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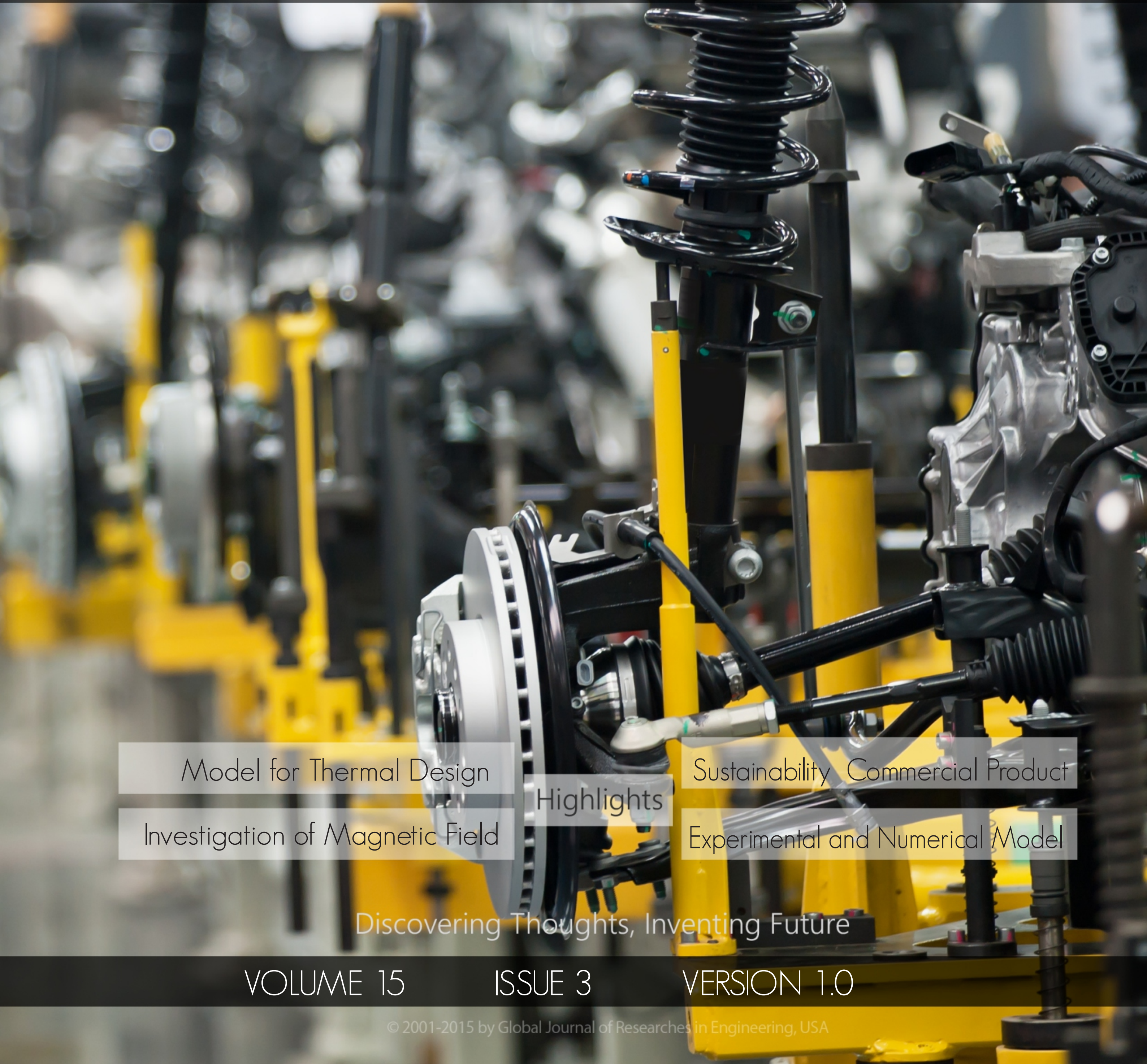

Model for Thermal Design

Investigation of Magnetic Field

Highlights

Sustainability Commercial Product

Experimental and Numerical Model

Discovering Thoughts, Inventing Future

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Design for a Sustainability of a Commercial Product: A Case Study of a Dynamic Loudspeaker

By Alimasunya E, Olotu Yahaya & Abudu Mohammed
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Keywords: loudspeaker, client, efficiency, analysis, system, reliability, performance.

