00	67,46	67,00
350	38,79	38,33	43,79	43,33	53,79	53,33	63,79	63,33
400	36,04	35,58	41,04	40,58	51,04	50,58	61,04	60,58
450	33,90	33,43	38,89	38,43	48,89	48,43	58,89	58,43
500	32,18	31,72	37,18	36,72	47,18	46,72	57,18	56,72
550	30,78	30,32	35,78	35,32	45,78	45,32	55,78	55,32
600	29,61	29,15	34,61	34,15	44,61	44,15	54,61	54,15
650	28,62	28,16	33,62	33,16	43,62	43,16	53,62	53,16
700	27,78	27,32	32,78	32,32	42,78	42,32	52,78	52,32
750	27,04	26,58	32,04	31,58	42,04	41,58	52,04	51,58
800	26,40	25,94	31,40	30,94	41,40	40,94	51,40	50,94
850	25,83	25,37	30,83	30,37	40,83	40,37	50,83	50,37
900	25,33	24,87	30,33	29,87	40,33	39,87	50,33	49,87
950	24,88	24,42	29,88	29,42	39,88	39,42	49,88	49,42
1000	24,47	24,01	29,47	29,01	39,47	39,01	49,47	49,01

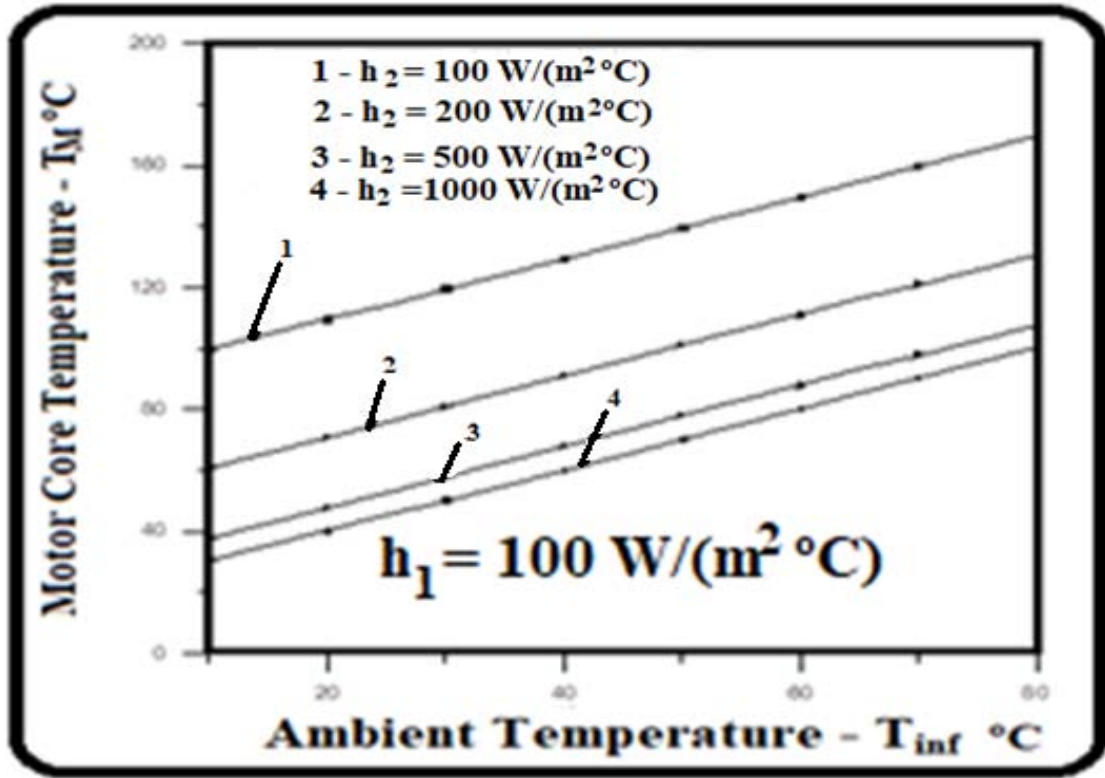
For analysis purposes, a maximum engine core working temperature of 98 ° C is assumed. The manufacturer sets the maximum operating temperature equal to 120 ° C.

Analyzing Figure 2, for the external temperature of 40 ° C, we have that, for Cast Iron the motor to work in the acceptable temperature range, the value of h_2 must be greater than or equal to 200 W / (m². °C).

For the value of $h_1 = 200 \text{ W} / (\text{m}^2 \cdot ^\circ\text{C})$, shown in Figure 3, the motor works at the limit established in the research and we can conclude that the motor works properly for values of h_1 above 200 W / (m². ° C).

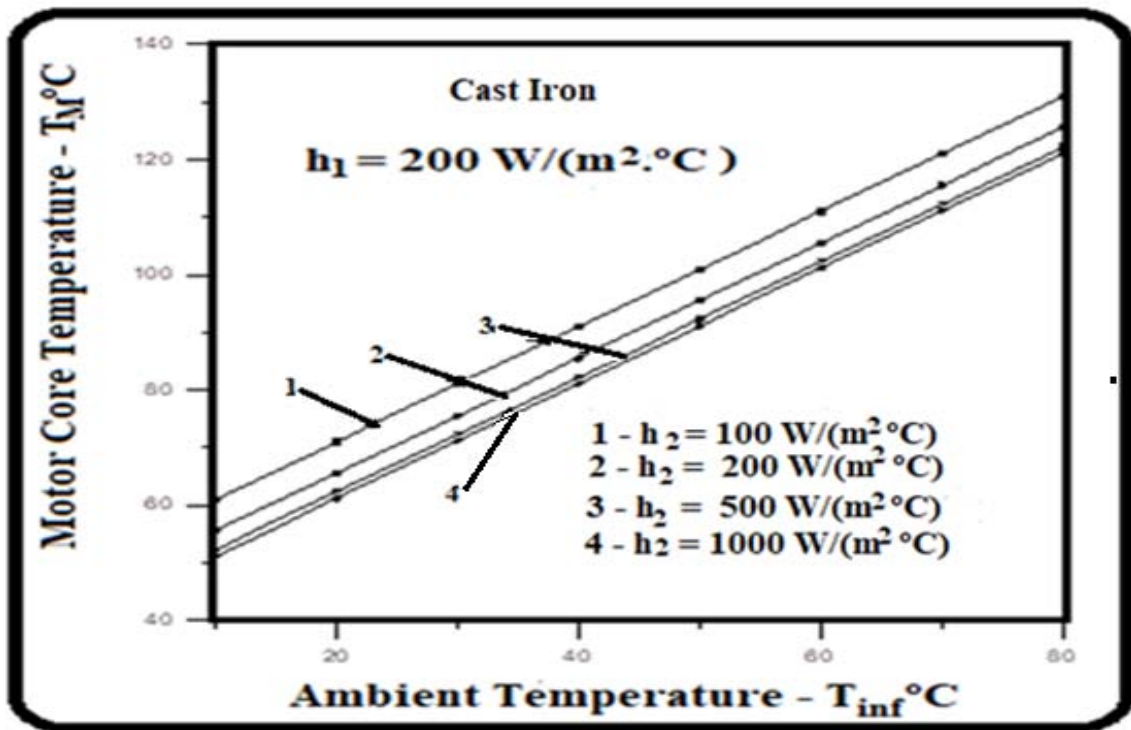
Analyzing Figure 4, for the external temperature of 40 ° C, we arrive at the following conclusions: for $h_1 = 100 \text{ W} / (\text{m}^2 \cdot ^\circ\text{C})$ the motor temperature is equal to 128.61 ° C, which goes beyond the limit value. From research of 98 ° C. In the same Figure 4, for $h_1 = 200 \text{ W} / (\text{m}^2 \cdot ^\circ\text{C})$ the motor temperature is equal to 90.06 ° C, below the search limit value. The value of $h_1 = 200 \text{ W} / (\text{m}^2 \cdot ^\circ\text{C})$ is feasible and achievable in natural ventilation.





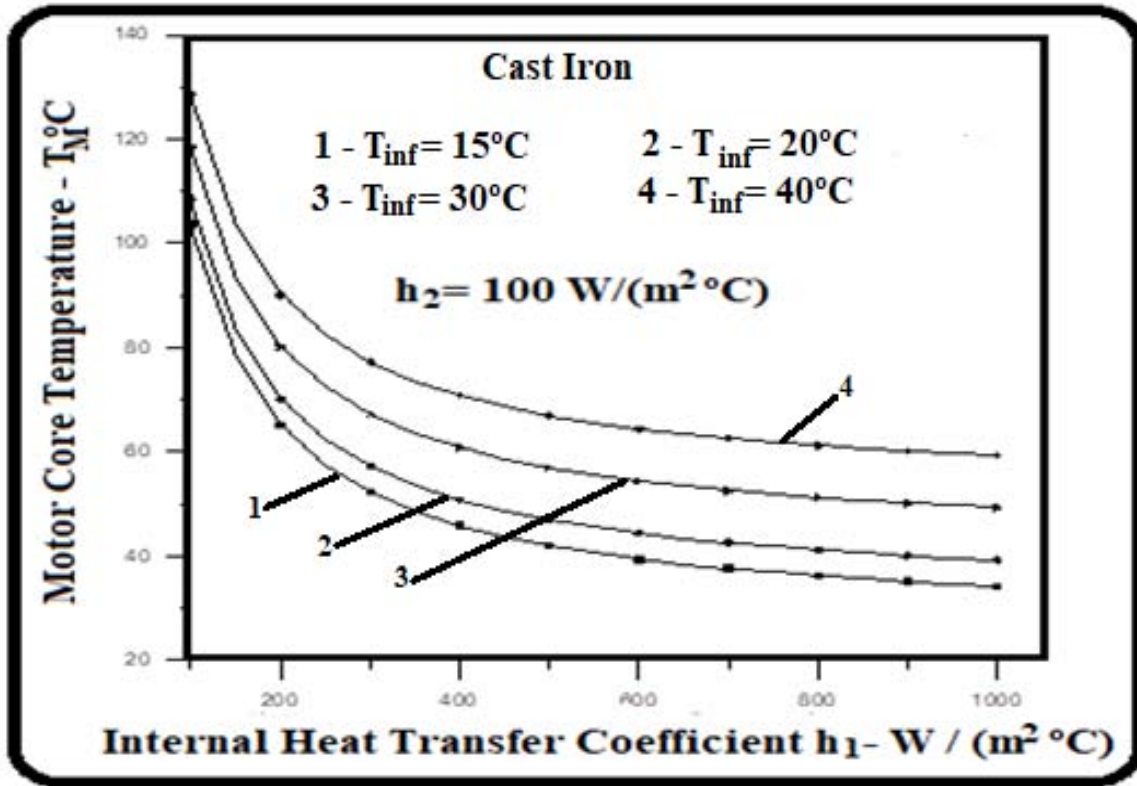
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Figure 2: Motor Core Temperature – $T_{inf} \times T_M$



Authors

Figure 3: Motor Core Temperature – $T_{inf} \times T_M$



Authors

Figure 4: Motor Core Temperature - $h_1 \times T_M$

Looking at Figure 5 for the external temperature of 40 ° C, we arrive at the following conclusions: for $h_1 = 150 \text{ W} / (\text{m}^2 \cdot \text{° C})$ the motor temperature is equal to 97.48 ° C, very close to 98 ° C, but already below search limit. In the same Figure 5, for $h_1 = 200 \text{ W} / (\text{m}^2 \cdot \text{° C})$ the

motor temperature is 84.63 ° C, below the search limit value.