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Design for a Sustainability of a Commercial Product: A Case Study of a Dynamic Loudspeaker

Alimasunya E [α], Olotu Yahaya [σ] & Abudu Mohammed [ρ]

Abstract- Sensitivity-based analysis carried out on the production of dynamic loudspeakers for client (A) and (B) showed that client (A) has reliability efficiency 0f 20.4% with 90% of Tp, 30%-Ep, 50%-Ecp, while client (B) has 30%-Tp, 90%-Ep and 50%-Ecp respectively. Sustainability of client (B) is higher than (A) with 0.06. It has 99% and 20.1% system and efficiency reliabilities. Client (B) has the flexibility of indoor and outdoor which Client (A) lacks. The overall simulation analysis shows that client (B) product is better than (A).

Keywords: loudspeaker, client, efficiency, analysis, system, reliability, performance.

I. Introduction

Loudspeakers and the variety of enclosure box in which they may be mounted have been studied intensively, in order to achieve high quality standards in terms of product performance. These loudspeakers are complex electromechanical systems, with behaviour governed by an interaction of acoustics, electricity and mechanics (Basilio *et al*, 2009).

In sustaining a loudspeaker, a better policy and strategy were ensured in prolonging the efficiency and usage of this product. A product can be relevant today and be obsolete or irrelevant in the nearest future. According to Telsang (2006) ''the main objective of every organization is to satisfy the implied needs of the customer''. Thus, there are needs for an effective decision making and dynamic product restructuring, in order to sustain the relationship existing between the manufacturer and the end-user of the product. Philip Sutton (2004), argue that sustainability is the balancing or integration of environmental, social, and economic issues. The World commission on Environment and Development (WCED) 1987 defined sustainability as ''the development that meets the needs of the present without compromising the ability of future generations to meet their own needs'' (Oyedepo and Olayinka, 2012).

The object of this study is to critically evaluate and compare relevant factors of sustainability, which are technical, environmental and economical, for two selected models of dynamic loud speakers and deduce the market needs and performance.

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II. Sustainability of Dynamic Loudspeaker

Tore and Uday (2003) suggest that one of the approaches in the sustainability of product such as loudspeakers gives rise to implementation of RAMS in product design and development, this is related to integration of reliability, maintainability and risk analysis tools and methods to enhance performance efficiency, to reduce product life cycle cost (LCC) and delivery time, and to increase customer satisfaction and product attractiveness. The framework of the product manufacturer must define these stages involved in the life cycle of the product. Young (2000) identifies the stages of project life cycles as follows:

1. Product conception
2. Product definition
3. Product planning
4. Product launch and execution
5. Product closure
6. Post-product evaluation

The demand of the consumers must be the basic for redesigning of the loudspeakers as they are the customers with kin interest in the technicality of the speakers, the economical and environment friendliness of the loudspeaker product. This performance map can be bridge by closing the reliability gap that exists in the existing product and the desired once.

Nave (2006) describes the mechanism of loudspeaker as an electromechanical process in which the amplified audio signal moves the speaker cone in order to produce sound corresponding to the original sound wave or audio signal. Nave (2006) explains that the audio signal of a dynamic loudspeaker produces an electrical signal with the same harmonic and frequency of the audio signal and a sound image that reflects the relative intensity of the audio signal and sound as it changes. It amplifier magnifies the electrical signal in order to power the coils of a loudspeaker, and it transferred the electrical signal to the voice coils of the loudspeaker. This creates a vibration in the voice coil with a vibrating sequence corresponding to the variations of the original sound signal. The purpose of this voice coil is to power the cone of the loudspeaker which drives the air surrounding it, and this in turn produces audio sound outwardly of the original audio signal. Most loudspeakers are enclosed in such a way that it generates pleasant sound.

The diaphragm in a dynamic loudspeaker is connected to a voice coil positioned in the air space of a magnet system with the aid of a flexible suspension. Immediately the current flows through the voice coil in the presence of a magnetic field, both the diaphragm and coil are accelerated as a result of theLorentz force. Both an inhomogeneous magnetic field and the excursion-dependent stiffness of the suspension account for a nonlinear behaviour of the transducer. (Dietrich et. *al*, 2001).

The nature of the voice coil and the kind of enclosure of the loudspeaker actually reflects the quality of sound from these speakers, thus there is need to reengineer and redesign the loudspeaker component and compartment in order to boost its sustainability (Nave, 2006).

Based on this, Client A's concern is on optimum performance and minimum emphasis on life cycle cost and environmental impart, with a 90% technical performance, 30 % environmental performance and 50% economic performance.Client B is highly environmental conscious in line with regulations irrespective of the cost of implementing a well functional loudspeaker, with a 90% environmental performance, 50% economic performance and 30% technical performance.