Figure 6, is the graph constructed from the data generated for engine efficiency. Note how aluminum results are far superior to cast iron.

$$\eta_{motor} = \frac{Q_0}{h_2 \cdot [A_L + (A_{Motor} - 32 \cdot A_b)] \cdot (T_b - T_\infty)} \quad 25$$

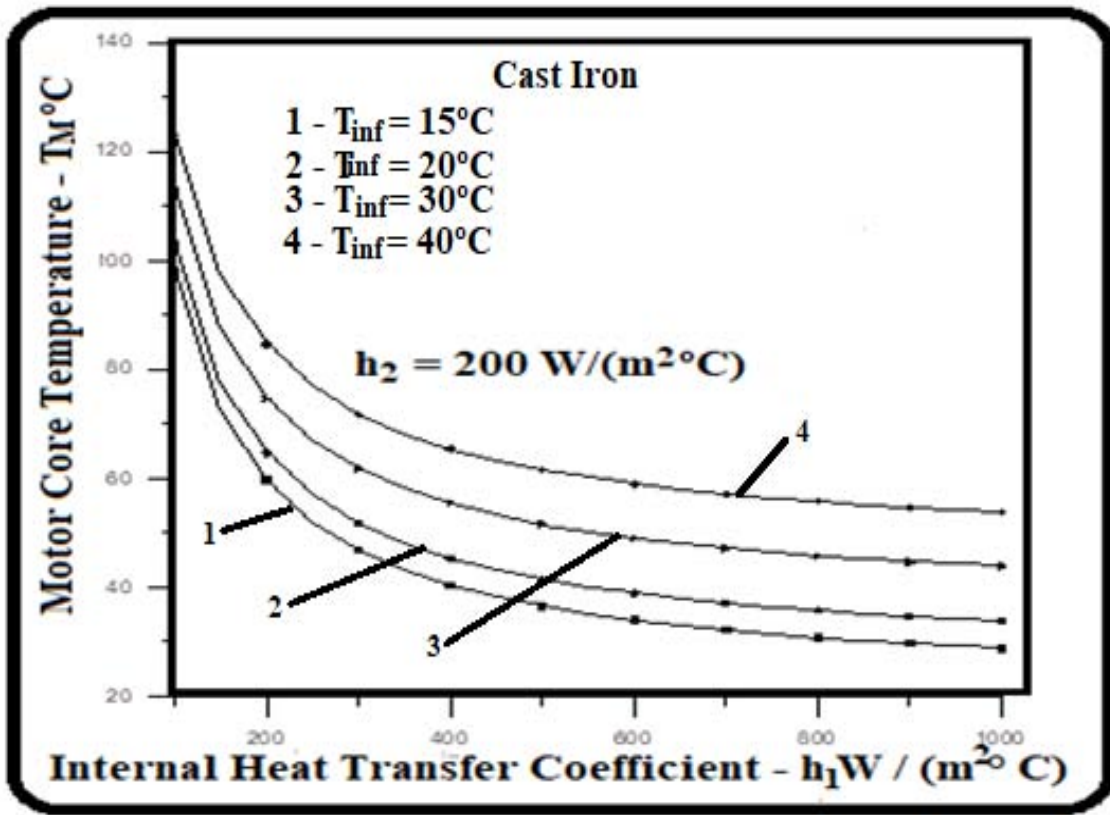
Another parameter to be analyzed is the effectiveness of the engine, which is the ratio between

fin and non-fin motor heat exchange. The efficacy formulagiven by:

$$\varepsilon_{motor} = \frac{Q_0}{h_2 \cdot A_{Motor} \cdot (T_b - T_\infty)} \quad 26$$

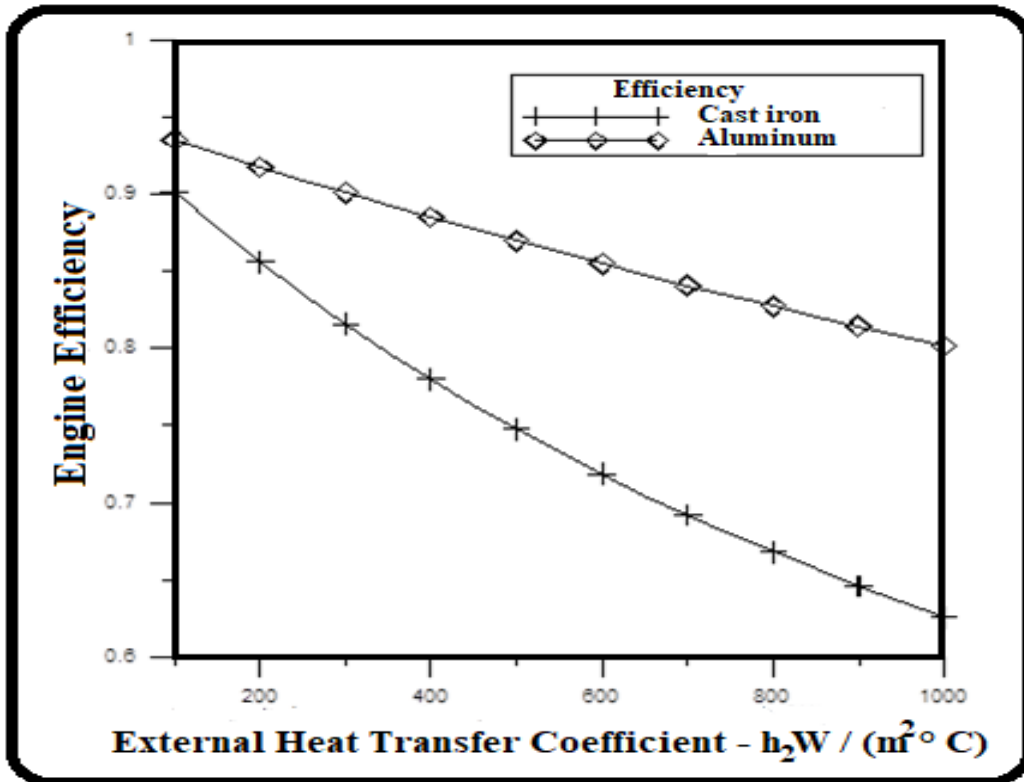
Again, Figure 7, demonstrates that the results for aluminum are much higher than those obtained by cast iron.

Looking at Figure 7, we can conclude that a reasonable effectiveness value for a fin of 2.5 is achieved when h_2 is near $400 \text{ W} / (\text{m}^2 \cdot \text{° C})$ for cast iron.



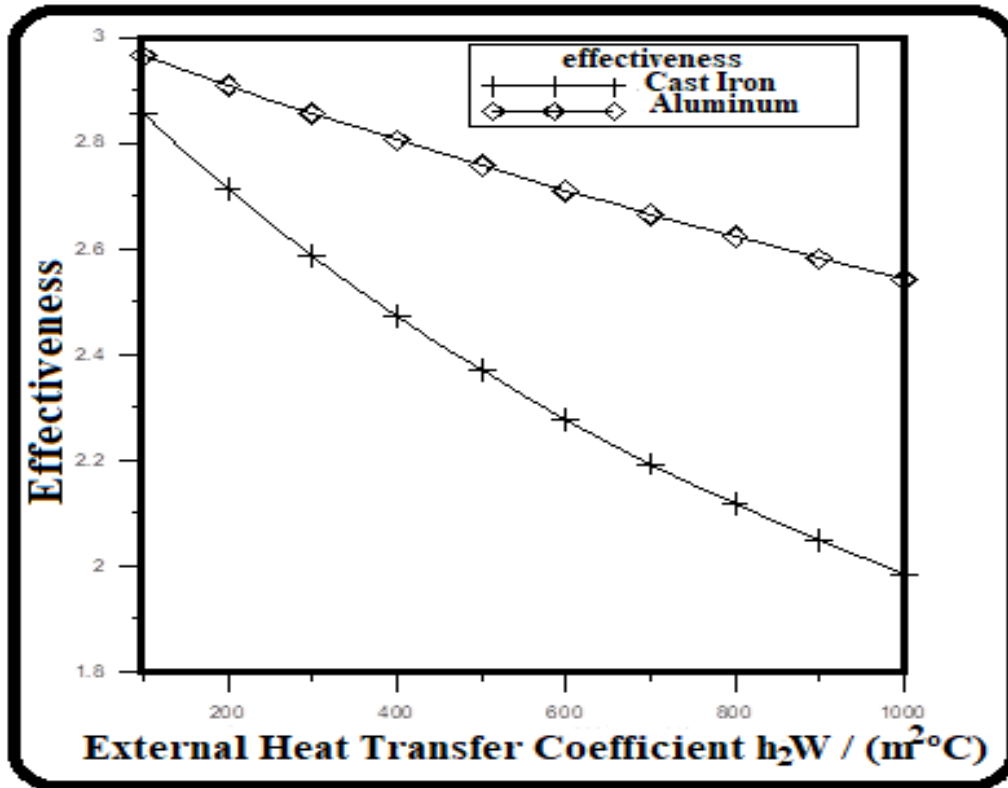
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Figure 5: Motor Core Temperature - $h_1 \times T_M$



Authors

Figure 6: Engine Efficiency



Authors

Figure 7: Engine Effectiveness

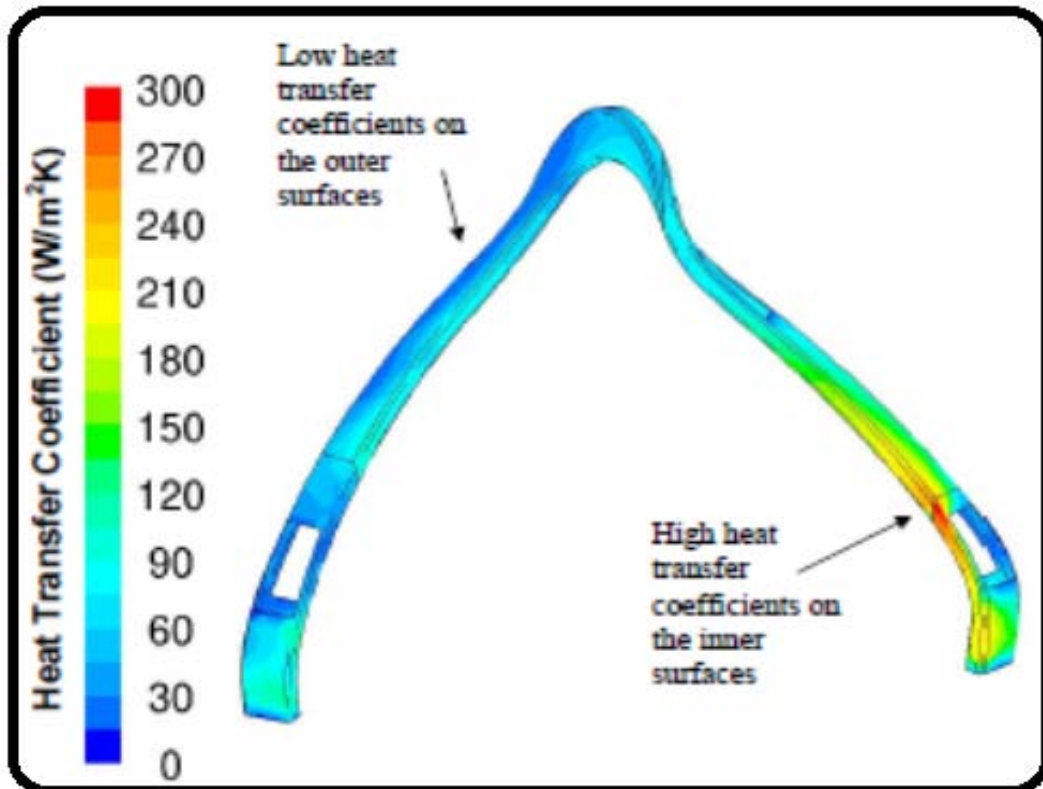


Figure 8: Contour for Local Heat Transfer Coefficient
Beng, Christopher Micallef(2006)

Based on the results observed above, and in the graphs of efficiency and effectiveness, we conclude that for any values of $h_1 \geq 200 \text{ W / (m}^2 \cdot \text{° C)}$ and $h_2 \geq 200 \text{ W / (m}^2 \cdot \text{° C)}$ the engine temperature will have a satisfactory value. However, the values of h_1 and h_2 are physically limited. For h_1 to assume values greater than $400 \text{ W / (m}^2 \cdot \text{° C)}$, forced ventilation must be used with the aid of a fan inside the engine or by drilling holes in the housing to increase natural ventilation. In addition, for h_2 to assume values greater than $400 \text{ W / (m}^2 \cdot \text{° C)}$, ventilation must be increased in the environment where the engine is installed, which would generate more costs for the company.