III. Reliability of Dynamic Loudspeaker

The loudspeaker comprises a bass speaker, woofers large to efficiently impedance match to the air, tweeters with high frequency sound signal, framework and enclosure box. In order for a more reliable performance in terms of audio output, the aperture is made on the enclosure to assist in echoing the sound from the loudspeaker in form of sub-woofer. The complete life cycle of the loud speaker is taken to consideration, from manufacturing stage of it sub-components, to the components assembling, the distribution of the speakers and its exact life spam in the hands of the customers. This defines the performance of the loudspeaker and its durability, which can be computed by software.Software is design which focused on final with emphases on the parameter relationships of the speakers. The purpose of the software is to avoid the computation of equations governing loudspeaker systems and to highlight the features the designed loudspeaker before production as reviewed by (Basilio *et al*, 2009).

IV. Supportability and Sustainability Index of DYnamic Loudspeaker

A thorough sequence of step-by-step processes involved in the product redesign is study so as to define what goes into the system and what comes out of the system

''Due to design problems and poor product support, manufacturer equipment and systems are not able to meet these requirements. However with proper consideration of reliability, availability, maintainability and supportability(RAMS) in the design, manufacturing, and assembly phase of the dynamic loudspeaker, the number of failure could be reduced and their consequences minimized''.(Saraswat and Yada 2008)

In the quest for system sustainability, most products fails to sustain in meeting the manufacturer goals if its design is no longer compatible with the objective, vision, culture and structure of the manufacturing firm in the face of present development. So a product must be of positive socio-economic significance to both the manufacturer and the customers with little or no effects on the human environment.

The product can then be redesign by introducing present constrains or necessity the existing once fails to handled, and reengineered in such a way that the system of the product can be well supported, and this will not affect the life cycle of the product. At this phase, the manufacturer tends to put in all available resources in re-building a new product with high level of system supportability and acceptability.

"A parametric loudspeaker has a potential of fascinating usage because it has a sharp directivity compared to a conventional loudspeaker, and is then feasible to transmit speech or audio signals to a specific area that cannot be detected by people in adjacent locations. Especially, such kind of loudspeakers enables us to create quietsound environments outside the area and to retain private listening space"(Sakaiand Kamakura, 2008).

V. Life Cycle Assessment of the Loudspeaker

Sustainability and Life Cycle Management (LCM) of product is focused on information management of system, effective reengineering and product redesigning and system analysis associating with product customer's response. This creates a road map of the product from the manufacturer down to the customers with a corresponding constraint and feedback at each stage of the road map or pathway (Lecturer's note, 2013). At a glance, one can tell the level of product sustainability, when to enhance or modify the product and the development of new product.

VI. Technological Obsolescence

The life cycle of the dynamic loudspeaker system is considered as a device ranging from manufacture, distribution and functional life span up to recycling and disposal operation. The environmental performance of the dynamic loudspeakers is calculated by conducting an LCA study according to International Standards Organization (ISO) 14O40 series, (Guinee, 2002, pp.311-313). and Johnannes(1998). Duan *et.al* (2008) explains that PC can be related to dynamic loudspeakers as follows: The functional unit of dynamic loudspeakers is the tweeter, woofer, sub-woofer, voice coil, cone and enclosure made up of wood. It is assumed that the speakers use 8.2hours per day active and 4.6hours in standby. The speakers are expected to technically work at least 90% for the duration of 5years to complete its life cycle before handing over for treatment. Once they are no longer in use, they can be recycled by recoiling the voice coil and replacing the cone with a new once. Those whose enclosure box were destroyed, are either rebuild, amended or reconstructed in other to serve its exact purpose.

VII. Material Utilization Principle/Life Cycle Costing and Economic Analysis

The voice of customer was the most important factor in designing these Loudspeakers in other to satisfy their needs. In view of this, quality function deployment (QFD) has to be employed in other to developed ''technical specifications that can be used by designer and production''Telsang (2006,p.547). Loud-speaker is usually enclosed in a box or single compartment, and the resulting sound output was not meeting the desired taste of its customers. In restructuring this compartment, one must first define the type of vibration emanating from the voice coil and its sound. So the question is "what is the strength of the electric signal powering the voice coil?" It is discovered that the level of vibration of a lighter voice cone is different from that of a heavier voice cone when subjected to the same electrical signal. Thus, in redesigning of a loudspeaker, a light voice coil is used which can vibrate freely inside the magnetic field of a strong permanent magnet.

Table 1 : Material Utility Analysis for a Dynamic Loudspeaker

Component	Material utilization m	Cost of production /component y	Relative Production Cost X=y\∑y	Partial utilization value mX
MA	0.185 1.5\8.1	£0.95	0.446	0.083
MB	0.247 2.0\8.1	£0.58	0.272	0.067
MC	0.173 1.4\8.1	£0.18	0.085	0.015
MD	0.222 1.8\8.1	£0.20	0.094	0.021
ME	0.173 1.4/8.1	£0.22	0.103	0.018
TOTAL		£2.13	1	0.204

Weight of loudspeaker compartment- 8.1 kg

a) *Material description*

MA- Pioneer TS-G1321i 13cm dual cone speaker system 200 Watts, 1.5kg

MB-Loudspeaker enclosure box, 2.0kg

MC- Tweeter speaker, 1.4kg

MD- Woofer, 1.8kg

ME- Sub-woofer, 1.4kg

Material Utility (m) = `$W_{component}$\ $W_{material\ used}$ (Lecturer's note, 2013)

The efficiency of the producing Loudspeaker with the above component is 20.4%, which needs improvement in boosting its usability.

b) *Technical Description of Producing Loudspeaker for Client A*

i. *Product A*

Technically is made up of a heavier voice coil and cone, with a moderate sound output and intensity. It is composed of multiple loudspeakers, since a single loudspeaker cannot deliver optimally balanced sound desired by the customer over the audio sound

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spectrum. Typically, these loudspeakers are enclosed with a crossover network to produce a nearly uniform frequency. This is done in order to minimize the impact of this resonant frequency among the speakers.

The compartment speakers comprises of a tweeters (with high frequency sound signal),a bass speaker to balance the audio sound, a woofer and sub-woofer.

Thus, in producing loudspeaker with 90% technical performance, 30 % environmental performance and 50% economic performance, emphases must be on improving the quality of the sub-woofer speaker, by replacing the existing one with a more powerful and reliable one (with about a moderate cost and same component weight).

Table 2 : Material Utility Analysis for Client A loudspeaker with an improved Sub-woofer

Component Number	Material utilization (m)	Cost of production /component (y)	Relative Production Cost (X=y\∑y)	Partial utilization value (mX)
MA	0.185 1.5\8.1	£0.95	0.361	0.067
MB	0.247 2.0\8.1	£0.58	0.221	0.055
MC	0.173 1.4\8.1	£0.18	0.068	0.012
MD	0.222 1.8\8.1	£0.20	0.076	0.017
ME	0.173 1.4/8.1	£0.72	0.274	0.474
TOTAL		£2.63	1	0.625

The efficiency of Client A producing a Loudspeaker with an improved Sub-woofer having same weight and a cost of **£0.72** (because it is the main component that can increase the technicality performance of the loud speaker), will increase from 20.4% to 62.5% performance, thus boosting its usability and market value

a. *System Reliability*

The loudspeaker is design for a life span of 5 years, of which the loudspeaker compartment is at use at 14 hours a day (both usage and standby) and switch off at 10 hours a day.

For 5 years, the total operating hours of the loudspeaker = 14x365x5= 25,550 hours In assumption, 1 system fails in every 5,000 hours, an average of 5 loudspeakers is likely to fail throughout the life cycle of the system.

Failure rate of the loudspeaker for Client A:

λ= number of failure\total operating hours

= 5\ 25,550 = 0.0001957

MTBF = 1\λ

= 1\ 0.0001957 = 5109.86 hours

The Reliability of the loudspeaker at 5 years of 25,550 operating hours,

$$R(t) = e^{-\lambda t} = e^{-t/m}$$

$$= e^{-0.0001957 \times 25550}$$

= 0.0067 (Telsang , 2006 pp.488-494)

The probability of the loudspeaker surviving for 25,550 operating hours is 0.67%.

ii. *Maintainabilityof Dynamic Loudspeaker System*

The loudspeaker system for Client A to have high surviving rate and high reliability, the operating hours must be reduced from the total life span of 5 years, by neutralizing the standby period of the system. It is advisable that, when the system is not in use, the relative power supply into the loudspeaker will be zero, thereby reducing the usability of the system from 14 hours to an average of 5 hours by day (the direct usability period), therefore the operating hours at more improved system will be,

Operation hours = 5x365x5= 9125 hours.

This will increase the survival of the system to $R(t) = e^{-0.0001957 \times 9125} = 16.7\%$

It is advisable that the life span of the loudspeaker be reduced as well as it operation hours in order to increase its reliability.