The above results are consistent with the results presented and experimentally confirmed by Micallef (2006), Figure 8 above, in his doctoral dissertation entitled "*End Winding Cooling in Electric Machines*". In his studies, using experimental and numerical method CFD - Computation Fluid Dynamic, the author applied three distinct turbulence models, and the results showed that the closer to the motor core, the higher the heat transfer coefficient by convection acting on the internal surfaces.

The measured internal coefficient assumed values close to $300 \text{ W / (m}^2 \cdot \text{K)}$, a value that is included in the working range proposed by this study.

IV. CONCLUSION

The motor core temperature was computationally simulated by varying the internal (h_1) and external (h_2) convection heat transfer coefficients and the ambient temperature. The results demonstrated two things: the importance of the internal heat transfer coefficients and their physical limitations.

Regarding the heat transfer coefficients, we can conclude that the values of h_1 and h_2 cannot be treated separately. For very low h_1 and h_2 values the fins tend to be at the same temperature as the outside temperature, so there is no efficient heat exchange, overheating the engine. For very high h_1 values, which is physically impossible to obtain, we have that the fin base tends to stay with the motor core temperature, with is the usually conditions generally used by the one-dimension and two-dimension fin models.

We conclude that for any values of $h_1 \geq 200 \text{ W / (m}^2 \cdot \text{° C)}$ and $h_2 \geq 200 \text{ W / (m}^2 \cdot \text{° C)}$ the motor temperature will have a satisfactory value. However, as already mentioned, the values of h_1 and h_2 are physically limited. For h_1 to assume values greater than $400 \text{ W / (m}^2 \cdot \text{° C)}$, which is already a critical value to obtain for mechanical reasons, it is necessary to use forced ventilation inside the engine or drill holes in the housing to increase nature ventilation. The same reasoning can be used for the external coefficient h_2 , which would entail a higher cost to the company, as it would be

necessary to increase ventilation at the engine installation site.

Thus, the ranges, $200 \leq h_1 \leq 300$ and $200 \leq h_2 \leq 400$, are the limit values that guarantee the lowest value for the heat transfer rate required for efficient heat removal. Any values above these will increase the transfer rate and consequently decrease the motor core temperature, however, considering the difficulties of achieving these values in practical terms.

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The Configuration of Solar Sail Catamaran Fishing Vessel

By PI Santosa

Abstract- Currently, the catches of fishing vessels supplies the daily food needs and sustains the food security of millions people in the world. In the field of shipping, consumption of fossil fuel is quite large, especially as fuel to drive ship-engines. The high fuel price is not at all beneficial to the shipping industry and fishermen as users of ship-engines. The use of fuel for ship-engines is not only un-economical but also not environmentally friendly. The more expensive fuel is anticipated by wind and solar energy in the form of Solar-Sail Vessels (SSV) as Fishing Vessels. This paper presents a study on the efficient use of fuel in SSV as a driver that does not utilize fuel to develop of environmentally friendly fishing vessels. There is a potential savings in the use of fuel 90% almost.

Keywords: *fishing vessel, solar-sail vessels, wind energy, solar energy, efficiency.*

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Keywords: fishing vessel, solar-sail vessels, wind energy, solar energy, efficiency.

I. INTRODUCTION

The mission of a fishing boat is to catch fish from the sea to get fish that meet the quality in appropriate ways and deliver the fish to land or to another vessel for further processing,[1]. The fishing

activities have an impact on the increase of air pollution levels (such as CO_2 , SO_2 and NO_x) in the atmosphere, especially on fish boats that use diesel engines. The impact of the activities is one of the most crucial problems in the world, thus many efforts have been done to look for solutions that the operation of fishing vessels become environmentally friendly, [2].

In general, the operation of a fishing vessel is always associated with economic and environmental issues. Economic factor is the cost of fuel, while the environmental factor is related to the level of pollution produced. Economic problems and strong environmental pressures forcing the ship designers and owners to create more efficient vessels to minimize the use of ship propulsion. Reduced magnitude of ship propulsion (and fuel requirements) can be fulfilled since the ship design stage by creating more efficient hull design and propulsion systems as well as ship operational activities including ship operations, such as: Solar Sail Vessels (SSV), [3].

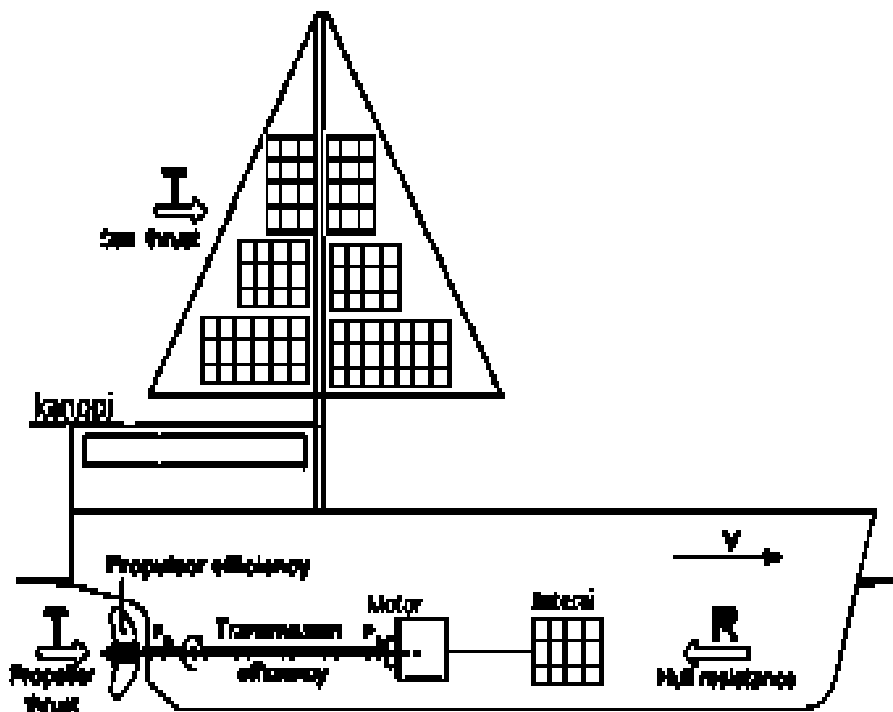


Figure 1: Configuration of Solar-sail Vessels (SSV),[1].

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Figure 1. shows the configuration of the vessel with the solar-sail driver. The concept of energy conversion in the ship's configuration is to convert wind and solar energy into the required thrust force of the ship through the propeller (electric motor) and sail. The thrust (T) force generated from one or more of the ship's propulsion sources operates simultaneously or together known as the hybrid system [1].

Environmentally friendly vessels that have ever been built in the world

- Foscat32 catamaran tourism boat, the concept of a hybrid drive that combines diesel motors, sail and solar panels (Foscat32,2015)



Figure 2: Foscat32 catamaran tourism boat hybrid (Foscat32, 2015)

Figure 2. shows the configuration of the Foscat32 catamaran tour boat equipped with hybrid propulsion which, in this case, the screen and solar panel are placed vertically above the ship's navigation space as the screen whose placement is adjusted according to: stability, load space requirements, vessel operations and energy requirements to drive the ship. Foscat32 (Folding Solar Catamaran) is a folding sailboat utilizing natural energy from wind and sun, has a length of 32 meters and a height of 52 meters with a solar

panel (95 m²) placed on the main pole and has two electric motors placed on the hull. This ship has high performance because it uses a lightweight system, which is a combination of the power of the sun and wind by reducing CO₂ to almost zero during sailing.

- Greenpeace Rainbow Warriors, this eco-friendly vessel is actively carrying out a campaign to save the environment by sailing around the world (Greenpeace, 2015).



Figure 3: Greenpeace Rainbow Warriors ship (greenpeace, 2015)

Figure 2. shows the configuration of the Greenpeace Rainbow Warriors Ship, which is equipped with a driving force of sail combination, hybrid engine. While what is meant by a hybrid engine is a diesel engine that is equipped with an electric motor that can work alternately or simultaneously. Hybrid engine and sail will work alternately or simultaneously. The thrust force used to drive this ship is generated from the

propeller and sail. The New York Horn blower passenger vessel, the "San Francisco Horn blower Hybrid" ship made in 2008 and the "New York Horn blower Hybrid" vessel in April 2011, is a passenger vessel with a capacity of 600 passengers equipped with a combination of diesel engines, solar power and power turbines. wind (New York Horn blower, 2015).



Figure 4: Hybrid passenger ship (Newyork hornblower, 2015)

Figure 4: shows the configuration of a hybrid passenger ship by utilizing natural energy from wind and solar because this ship will run its diesel engine if needed as additional power. The wind will drive wind power turbines to produce electricity, while solar power will be converted into electricity as well.

- Norwegian fishing boats, Eld by, (2014), in their article writing about the collaboration of Norwegian

fishermen and SINTEF researchers, have succeeded in simulating small fishing boats equipped with a battery-driven electric (as shown in Figure 5, the results show that the energy consumed about 60 to 70% of total energy during the time of operation of the fishing vessel.



Figure 5: Fishing boats equipped with a battery-driven electric engine, (Eldby, 2014)

Furthermore, the idea of developing an innovative hybrid catamaran fishing vessel design is intended to produce a fuel-efficient, environmentally friendly and well-performing vessel, which is a proposal for the concept of a future fishing vessel. Whereas the relevance of this research is related to efforts to create an efficient ship and save fuel and the possibility of its contribution to the layout of the catamaran vessel space which is more flexible in the application of fishing vessels.