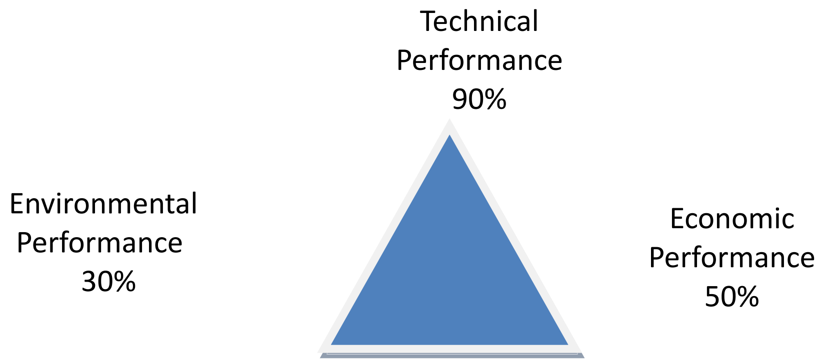

Fig. 2 : Product Triangle for producing Loudspeaker for Client A

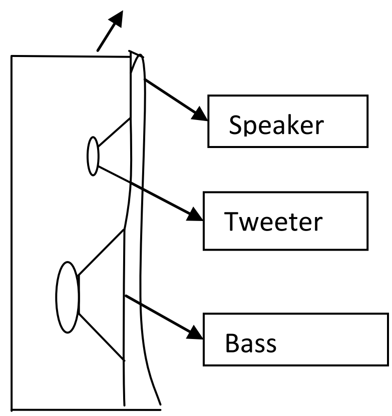

Fig. 3 : Product A Loudspeaker

iii. *Economic Descriptions of Loudspeaker A*

Economically, the cost of producing this product, increases from **£2.13 to £2.63, which** is relatively low and it can easily be afforded by most customers, with more value for their money and improved technical performance. The problem associated to this product is that when placed in a very wide sitting room such as shown in Fig 4 below, the efficiency of the loudspeaker reduces. It is manufactured for indoor purpose and cannot be used for outdoor purposes.

Fig. 4 : Showing a room with a dynamic loudspeakers. Paul McGowan (2011)

iv. *Environmental Effects of Loudspeaker A*

The environmental effects of the loudspeaker is relatively low, it can pose a major threat if the speaker is turn to its maximum volume, and this is dangerous to human ear, as it can affect the ear drum.

c) *Technical Description of producing loud speaker for Client B*

Product B technically is made up of a lighter voice coil and voice cone, with a very high sound output and intensity. It is composed of multiply loudspeakers with optimally balanced sound delivery. Typically, these loudspeakers are enclosed with a crossover network to produce a nearly uniform frequency, with a woofer compartment. This loudspeaker requires more power input in driving all components effectively and the resonant frequency among the loudspeakers is minimized as well. A speaker comprises of tweeters (with high frequency sound signal) and a bass speaker is a superb woofer with a bass reflex enclosure used and extending the bass range of the loudspeakers.

The purpose of the woofer speaker is to serve as an impedance match to the surrounding or air, this gives the loudspeaker more driving force in powering it sound output, and the resulting output is a smooth sound with a high audio intensity.

Thus, in producing loudspeaker for Client B is highly environmental conscious in line with regulations irrespective of the cost of implementing a well functional loudspeaker, with a 90% environmental performance, 50% economic performance and 30% technical performance.

Table 3 : Material Utility Analysis for Client B loudspeaker with an improved Sub-woofer

Component	Material utilization m	Cost of production /component y	Relative Production Cost X=y\∑y	Partial utilization value mX
MA	0.185 1.7\9.2	£1.05	0.319	0.059
MB	0.247 2.2\9.2	£0.88	0.268	0.066
MC	0.173 1.4\9.2	£0.28	0.085	0.015
MD	0.222 2.0\9.2	£0.30	0.091	0.020
ME	0.173 1.9/9.2	£0.78	0.237	0.041
TOTAL		£3.29	1	0.201

The efficiency of Client B producing a Loudspeaker with improved materials that is more environmental friendly will increase from 20.1%. Technically the loudspeaker performance is low, with a moderate cost of production, with materials that have very low or negligible environmental effects.

i. *System Reliability*

The loudspeaker is design for a life span of 5 years, of which the loudspeaker compartment is at use at 14 hours a day (both usage and standby) and switch off at 10 hours a day.

For 5 years, the total operating hours of the loudspeaker = 14x365x5= 25,550 hours

In assumption, 2 system fails in every 5,000 hours, thus an average of 10 loudspeakers is likely to fail throughout the life cycle of the system (due to low technical performance).

Failure rate of the loudspeaker for Client A;

ʎ= number of failure\total operating hours

= 10\ 25,550 = 0.0003914

MTBF = 1\ʎ

= 1\ 0.0003914 = 2555 hours

The Reliability of the loudspeaker at 5 years of 25,550 operating hours,

$R(t) = e^{-ʎt} = e^{-t/m}$

$= e^{-0.00039147 \times 25550}$

$= 0.9999$

The probability of the loudspeaker surviving for 25,550 operating hours is 99.9%. This implies that the system has very negligible failure rate.