II. LITERATURE REVIEW

- *Ship Moving Theory*
The vessel may move forward due to a sufficient thrust to resist ship resistance at a certain service speed [4]. Based on the above concept, then requirement of ship can move.

$$T \geq R_T \quad \text{or} \quad T - R_T \geq 0 \quad (1)$$

where: T is Thrust (kN), R_T is Resistance (kN)

- *Ship Resistance*
The total vessel resistance (R_T) is calculated according to Equation (2) where ρ is the sea water mass, CT is the total resistance coefficient, WSA is the wet surface area, and V is the velocity of the vessel, [4]

$$R_T = \frac{1}{2} \rho C_T (WSA) V^2 \quad (2)$$

- *Thrust*
Thrust (T) is the energy or force required to drive the vessel and can be expressed as Eq. (3), [4].

$$\text{Thrust } (T) = R_T / (1-t) \quad (3)$$

where: t is thrust deduction factor

$$\text{For double screw [3]: } t = k_R \quad (4)$$

where: k_R is 0.5 for thin rudder.

$$wt = -0.0458 + 0.3745C_B^2 + 0.1590D_w 0.8635Fr + 1.4773Fr^2$$

$$D_w = \frac{B}{v^{1.5}} \sqrt{\frac{v^{1.5}}{D}}$$

To move itself, the thrust (T) force generated through the propeller and the sail must be greater than the existing total vessel resistance (R_T), mathematically expressed in (5), [4].

$$T_{propeller} + T_{sail} \geq R_T$$

$$\text{Propeller thrust, } T_{propeller} = K_T \cdot \rho \cdot n^2 \cdot D^4$$

where: thrust coefficient (K_T), Salt water density (ρ), Propeller Rpm (n), Propeller diameter (D) . w_t

$$\text{Sail thrust, } T_{sail} = q \cdot A_s$$

where: Dynamic wind pressure (q) = $\frac{1}{2} \times \rho \times \epsilon \times V_w^2$ (ton/m²), Air mass density (ρ) = γ/g , Weight per unit volume (γ) = 1.2265 t/m³, g = 9.81ms⁻², ϵ = wind pressure coef. (1.1), wind speed (V_w), sail area (A_s).

- Powering
Engine conventional is the prime mover of the vessel which works by converting the fuel energy to rotate the blades thereby producing sufficient thrust to resist ship resistance at certain service speeds. One of the most fundamental methods of power sharing in this conventional driving force is to distinguish between the effective power (PE) required to drive the ship and power delivered (PD) on the ship propulsion unit, [4].

The formulations used according to [4] are as follows:

$$\text{Effective power (PE)} = R_T \times V_s \quad (8)$$

$$\text{Delivered power (PD)} = PE / H_d \quad (9)$$

$$\text{Quasi propulsive coefficient } (\eta_D) = \eta_P \cdot \eta_H \cdot \eta_R \quad (10)$$

$$\text{Service power (Ps)} = PD / \eta_T$$

where: η_T is 0.98 with gearbox, 0.95 without gearbox

$$\text{Installed power (PI)} = Ps + \text{Margin}$$

Margins (*roughness, fouling, weather*) 15 – 20% depend ship route.

The concept of solar vessel energy conversion is converting solar energy into the driving force required by vessels through solar panels, batteries, electric motors, transmissions and propellers at a certain speed. In detail can be explained as follows: Solar panels function to capture solar energy and convert it into electrical energy, then stored in a battery. Power stored in the battery will be used to supply the electric motor

and rotate the propeller. So that the vessels can move forward due to the thrust force produced by the propeller (T_p).

Since 2002 research on the technology of combined use of wind and solar power in the form of a Solar sail has been developed in the USA, (Herbeck et al., 2002). Solar sail is made of thin Mylar or Kapton films with a thickness of 7.6 mm and has a broad density (defining the weight of the material divided by the area of material) about 11 g / m² as shown in Fig.7. The solar sail has 2 functions, namely: 1) As a propeller vessel, 2) As a system of Photovoltaic technology that converts sunlight into electrical energy. The existence of an efficient combination between the use of the sail and the solar panel if applied to the ship will be able to save the use of the deck of the ship.

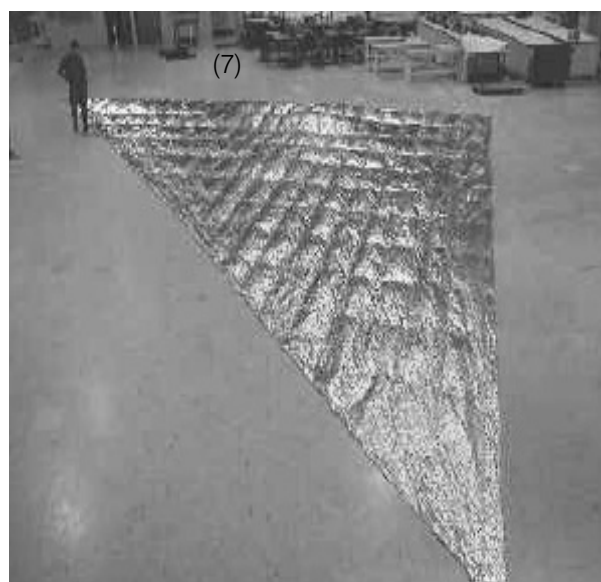


Figure 6: Solar sail NASA JPL Type

Besides functioning as a booster of vessel (in the form of sail), Solar Sail can also function as a solar panel that collects electrical energy and is very suitable to be applied as an environmentally friendly vessel. Sail is one of the propeller props without a propeller on the ship that can work due to the wind force (catch the wind) on the surface of the screen, resulting in a drifting force on the ship at a certain speed. The Sail is one of the propulsion devices on the ship. As with other propulsion devices such as propellers, the sail is attempted to produce an optimal thrust force, in order to produce maximum velocity of the ship. The forces on the Sailing Ship, as the ship moves due to the thrust of the propeller or sail there will be a lift that will lift the hull from the water. In addition, obstacles caused by the aerodynamic resistance of the sail are the forces acting on the sailboat, [5].

Determination of Sail Area almost as a comparison of sail area (A_s) with wetted surface area (WSA) is between 2.0 and 2.5. Comparison of sail area (A_s) with wetted surface area (WSA) known as sail ratio (SR), [6]. There is another way according to [7], where the determination of SR depends on the LWL of the ship by using the graph shown in Fig.7.

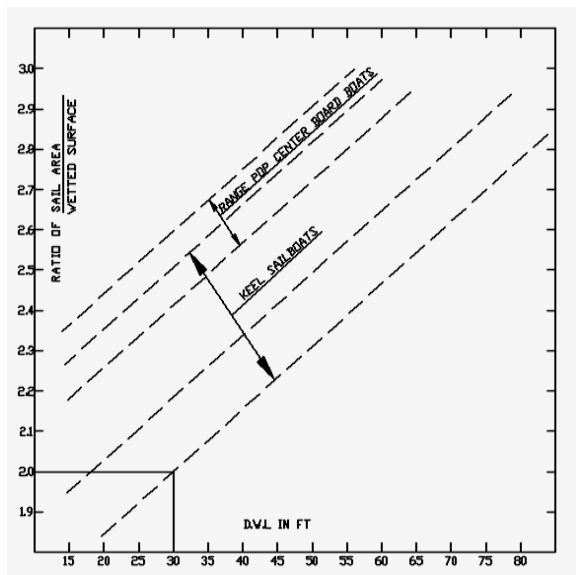


Figure 7: Graph of SR – LWL Relationship

Figure 8. shows graph of relation between SR with LWL which can be used to determine Sail Area with 15 - 80 feet or 5 - 25 m LWL limitation.

- Fishing Vessel

In general, the normal voyage profile of fishing vessels according to [9], are as follows: a) The ship departs and operates in the port (Departure from port), b) The ship goes to the location of the fishing ground (Outward bound), c) The ship arrives at the location fishing ground and fishing (On fishing ground), d) When the ship leaves the location of the fishing ground to the port (Homeward bound :), e) when the ship arrives at the port and docked at the port (Arrival at Port).

In its operation a fishing vessel must be completely safe (very seaworthy indeed), in bad weather even the ship must work. All work on the fishing boat must be done quickly, starting from the process of catching until the processing of the catch is a function of time. The slow catching process causes the fish to run all (migration), while the sluggish processing of the catch causes the fish to be damaged, [1].

III. MATERIAL AND RESULT

This research is a continuing research that has been done in [3]. All material data and information using the results of previous research to support scientific / academic and its application.



Figure 8: Towing Tank Experiment of Ship Resistance, [3]

Table 1: Dimension of Ship, [3]

Parameter	Catamaran	Demihull
LWL (m)	14.5	14.5
B (m)	7.118	1.318
H (m)	1.44	1.44
D (m)	0.694	0.694
C_B	0.434	0.434
Displ. (ton)	11.8	5.9

Figure 9. Demonstrate the Catamaran Hull Resistance Model Test through experiments in the hydrodynamic Tank, while Table 1 shows the ship dimension data as the model.

- Test result:

Table 2: Result of Resistance Test, [3]

Run No.	V (knots)	Fr	Catamaran Resistances (kN)		
			S/L=0.2	S/L=0.3	S/L=0.4
1	5.788	0.250	1.821	1.659	1.659
2	6.218	0.268	2.141	1.851	2.061
3	6.677	0.288	2.443	2.239	2.348
4	7.051	0.304	2.852	2.678	2.947
5	7.560	0.326	3.460	3.568	3.547
6	8.032	0.347	4.467	3.954	3.766
7	8.384	0.362	4.844	4.345	4.341
8	8.818	0.380	5.149	4.790	4.662
9	9.233	0.398	5.807	5.592	5.515
10	9.813	0.423	7.101	6.448	6.138

Table 2 shows the experimental results of catamaran Resistance in towing tanks. Furthermore, from this data will be developed as a basis for designing the concept of catamaran fishing boat with a combination of engine-sail, [1], [8].

Powering calculation result: Effective power (PE) 32,435 kW, quasi-propulsive coefficient (η_D) 0.664, delivered power (PD) 50.21 kW, transmission losses (η_T) 0.98 without gearbox, service power (P_s) 51.235 kW and installed power (PI) of 60 kW with total efficiency (PE / PI) is 54%. Engine specifications used 2 x 43 hp or 2 x 30 kW as shown in Fig. 9.

The result of Sail Area determination: Boats with 14.5 m LWL (47.56 feet) obtained approximately 125 m². The calculation results of Thrust is obtained for 6.685 kN with thrust deduction factor (t) of 0.038. Propeller thrust (T_p) is achieved at the speed of the ship's service (V_s) of 9.8 knots while the thrust force (T_s) is reached at wind speed (V_w) of 19.2 knots. The results of the above calculation are then used to create *Hybrid Curve Charts* as shown in Figure 5. This curve can be used to calculate ESV efficiency.



Figure 9: The Layout of SSV

Fig.6 shows the arrangement of fish holds and area for crew activities on the main deck, The wider space area for fishing activities on main deck is the main concern for the commercial fishing industry now. The Data's of Solar sail Catamaran Fishing Vessel (SSCFV) is LWL=14.5m, B=7.118 m, H=1.44 m, T=0.694 m, Tonnage 15 GT, Fish hold 1.723 ton, Electric power 2 x 30 kW at 2800 rpm.

The relationship between propeller thrust (T_p), see Equation (3) and sail thrust (T_s), see Equation (7) is shown in Figure 11, namely T_p-T_s curve. Meanwhile, the relationship between wind speed (V_w) with the sail thrust (T_s) is shown in Figure 6, namely the V_w-T_s curve. Likewise, the relationship between ship service speed (V_s) and propeller thrust (T_p) is also shown in Figure 6, namely the V_s-T_p curve. The relationship between wind speed (V_w) and ship service speed (V_s) is called the V_w-V_s curve.

Table 3: The Hybrid System work at V_s 9.813 knots

Sail		Propeller		Prime mover
V_w (Knots)	T_s (kN)	T_p (kN)	Electric motor Rpm	
0.0	0	6.685	1700	Propeller
4.0	0.5	6.185	1550	Propeller-sail
8.0	1.2	5.485	1480	Propeller-sail
12.0	2.4	4.285	1300	Propeller-sail
16.0	5.4	1.285	1000	Propeller-sail
19.2	6.685	0	0	Sail

Table 4 shows the Hybrid System (ESV) work, the propeller and sail can work individually/separately or together as a hybrid system when the ship moves.