Thus, for the loudspeaker system for Client B have a high surviving rate and high reliability, the operating hours must be maintained with the total life span of 5 years, and a powerful standby system. It is advisable that the life span of the loudspeaker be maintained as well as it operation hours for effective performance and system reliability (Telsang, 2006).

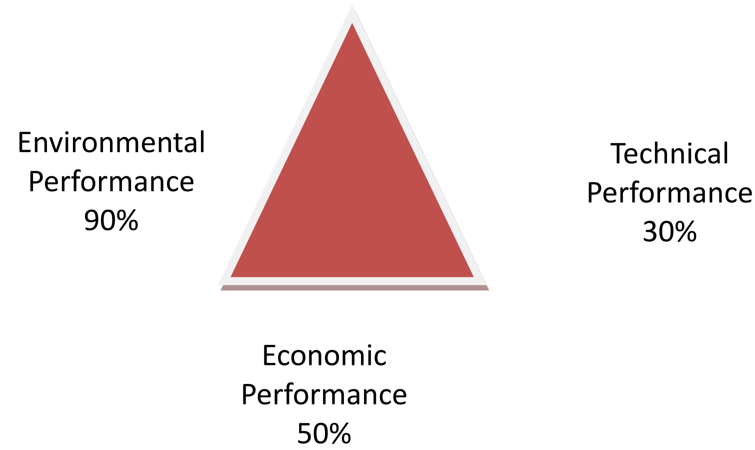

Fig 5 : Project Triangle for producing Loudspeaker for Client B

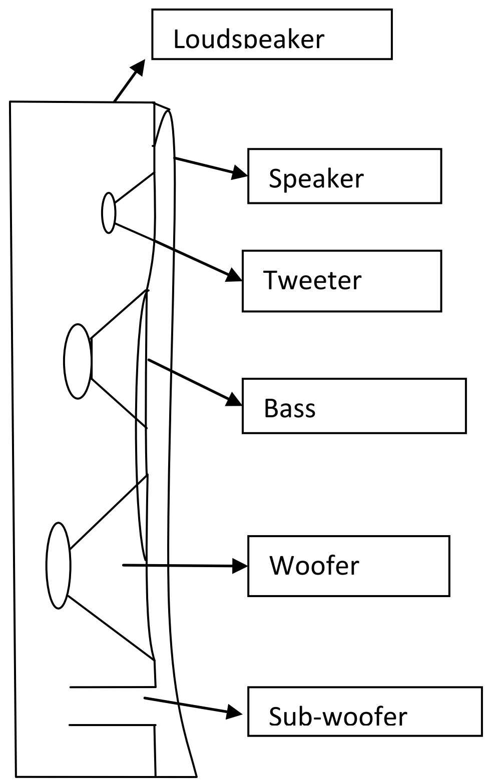

Fig 3 : Product B Loudspeaker

ii. *Economic Description of Product B*

Economically, the cost of producing loudspeaker for Client B is **£3.29,** this product is relatively high but it is still afforded by most customers. The loudspeaker is design for both sitting rooms, indoor and outdoor purposes.

The loudspeaker is more reliable with an efficiency of 20.1%, and a system reliability of 99.0%. Although, it mean time between failure (MTBF) is 2555 hours, which can be improve upon by a well supporting system that can regulate the energy supply to the system, reduces system vibration, and temperature, which can account for system failure (apart from factory fault).

Fig 4 : Loudspeakers for indoor and out-door uses. Wilson Audio's Alexandria x-2(2004)

The environmental effects of these products are very low or negligible with little effects on human hearing since it maximum sound output which is moderate to the hearing of the ear with a relatively low noise pollution, and its recyclability has no environmental effects when burnt and the unused once can be disposed by burning.

VIII. Comparative Analysis of Products A and B

Table 5 : Comparative Analysis of Product A and B

PARAMETERS	CLIENT A	CLIENT B
System Reliability	0.68	0.73
System Supportability	0.92	0.67
Sustainability Index	0.12	0.24
Life Cycle Assessment	0.12	0.21
Material Utility Principle	0.03	0.01
Maintainability	0.001	0.002
Life Cycle Costing and Economic Analysis	0.41	0.21
Technological Obsolescence	0.51	0.31
Energy Use	0.005	0.07
Resource Management	0.25	0.31
TOTAL	0.304	0.332

Average mean ratio = client A/client B: client B / client A 1.057 1

The table above shows that client B is more than client A in terms of sustainability. By comparing the product of client A and B using the parameters above, shows that client A has 100% product sustainability while client B has about 106%. This implies that client B's product has 6% performance sustainability rate more than client A's product.