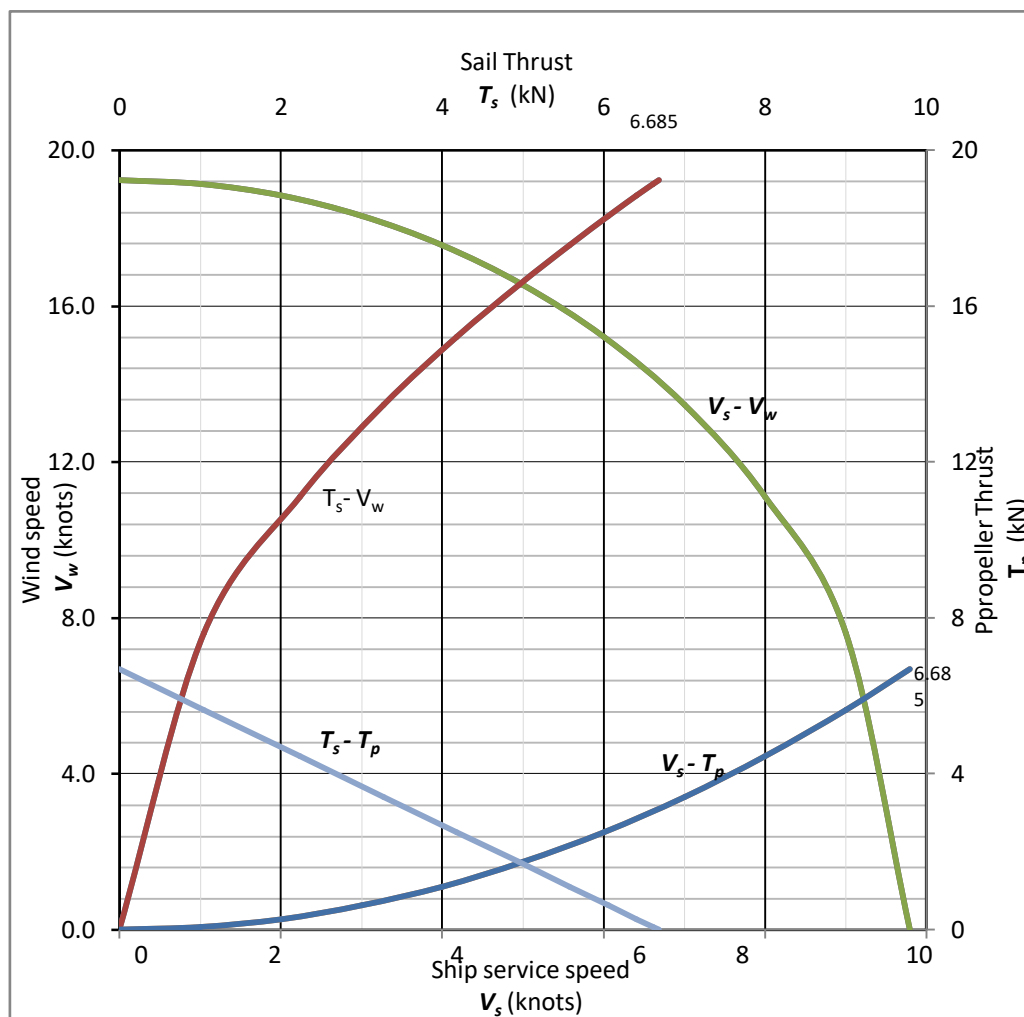


Figure 10: Hybrid Curve Chart, [1]

IV. DISCUSSION

Service speed (V_s) on fishing boats is a major requirement because fishing vessels must arrive at the fishing ground as quickly as possible so as not to lose the right time to catch fish. This fishing vessel operates with service speed of around 9.8 knots. At this speed the ship will experience a drag force (RT) of 6,423 kN with the need for thrust (T) of 6,685 kN. To meet the needs of the thrust force is supplied from propeller propulsion (T_p) with a 2x30 kW electric motor and sail (T_s) with an area (A_s) 125 m².

V. CONCLUSION

Application of hybrid technology use a combination Solar-Sail has potency to save fuel usage until 90%. It is very useful when applied to catamaran fishing vessels and hence reduce emission of greenhouse gases. The present work apparently portraits of study into the development of more energy efficient and less polluted fishing vessel.

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Inbound Marketing Strategies in a Brazilian Metal Mechanical Industry 3.0

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Abstract- The diffusion between the internet and marketing has allowed companies to explore new fields of action in front of the market, so digital marketing has emerged to facilitate the buying and selling process, among the tools used by it, is inbound marketing. The aim of the present study was to propose a discussion about the use and application of inbound marketing strategies and to verify the application of this new marketing philosophy by a Brazilian industry of metallurgy sector 3.0. Thus, an analysis was made through monthly reports, from January to July 2019, of all campaigns carried out on the Google Adwords platform for information on the application of inbound marketing in the same and the campaigns in other countries as they were targeted. and about the budgets used for that.

Keywords: *marketing. digital marketing. inbound marketing. attraction marketing. google adwords. google analytics.*

GJRE-A Classification: FOR Code: 290501



INBOUNDMARKETINGSTRATEGIESINBRAZILIANMETALMECHANICALINDUSTRY30

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Inbound Marketing Strategies in a Brazilian Metal Mechanical Industry 3.0

Estratégias de Inbound Marketing numa Indústria Brasileira Metal Mecânica 3.0 resumo

Sueli Sales Almeida

Resumo- A difusão entre a internet e o marketing permitiu as empresas explorarem novos campos de atuação frente ao mercado, assim o marketing digital surgiu para facilitar o processo de compra e vendas, entre as ferramentas utilizadas por este, está o inbound marketing. O objetivo do presente estudo foi propor uma discussão sobre o uso e aplicação de estratégias de inbound marketing e verificar a aplicação desta nova filosofia de marketing por uma indústria brasileira do setor de metalurgia 3.0. Desta forma, foi feita uma análise através de relatórios mensais no período de janeiro a junho de 2019, de todas as campanhas realizadas na plataforma Google Adwords para se obter informações sobre a aplicação do inbound marketing na mesma e as campanhas em outros países como foram segmentadas e quanto aos orçamentos utilizados para tal. Os resultados do estudo demonstraram que as estratégias do Google ADS são os meios mais eficazes de marketing que atraem e fidelizam clientes, porém o acompanhamento das campanhas devem ser diárias. Dentre as principais dificuldades foram que tem alguns períodos do mês que ficam sem saldo na conta e como foi solucionado tal problema, como por exemplo os anúncios que foram pausados pois consumiram bastante verba e não trouxeram resultados, as parcelas de impressão e seus anúncios. Este trabalho de pesquisa é muito importante porque melhorará a situação da empresa, uma vez que a aplicação da estratégia Inbound Marketing permitirá seu crescimento e ainda pode ser benchmarking para outras indústrias, já que se a empresa tem uma boa estratégia e está obtendo bons resultados com poucos recursos e está estruturada corretamente.

Palavras-chave: marketing. marketing digital. inbound marketing. marketing de atração. google adwords. google analytics.

Abstract- The diffusion between the internet and marketing has allowed companies to explore new fields of action in front of the market, so digital marketing has emerged to facilitate the buying and selling process, among the tools used by it, is inbound marketing. The aim of the present study was to propose a discussion about the use and application of inbound marketing strategies and to verify the application of this new marketing philosophy by a Brazilian industry of metallurgy sector 3.0. Thus, an analysis was made through monthly reports, from January to July 2019, of all campaigns carried out on the Google Adwords platform for information on

the application of inbound marketing in the same and the campaigns in other countries as they were targeted, and about the budgets used for that. The results of the study showed that Google ADS strategies are the most effective means of marketing that attracts and build customer loyalty, but campaign tracking should be on a daily basis. Among the main difficulties were that there are some periods of the month that run out of account balance and how this problem was solved, such as ads that were paused because they consumed a lot of money and did not bring results, print installments and their ads. This research work is very important because it will improve the company's situation, as the application of the Inbound Marketing strategy will allow its growth and can still be benchmarking for other industries, since if the company has a good strategy and is getting good results with few resources and is structured correctly.

Keywords: marketing. digital marketing. inbound marketing. attraction marketing. google adwords. google analytics.

I. INTRODUÇÃO

Com certeza, hoje o caminho para a nossa indústria prosperar é a inovação de seus produtos e serviços. Uma visão de futuro da Indústria 4.0 prevê-se que, nos anos 2020, o maior "grupo de usuários" da internet serão produtos inteligentes e conectados (algo em torno de 24 bilhões de dispositivos). Segundo Turchi (2018), mais da metade da população brasileira (cerca de 139 milhões de pessoas) está presente na web. São pessoas se relacionando, produzindo e disseminando conteúdo, usando diversos entretenimentos online ou buscando informações e promoções pela internet. E com o desenvolvimento da internet, o ambiente digital passou a ser visto pelo setor corporativo como um terreno fértil a ser explorado e como forma de imprimir maior agilidade aos negócios. Inclui-se aqui aspectos importantes para os consumidores, tais como: os produtos inteligentes serão identificados de forma única e poderão ser localizados a qualquer momento, desde quando ainda estão sendo fabricados até o fim da sua vida útil; será possível incorporar características específicas de cada consumidor individual em todas as fases, do projeto à reciclagem ou disposição final; será possível incorporar mudanças de última hora, inclusive

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durante o processo de fabricação. Assim, nesse novo modelo, a entrega do produto não é o fim, mas, o início do processo de intensa interação entre produtor e consumidor.

A luz de todas essas revoluções trazidas pela internet percebe-se mudanças profundas no comportamento das pessoas, tirando-as de um estado de passividade e tornando-as mais críticas, exigentes e ativas junto às marcas. E também está exigindo das empresas uma postura de atualização e inovação permanentes, podendo-se afirmar que há realmente mudanças que alteram o conhecimento que as empresas tinham de seus consumidores e sobre qual a melhor forma de alcançá-los. Dessa maneira, o outbound marketing, que tem como objetivo obter a atenção de potenciais clientes unicamente por meio da publicidade (PIEDRAHITA, 2015), precisou ser revisto, pois não compreende de forma eficaz o indivíduo moderno. Entender o indivíduo passou a ser uma difícil tarefa e, para isso, outras formas de se fazer o marketing tiveram de ser pensadas, como o inbound marketing.

O inbound marketing, também chamado de marketing de atração, para Burnes (2015, apud OLIVEIRA, 2015, p. 60), o inbound marketing rompe com os antigos conceitos de marketing e apresenta uma nova visão que se baseia em ganhar o interesse das pessoas e fazer com que os potenciais clientes procurem e encontrem as empresas.

Ainda de acordo com PIEDRAHITA (2015), a razão para implementar estratégias de inbound marketing é porque é desejável criar um canal próprio de aquisição de clientes que não dependa de plataformas externas, representando-o como um ativo para a empresa, já que quando é investido nele, é possível aumentar o número de pessoas que acessam nossa página e que se tornam leads e clientes.

No entanto, percebe-se que o domínio sobre o assunto no cenário nacional é escasso, e ainda pouco se utiliza dessa nova forma de se fazer o marketing pelas empresas. Assim, a presente pesquisa tem o objetivo de propor a discussão sobre o uso e aplicação de estratégias de inbound marketing e verificar a aplicação desta nova filosofia de marketing pelas empresas industriais, cujo relacionamento principal é o B2B (Business to Business).

II. REFERENCIAL TEÓRICO

a) *Marketing: da evolução à conceituação*

De acordo com a American Marketing Association – AMA (2013), o marketing é definido como a “atividade, conjunto de instituições e processos para criar, comunicar, distribuir e negociar ofertas que

tenham valor para os consumidores, clientes, parceiros e sociedade em geral”.

Com o passar dos anos, desde a sua primeira conceituação, o marketing vem evoluindo de forma intensa. Para Kotler, Kartajaya e Setiawan (2010, p. 3), o marketing divide-se em 4 estágios: Marketing 1.0 (foco no produto); 2.0 (foco no consumidor); 3.0 (foco nos valores) e 4.0 (foco nos sentimentos humanos). O marketing 1.0 surge “durante a era industrial – quando a principal tecnologia se relacionava a equipamentos industriais, o marketing dizia respeito a vender produtos da fábrica a todos que quisessem comprá-los”. Já o marketing 2.0 “surgiu na atual era da informação – orientado para o consumidor, sendo que o profissional da área deve segmentar o mercado e desenvolver um produto superior para um mercado-alvo específico” (KOTLER; KARTAJAYA; SETIAWAN, 2010, p. 4). O marketing 3.0 tem a ideia de satisfazer os consumidores, que são pessoas complexas, com necessidades que jamais devem ser deixadas de lado. Além disso, completa “o marketing emocional com o marketing do espírito humano” (KOTLER; KARTAJAYA; SETIAWAN, 2010, p. 5).

Segundo Jara, Parra e Skarmeta (2012), o marketing 4.0 continua concentrando-se nas necessidades e desejos das duas primeiras gerações do marketing, bem como satisfaz os desejos, ansiedades, criatividade e valores do marketing 3.0. Porém, trata-se de estratégias que tornam as pessoas mais conscientes dos valores e das ações sociais da marca, ou seja, os recursos oferecidos devem ser condizentes aos valores defendidos pela organização.

b) *Marketing Digital*

Diante da evolução tecnológica e a necessidade de expansão das empresas, viu-se a possibilidade de unificar as duas áreas (computacional e marketing), surgindo, então, o conceito de marketing digital, sendo este aplicado para facilitar o processo de compra e venda de produtos/serviços.

Segundo Vaz (2010, p. 54), o advento da era da informação criou um novo tipo de consumidor, com diferentes perspectivas, desafios e oportunidades “para aqueles que souberem como funciona essa nova máquina”. O autor ainda salienta que um novo caminho deverá ser percorrido pelas empresas que desejam sucesso em sua trajetória, dando o codinome de “máquina” ao que se refere ao marketing digital.

Para Keller e Machado (2006, apud AGUIAR; BASTOS, 2016), “os profissionais de marketing vêm abandonando as práticas de marketing massivas que fortaleceram marcas poderosas nas décadas de 50 até 70 para implementar novas abordagens”.

Assim, o emprego do marketing digital desde então foi estendido aos demais mercados, com objetivos diferentes, não mais limitados à compra e venda de produtos pela internet, mas sim como uma ferramenta essencial para o desenvolvimento de novas estratégias para se chegar ao indivíduo.

Vértice (2010 apud OLIVEIRA, 2015, p. 56), salienta que “o marketing digital utiliza instrumentos que lhe permitem manter uma relação contínua entre a empresa e os seus clientes e este reúne características próprias do marketing direto”.

Segundo Endeavor (2018) para que este novo instrumento seja utilizado de modo efetivo, são necessários cinco requisitos básicos:

- i. *Atração*: Produção de conteúdo, otimização de conteúdo e compra de mídia.
- ii. *Conversão*: Geração de leads, oferta, landing page e promoção.
- iii. *Relacionamento*: Mídias Sociais, e-mail marketing e nutrição de leads.
- iv. *Venda*: Qualificação de leads, alinhamento entre marketing e vendas.
- v. *Análise*: Análise de dados.

Dentro do marketing digital, existem seis pilares fundamentais para seu pleno funcionamento, a saber:

- *Mídia Online*: compreende os meios de comunicação que se utilizam da linguagem binária da informática (PERNISA JR, 2002, p.1).
- *SEO (Search Engine Optimization)*: traduzido como Otimização de Motores de Busca, trata-se de um conjunto de técnicas que possuem o objetivo de melhorar o posicionamento de páginas nos mecanismos de buscas online. Dessa forma, quando o usuário realiza uma pesquisa pela palavra-chave, o SEO faz com que uma ou algumas páginas do seu website sejam encontradas e apareçam entre os primeiros resultados das buscas orgânicas, ou seja, excluindo-se os anúncios pagos (RICOTA, 2007).
- *Social (Mídia Social)*: definida como um conjunto de dinâmicas que permite a criação de conteúdo, difusão e trocas de informações, dentro de grupos sociais em plataformas online, ou seja, as chamadas redes sociais. Estas ações são produzidas pela interação de seus usuários por meio da propagação de informações, compartilhamento de conteúdo, e demais mobilizações sociais realizadas em meio eletrônico (RECUERO, 2010).
- *Marketing de Conteúdo*: trata-se de um conjunto de ações em marketing ou negócios que visa criação e distribuição de conteúdo para atrair, conquistar e envolver o público-alvo com a sua marca, sempre com a intenção de gerar lucro (PULIZZI, 2016, p.4).

- *Web Analytics (Web Análise)*: consiste no monitoramento de ações da marca na internet, por meio da coleta de dados estatísticos, medição e análise quantitativa, para otimizar os websites e as iniciativas de marketing na web (WEB ANALYTICS ASSOCIATION, 2010 apud TELMA, 2011).

- *Inbound Marketing*: segundo Burnes (2015, apud OLIVEIRA, 2015, p. 62), são ações estratégicas de marketing contrária ao outboundmarketing, tendo como objetivo fazer com que o cliente, voluntariamente, ao buscar informações importantes ou respostas às suas perguntas, seja capaz de encontrar a marca por meio de mecanismos de busca online ou offline.

c) *Inbound Marketing*

Antes de tratar especificamente do inbound marketing, importante se faz conceituar outbound marketing. Segundo Piedrahita (2015), o outboundmarketing “se baseia em conseguir a atenção de potenciais clientes através de publicidade, tentando conduzir os mesmos a realizar determinada ação”. Ou seja, o outboundmarketing pode ser entendido como estratégias tradicionais de marketing, sendo: publicações em revistas e jornais, comerciais de rádio e televisão, outdoor, banners em sites ou blogs, etc. Neste tipo de estratégia, a empresa expõe seus possíveis clientes a formas de propagandas que, muitas vezes, podem ser interpretadas como invasivas e indesejadas. A vantagem desse tipo de estratégia está no fato de que o profissional de marketing está no controle de todas as variáveis da mensagem enviada ao mercado. Por outro lado, exige que a empresa conheça intimamente seu público-alvo, pois a mensagem deverá chegar até ele e ser corretamente compreendida.

Já no inbound marketing, as estratégias devem ser focadas nos interesses dos consumidores de forma individual, apresentando alternativas e deixando com que eles procurem e se envolvam com a marca. Dessa forma, é deixado seduzir-se, acontecendo o engajamento do cliente com a marca, ao passo que quem fornece a informação torna-se referência no assunto.

O inbound marketing tem a intenção de posicionar a empresa como um especialista sobre o assunto, oferecendo informação ao seu público-alvo, fazendo com que seus mercados se dirijam até a marca para consumir o que ela tem para oferecer.

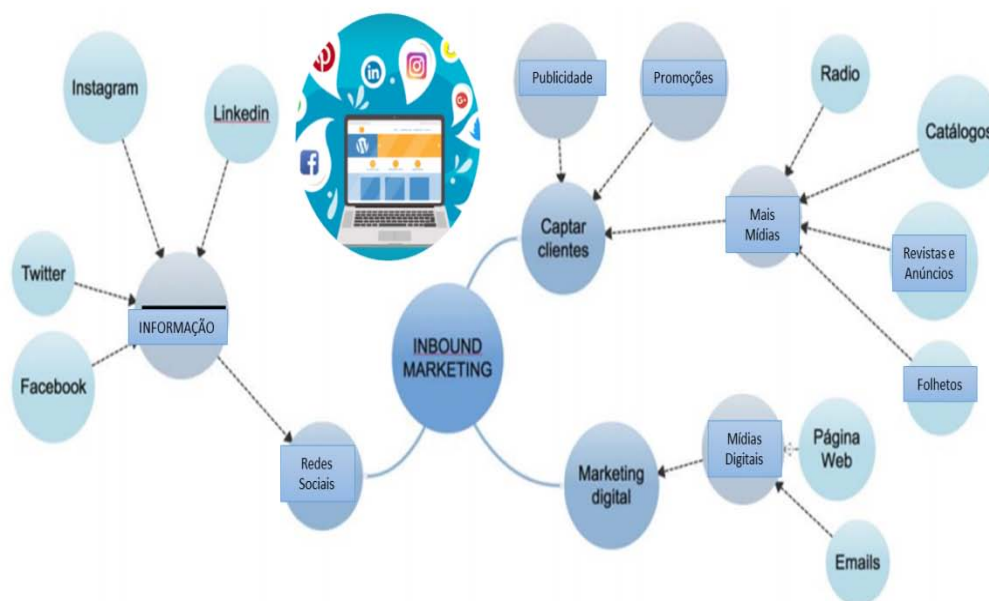
O conceito de inbound marketing foi concebido em 2005 nos EUA, sendo popularmente difundido em 2009 após a publicação do livro “Inbound Marketing: seja encontrado usando o Google, a mídia social e os blogs”, de Brian Halligan e Dharmesh Shah (SFREDO, 2017).

De acordo com Sfredo (2017 apud HALLIGAN; SHAH, 2010), o inbound marketing consiste em ser encontrado online por meio de mecanismos de buscas e em redes sociais, como Facebook, Twitter e Youtube, que milhões de pessoas usam diariamente para encontrar respostas. No entanto, assim como no outbound marketing, o inbound pode ser usado também offline, quando empresas que, mesmo através de meios tradicionais, como os encartes, tentam atrair os clientes para si, sem forçá-los a interagir com a marca. Conteúdos “faça você mesmo” em impressos são exemplos dessa aplicação.

Para Assad (2016), o inbound tem o propósito de transformar usuários em contatos qualificados (também chamados de leads), e de forma espontânea converter leads em clientes, e estes em divulgadores da marca.

A HubSpot, plataforma criada por Halligan e Shah para apoiar a ideia de inbound marketing, cunhada em 2005, tem uma metodologia dividida em quatro fases (HUBSPOT, 2018), caracterizando o “funil de vendas” sendo:

1. *Atração (Attract)*: desenvolvimento de conteúdo na internet que atrai cada vez mais visitante até a sua marca/site, utilizando de redes sociais, blogs, vídeos, etc. Dessa forma, converte-se “estranhos (strangers) em visitantes (visitors)”.
2. *Conversão (Convert)*: uma vez que captada a atenção de estranhos para a marca, é necessário transformá-los em leads (contatos qualificados) para conhecê-los melhor, ou seja, abrir canais de contato por meio de formulários, encontros, mensagens ou CRM - Customer Relationship Management (Gestão de Relacionamento com o Cliente). Aqui têm início do processo de vendas propriamente dito.
3. *Fechamento (Close)*: esse processo é focado em leads que, possivelmente, irão se tornar clientes (customers), ou seja, nos indivíduos que estão mais propensos a finalizar o processo de compra/venda. Nesta etapa, deve-se investir mais em relacionamento, mostrando-se sempre presente, visando a manutenção de suas relações.
4. *Encantar (Delight)*: o processo do funil de vendas, diferentemente do que se imagina, não acaba na fase vendas, pois o inboundmarketing proporciona uma excepcional experiência para seus clientes. Desta forma, o encantamento é a fase mais importante para a marca, fazendo com que os clientes se tornem defensores (promoters) e advoguem a favor da marca, indicando-a para seus conhecidos. Aqui se pode investir mais em relacionamentos e pesquisas, para tornar os clientes mais engajados com a marca, propagando-a pelo mercado.