Table 6 : Client Comparative

	Technical performance	Environmental performance	Economic performance	Total
Client A	0.9	0.3	0.5	0.17
Client B	0.3	0.9	0.5	0.17

Client B is most sustainable in terms of market needs because of high environmental performance of 90% and 30% technical and 50% economic performance respectively.

IX. Conclusion

The market needs of client A and B product indicate that product B is more sustainable than A because it has 90% Environmental performance,30% technical performance and 50% economic performance. Since product A can only be used for indoor purposes while product B can be used for both indoors and outdoors purposes it therefore means that in terms of sustainability, reliability, life cycle assessment, affordability client B product is the best.

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Experimental and Numerical Model for Thermal Design of Air Cooled Condenser

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I. Introduction

In ACC, heat is transferred from the process fluid (steam) to the cooling medium (air) through the fin tube bundle. It depends on the temperature difference (driving force) between air and steam so that the dry bulb temperature of air is a key control of the ACC performance. Therefore, the dry cooling system with ACC is less efficient in hot ambient.

Kutscher and Costenaro (2002) [1]developed a model to assess the cost and performance of different methods for using supplemental evaporative cooling to boost the summer performance of air cooled condenser in geothermal power plants. A system in which water directly contacts the condensate tubes has the highest performance and is economically the most attractive. However, consideration of scaling and corrosion must be addressed.

Jabardo and Mamani (2003) [2] developed a simulation model based on dividing the condenser into three zones as superheating, condensing and sub-cooling.Each region was treated as an independent heat exchanger. The discrepancy between the experimental data and the simulation results has shown a good agreement.

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Gadhamshettyet al. (2006) [3], proposed a new approach to alleviate the performance decline in air cooled condenser with increasing the air dry-bulb temperature. A chilled water thermal energy storage system is used to pre-cool the inflow air to the ACC whenever the ambient air temperature increases above (20 °C). The proposed procedure used the test 171 MW plant saves (2.5%) of the power (4.2MW) without using any water or incurring any water treatment cost.

The work of **Tarrad and coworkers[4], [5]** and **[6]** was concentrated on the heat transfer performance and modeling of air cooled heat exchangers. Their work showed that the thermal enhancement is a dependent measure of the fin geometric variables and row intensity of the air cooled heat exchanger. **Tarrad (2010) [7]** developed a numerical model for performance prediction of dry cooling of the air cooled condensers applied in power plants technology. A computer code was built that depends on the idea of using the row by row technique for estimating the heat transfer coefficient, air temperature and air physical properties distribution in the air flow direction from row to row. The model results showed an improvement in the condensation load up to (23%) when air pre-cooling mode applied to inflow air to the ACC to lower the dry-bulb temperature from (45) to (28) °C at air face velocity of (3.6) m/s.

Tarrad and Khudor(2015)[8] have presented quite a simple and adaptable correlation for the air side heat transfer coefficient in the form of dimensionless group criteria. It depends on the fin geometry, row and tube intensity and operating conditions. They concluded that their correlation predicts the heat duty and overall heat transfer coefficient of the case study heat exchangers with total mean absolute errors of (13%) and (10%) respectively. More recently, **Tarrad and Al-Nadawi (2015) [9]** presented a model for the air cooled condenser. Its strategy depends on the tube by tube technique implemented for a window type air conditioning unit circulating different refrigerant such as R-22, R-407C and R-407A. They postulated that the predicted heat duty of these refrigerants by their model has showed excellent agreement and was within the range of (-5%) and (+1.7%).

II. Experimental Work

a) Test Rig

An experimental facility was constructed to allow two types of condensing system worked as a test arrangement, Altameemi (2007) [10]. Each one represents a separate unit having all the specifications and instruments which allows condensation data to be collected over a range of operating conditions, figure (1). Air cooled condenser and shell and tube heat exchanger were used as a single or in a hybrid arrangement.The experimental apparatus was modified after a first set of data to ensure an accurate operation condition compatibility to weather criteria in Iraq in hottest period. This was accomplished by adding an electrical heating coil works as air heater for a set exit temperatures.

b) Heat Exchanger

Air cooled condenser is a finned tube heat exchanger, typically used for the process which consists of a finned-tube bundle with rectangular box headers on both ends of tubes. The "ACC" used in the present work was a vertical type, a single pass having two rows with flat side tubes occupied each rowas shown in figure (2).Flat side tube geometry used to enhance heat transfer inside tube with extra heat transfer area and reduce pressure drop outside tube. The tubes material are brass which has excellent physical properties [11], compared with other materials.