Elaborado pela autora (2019).

Quadro 1: Ciclo de leads de Inbound Marketing

III. MÉTODO DE PESQUISA

Para o desenvolvimento do presente estudo foi utilizado pesquisa bibliográfica e estudo de caso de

marketing digital junto à uma empresa metalúrgica, localizada no interior de São Paulo, cuja fundação foi em 1957, portanto, uma empresa de mais de 60 anos atuando no mercado de rolamentos industriais. Seu

público-alvo são distribuidores, revendas, empresas fabricantes de máquinas e equipamentos e empresas de manutenção industrial de máquinas e equipamentos. A escolha da empresa foi em função de sua atuação ativa nas estratégias de marketing e também pela facilidade de acesso às respostas reais.

“O estudo de caso é caracterizado pelo estudo profundo e exaustivo de um ou de poucos objetos, de maneira a permitir o seu conhecimento amplo e detalhado, tarefa praticamente impossível mediante os outros tipos de delineamentos considerados.” (GIL, 2008, p. 58).

Qual o nível de utilização da empresa na aplicação do inbound marketing?

A nossa melhor mídia é o Google Ads. Segundo dados do Google Analytics (junho/18), as campanhas do Google Adwords foram a segunda fonte de tráfego para o site da empresa, perdendo somente para a busca orgânica. Temos uma assessoria mensal que nos auxilia afim de melhorar o desempenho no Google Adwords, fornecendo relatórios que contém as campanhas, taxas de conversões, grupos de anúncios, conversões por dispositivo, cliques por gênero, cliques por localização, relatório por palavras-chave, etc,

Por tudo isso das diversas estratégias de Inbound Marketing, especificamente analisar-se-a estratégia de SEO (Search Engine Optimization)

traduzido como Otimização de Motores de Busca. Trata-se de um conjunto de técnicas que possuem o objetivo de melhorar o posicionamento de páginas nos mecanismos de buscas online. Dessa forma, quando o usuário realiza uma pesquisa pela palavra-chave, o SEO faz com que uma ou algumas páginas do seu website sejam encontradas e apareçam entre os primeiros resultados das buscas orgânicas, ou seja, excluindo-se os anúncios pagos (RICOTA, 2007).

É no Google que as pessoas pesquisam o que fazer, aonde ir e o que comprar. O anúncio pode ser exibido na rede no momento exato em que uma pessoa estiver pesquisando produtos e serviços. Seja no computador ou no dispositivo móvel. O Google Adwords funciona com qualquer orçamento de publicidade. Defina um limite de orçamento mensal e nunca o ultrapasse. Além disso, você pode pausar ou ajustar seus gastos a qualquer momento.

Para tanto foi elaborado especificamente uma análise do relatório semestral (janeiro a junho de 2019) do Google ADS, esse tem o objetivo de mostrar como foram feitas as campanhas, quais foram os orçamentos, parcela de impressões, mês a mês, cliques, conversões e segmentação geográfica de campanhas externas. Os próprios relatórios são gerados pela Google Analytics, como o exemplo do quadro 2 abaixo:



Quadro 2: Visão Geral Google Adwords

<https://datastudio.google.com/reporting/0BwYCBb48hHYjYU51SDkwald5VTQ/page/vhtH>

IV. ANÁLISE E RESULTADOS

Quadro 3: Visão Geral Google Adwords (planilha excel de janeiro-junho/19) Dados

Mês	Moeda	Cliques	Impressões	CTR	CPC médio	Posição méd.	Custo	Conversões	Custo / conv.	Taxa de conv.
Jan 2019	BRL	1.241	12.336	10,06%	0,72	1,77	899,65	24,50	36,71	1,98%
Fev 2019	BRL	1.025	14.964	6,85%	0,69	2,56	709,52	25,50	27,78	2,49%
Mar 2019	BRL	1.608	18.315	8,78%	0,69	2,20	1.108,55	30,50	36,35	1,90%
Abr 2019	BRL	942	11.219	8,40%	1,00	1,83	937,51	18,00	52,08	1,91%
Mai 2019	BRL	1.414	26.279	5,38%	1,03	1,41	1.449,44	24,00	60,39	1,37%
Jun 2019	BRL	1.266	22.207	5,70%	0,95	1,58	1.204,44	13,00	92,65	0,86%
Jul 2019	BRL	1.398	26.675	5,24%	1,04	1,55	1.449,85	23,00	63,04	1,35%

Extraídos dos relatórios do Google Analytics e elaborado pela autora (2019).

a) *Distribuição do orçamento*

- Campanha Institucional (palavra-chave com o nome da marca): R\$90,00
- Campanha Institucional (palavra-chave rolamentos): R\$750,00
- Campanha produto principal (peças para fabricantes de máquinas e equipamentos OEM): R\$750,00
- Campanha mercado de produtos secundários para indústria (reposição): R\$486,00
- Campanha no idioma inglês (mercado externo): R\$150,00
- Campanha no idioma espanhol (mercado externo): R\$150,00
- Campanha de conteúdo técnico (vídeos, APP, etc): R\$200,00
- Campanha produtos alternativos (reposição agrícola off road): R\$150,00
- Campanha produtos alternativos (reposição trucks): R\$90,00

Verba Total (mensal): R\$2.186,00

b) *Parcela de Impressões*

A parcela de impressões é uma porcentagem que mostra a quantidade de vezes que seus anúncios foram exibidos nas pesquisas dos usuários do Google. Quanto mais alta a parcela de impressões, melhor pois mostra que seus anúncios estão sendo exibidos com uma frequência alta. Os anúncios podem não ser exibidos com tanta frequência devido a 2 fatores: orçamento insuficiente ou classificação do anúncio (para determinar isso o Google analisa o anúncio, site de destino, lance, entre outros fatores).

No caso da empresa estudada, começou-se o ano (janeiro/19) com uma parcela de impressões de 13,75% nos anúncios.

Nos meses de abril e maio foi trabalhada a campanha do APP Técnico e por isso tive-se bons resultados de conversões neste período.

Entre os meses de fevereiro a junho/19, teve-se uma queda nas impressões, sendo 85% das vezes referente ao orçamento insuficiente das campanhas.

Visto isso, já no mês de julho, começou-se a recuperar as impressões, perdendo-se impressões por orçamento de 62,64% e por classificação foram 20% das vezes. Até o momento está com uma parcela de impressões de aproximadamente 23%, ou seja, mais alta que no início deste ano.

c) *Campanha (idioma português) Mercado Interno*

Com relação ao Brasil, mercado interno, o estado que mais consome verba é o estado de São Paulo e é também o que mais gera conversões e ao menor custo.

d) *Campanha (idioma inglês) Mercado Externo*

A campanha em inglês está segmentada nos seguintes países: Índia, África do Sul, EUA, Canadá, Malásia, Filipinas, Austrália, e países da Europa, Nova Zelândia, Bahamas, Fiji, Guiana Francesa, Malta, Áustria e Suíça.

Os países que tiveram cliques nos últimos 6 meses foram: Índia, África do Sul, EUA, Canadá, Malásia, Filipinas, Alemanha, Austrália, Irlanda, Paquistão, Bélgica, Portugal, França e Itália.

Como pode-se perceber, mesmo com um orçamento baixo para ser pulverizado entre tantas localidades, assim mesmo houve cliques: Paquistão, Bélgica, entre outros países da Europa.



GOOGLE ANALYTICS

43.786

SESSÕES

65,77%

NOVAS SESSÕES

30.070

USUÁRIOS

120.917

VISUALIZAÇÕES DE PÁGINA

2,76

PÁGINAS POR VISITA

55,73%

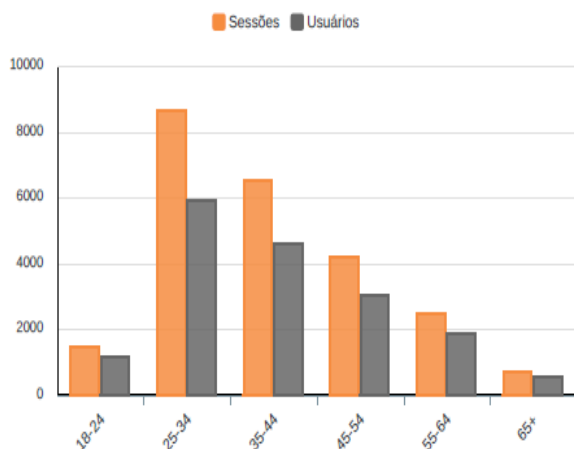
TAXA DE REJEIÇÃO

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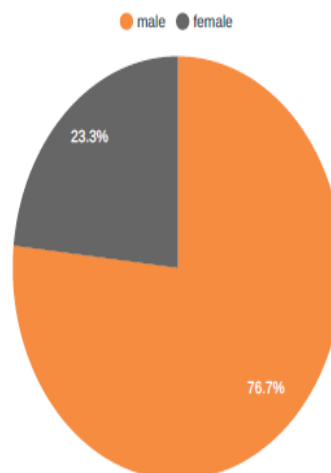
TEMPO NA PÁGINA

Quadro 4: Visão Geral Google Analytics (acumulado de janeiro-junho/19)
Dedasextraídos dos relatórios do Google Analytics (2019).

SESSÕES POR IDADE



GÊNERO DO VISITANTE



Quadro 5: Visão Geral Google Ads (acumulado de

V. CONSIDERAÇÕES FINAIS

No período de janeiro a junho de 2019 teve-se um total de 7496 cliques, sendo uma média mensal de 1250 cliques mensais aproximadamente e uma média de 7,5% de taxa de cliques, uma média muito boa, considerando-se que uma CTR ótima pode ser considerada acima de 3%.

O posicionamento médio das campanhas variou pouco durante estes meses, mas esteve-se em média entre a 1ª e 2ª posições nas buscas dos usuários.

O valor do investimento também teve algumas flutuações durante o período, mas manteve-se na média dos R\$ 1150,00 mensais.

Os melhores meses em número, taxa e custo de conversões foram os meses de fevereiro e março.

período foram feitos diversos ajustes significativos na conta, desde a criação de um novo grupo de anúncios para o produto "ferramenta de fixação", como a criação de anúncios de texto responsivos e alterações nas cópias dos anúncios pré-existentes, afim de otimizar os resultados das campanhas.

No final do mês de março também testou-se estratégias de lances diferentes em algumas campanhas com o objetivo de gerar mais conversões dentro do orçamento.

Em relação ao orçamento, sem contar com os finais de semana, teve-se mensalmente, dias em que as campanhas ficaram sem saldo, sendo que, os meses mais representativos foram abril e junho.

No geral, está-se consumindo mais verba mensalmente, porém, este aumento tem-se refletido numa melhora no posicionamento médio das campanhas e também na porcentagem de vezes que os anúncios são exibidos para os usuários nas buscas.

Atualmente está aparecendo em média em 26% das buscas dos usuários, sendo que, destas, 80% das vezes os anúncios são exibidos nas primeiras posições. A média dos concorrentes de parcela de impressões é de 11% (15% a menos que o nome da marca), portanto, pode-se dizer que, segundo estes números, números bem interessantes neste quesito.

Começou-se a mensurar as conversões na conta com os downloads de catálogos, o envio de contato pelo formulário do site, e as ligações provenientes dos anúncios, tanto da extensão de chamadas dos anúncios quanto do número de telefone que consta no site e percebeu-se que, em todos estes meses, as metas que mais geraram resultados foram as de ligações. Recentemente instalou-se no site também a meta de clique para envio de mensagem pelo WhatsApp, em breve teremos estes números contabilizados também na conta.

No período analisado, as campanhas de Google Ads representaram no Google Analytics, a segunda maior fonte de tráfego, ficando atrás somente da busca orgânica.

A recomendação para os próximos meses é de manter-se o orçamento na média dos últimos meses, ou, se possível, aumentar um pouco, chegando no máximo a R\$ 2000,00 / mês, pois assim pode-se destinar mais verba às campanhas limitadas, e também trabalhar com uma campanha de remarketing na rede de display para re-impactar usuários que não converteram no site, mas, para isso, precisa-se de verba adicional, caso contrário, pode perder desempenho das campanhas atuais, se tirar o orçamento das mesmas.

Percebe-se nesse contexto, que a empresa possui um estilo arrojado de vendas, e de uma forma geral podemos concluir que a empresa está muito bem posicionada da web, pois utiliza o inbound marketing em suas ações estratégicas de marketing com frequência, sendo o Google a forma mais utilizada para sua vinculação.

A pesquisa também revelou que, as principais dificuldades é manter um orçamento adequado para que em determinados períodos não fique sem saldo na conta, para isso, contratou uma assessoria de marketing digital a fim de solucionar e aumentar a frequência do pagamento dos boletos e realinhar as campanhas de acordo com as demandas.

Esses dados revelam que as empresas devem investir cada vez mais em ações de mídias sociais e estratégias de SEO, facilitadas por ferramentas e técnicas online, como mobile marketing, realidade aumentada, e-commerce, m-commerce, redes sociais, e-mail marketing, SMS, Bluetooth, Tv digital, Web digital, etc. imprescindíveis para que entendam a influência que a internet está trazendo na vida das pessoas e o que está ocorrendo no mercado, mantendo-se atualizada.

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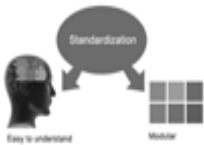
We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.





The FARSE can go through standards of OARS. You can also play vital role if you have any suggestions so that proper amendment can take place to improve the same for the benefit of entire research community.

As FARSE, you will be given a renowned, secure and free professional email address with 100 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders, Auto-Responders, Email Delivery Route tracing, etc.



The FARSE will be eligible for a free application of standardization of their researches. Standardization of research will be subject to acceptability within stipulated norms as the next step after publishing in a journal. We shall depute a team of specialized research professionals who will render their services for elevating your researches to next higher level, which is worldwide open standardization.

The FARSE member can apply for grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A. Once you are designated as FARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria. After certification of all your credentials by OARS, they will be published on your Fellow Profile link on website <https://associationofresearch.org> which will be helpful to upgrade the dignity.



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The FARSE member also entitled to get the benefits of free research podcasting of their research documents through video clips. We can also streamline your conference videos and display your slides/ online slides and online research video clips at reasonable charges, on request.





The FARSE is eligible to earn from sales proceeds of his/her researches/reference/review Books or literature, while publishing with Global Journals. The FARSE can decide whether he/she would like to publish his/her research in a closed manner. In this case, whenever readers purchase that individual research paper for reading, maximum 60% of its profit earned as royalty by Global Journals, will be credited to his/her bank account. The entire entitled amount will be credited to his/her bank account exceeding limit of minimum fixed balance. There is no minimum time limit for collection. The FARSE member can decide its price and we can help in making the right decision.

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MEMBER OF ASSOCIATION OF RESEARCH SOCIETY IN ENGINEERING (MARSE)

The 'MARSE' title is accorded to a selected professional after the approval of the Editor-in-Chief / Editorial Board Members/Dean.

The "MARSE" is a dignified ornament which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., MARSE or William Walldroff, M.S., MARSE.



MARSE accrediting is an honor. It authenticates your research activities. After becoming MARSE, you can add 'MARSE' title with your name as you use this recognition as additional suffix to your status. This will definitely enhance and add more value and repute to your name. You may use it on your professional Counseling Materials such as CV, Resume, Visiting Card and Name Plate etc.

The following benefits can be availed by you only for next three years from the date of certification.



MARSE designated members are entitled to avail a 25% discount while publishing their research papers (of a single author) in Global Journals Inc., if the same is accepted by our Editorial Board and Peer Reviewers. If you are a main author or co-author of a group of authors, you will get discount of 10%.

As MARSE, you will be given a renowned, secure and free professional email address with 30 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders, Auto-Responders, Email Delivery Route tracing, etc.





We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The MARSE member can apply for approval, grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A.



Once you are designated as MARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria.

It is mandatory to read all terms and conditions carefully.



AUXILIARY MEMBERSHIPS

Institutional Fellow of Open Association of Research Society (USA)-OARS (USA)

Global Journals Incorporation (USA) is accredited by Open Association of Research Society, U.S.A (OARS) and in turn, affiliates research institutions as “Institutional Fellow of Open Association of Research Society” (IFOARS).

The “FARSC” is a dignified title which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., FARSC or William Walldroff, M.S., FARSC.



The IFOARS institution is entitled to form a Board comprised of one Chairperson and three to five board members preferably from different streams. The Board will be recognized as “Institutional Board of Open Association of Research Society”-(IBOARS).

The Institute will be entitled to following benefits:



The IBOARS can initially review research papers of their institute and recommend them to publish with respective journal of Global Journals. It can also review the papers of other institutions after obtaining our consent. The second review will be done by peer reviewer of Global Journals Incorporation (USA). The Board is at liberty to appoint a peer reviewer with the approval of chairperson after consulting us.

The author fees of such paper may be waived off up to 40%.

The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.



The IBOARS can organize symposium/seminar/conference in their country on behalf of Global Journals Incorporation (USA)-OARS (USA). The terms and conditions can be discussed separately.

The Board can also play vital role by exploring and giving valuable suggestions regarding the Standards of “Open Association of Research Society, U.S.A (OARS)” so that proper amendment can take place for the benefit of entire research community. We shall provide details of particular standard only on receipt of request from the Board.

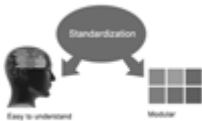


Journals Research
inducing researches

The board members can also join us as Individual Fellow with 40% discount on total fees applicable to Individual Fellow. They will be entitled to avail all the benefits as declared. Please visit Individual Fellow-sub menu of GlobalJournals.org to have more relevant details.



We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.



After nomination of your institution as “Institutional Fellow” and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf. The board can also take up the additional allied activities for betterment after our consultation.

The following entitlements are applicable to individual Fellows:

Open Association of Research Society, U.S.A (OARS) By-laws states that an individual Fellow may use the designations as applicable, or the corresponding initials. The Credentials of individual Fellow and Associate designations signify that the individual has gained knowledge of the fundamental concepts. One is magnanimous and proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice.



Open Association of Research Society (US)/ Global Journals Incorporation (USA), as described in Corporate Statements, are educational, research publishing and professional membership organizations. Achieving our individual Fellow or Associate status is based mainly on meeting stated educational research requirements.

Disbursement of 40% Royalty earned through Global Journals : Researcher = 50%, Peer Reviewer = 37.50%, Institution = 12.50% E.g. Out of 40%, the 20% benefit should be passed on to researcher, 15 % benefit towards remuneration should be given to a reviewer and remaining 5% is to be retained by the institution.



We shall provide print version of 12 issues of any three journals [as per your requirement] out of our 38 journals worth \$ 2376 USD.

Other:

The individual Fellow and Associate designations accredited by Open Association of Research Society (US) credentials signify guarantees following achievements:

- The professional accredited with Fellow honor, is entitled to various benefits viz. name, fame, honor, regular flow of income, secured bright future, social status etc.



- In addition to above, if one is single author, then entitled to 40% discount on publishing research paper and can get 10% discount if one is co-author or main author among group of authors.
- The Fellow can organize symposium/seminar/conference on behalf of Global Journals Incorporation (USA) and he/she can also attend the same organized by other institutes on behalf of Global Journals.
- The Fellow can become member of Editorial Board Member after completing 3yrs.
- The Fellow can earn 60% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.
- Fellow can also join as paid peer reviewer and earn 15% remuneration of author charges and can also get an opportunity to join as member of the Editorial Board of Global Journals Incorporation (USA)
- • This individual has learned the basic methods of applying those concepts and techniques to common challenging situations. This individual has further demonstrated an in-depth understanding of the application of suitable techniques to a particular area of research practice.

Note :

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- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of “Difference of Opinion [if any]” among the Board members, our decision will be final and binding to everyone.

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PREFERRED AUTHOR GUIDELINES

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from <https://globaljournals.org/Template.zip>

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

BEFORE AND DURING SUBMISSION

Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

1. Authors must go through the complete author guideline and understand and *agree to Global Journals' ethics and code of conduct*, along with author responsibilities.
2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s) names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
5. Authors should submit paper in a ZIP archive if any supplementary files are required along with the paper.
6. Proper permissions must be acquired for the use of any copyrighted material.
7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

Declaration of Conflicts of Interest

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

POLICY ON PLAGIARISM

Plagiarism is not acceptable in Global Journals submissions at all.

Plagiarized content will not be considered for publication. We reserve the right to inform authors' institutions about plagiarism detected either before or after publication. If plagiarism is identified, we will follow COPE guidelines:

Authors are solely responsible for all the plagiarism that is found. The author must not fabricate, falsify or plagiarize existing research data. The following, if copied, will be considered plagiarism:

- Words (language)
- Ideas
- Findings
- Writings
- Diagrams
- Graphs
- Illustrations
- Lectures



- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

AUTHORSHIP POLICIES

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1. Substantial contributions to the conception and acquisition of data, analysis, and interpretation of findings.
2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

Changes in Authorship

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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Appealing Decisions

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

PREPARING YOUR MANUSCRIPT

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.



Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

- a) A title which should be relevant to the theme of the paper.
- b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
- c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
- d) An introduction, giving fundamental background objectives.
- e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
- f) Results which should be presented concisely by well-designed tables and figures.
- g) Suitable statistical data should also be given.
- h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

- i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
- j) There should be brief acknowledgments.
- k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.



FORMAT STRUCTURE

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.



Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

PREPARATION OF ELETRONIC FIGURES FOR PUBLICATION

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

TIPS FOR WRITING A GOOD QUALITY ENGINEERING RESEARCH PAPER

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow [here](#).



6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.



21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

INFORMAL GUIDELINES OF RESEARCH PAPER WRITING

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.



Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.



Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.



Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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	A-B	C-D	E-F
<i>Abstract</i>	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
<i>Introduction</i>	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
<i>Methods and Procedures</i>	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
<i>Result</i>	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
<i>Discussion</i>	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
<i>References</i>	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring



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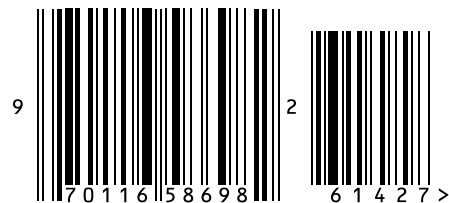


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