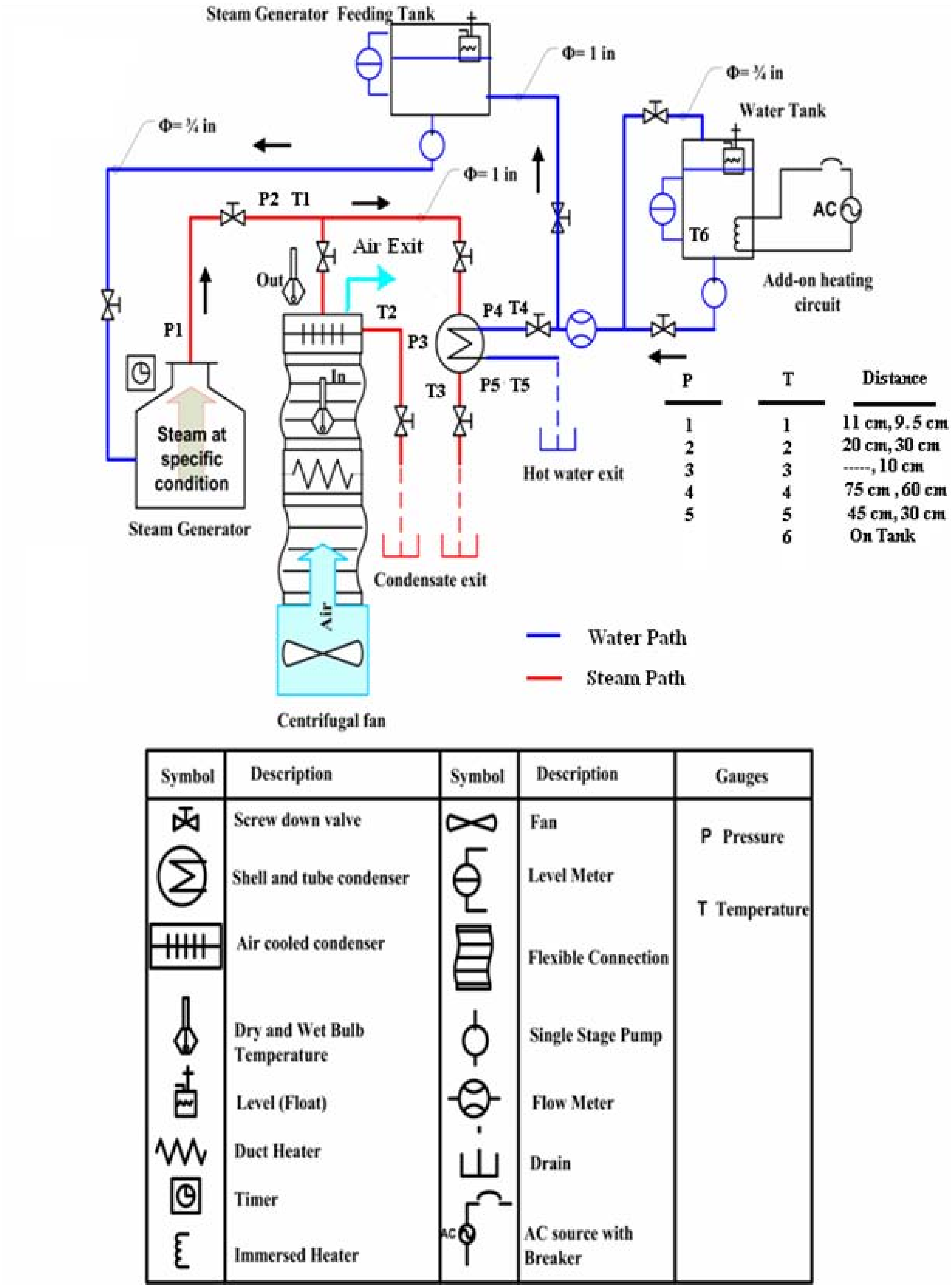

Figure (1) : A Schematic diagram for the test rig, Altameemi [10]

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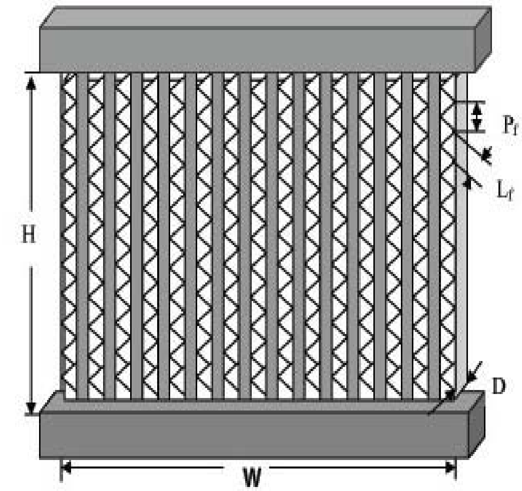

Figure (2.a) : Heat exchanger dimension designation

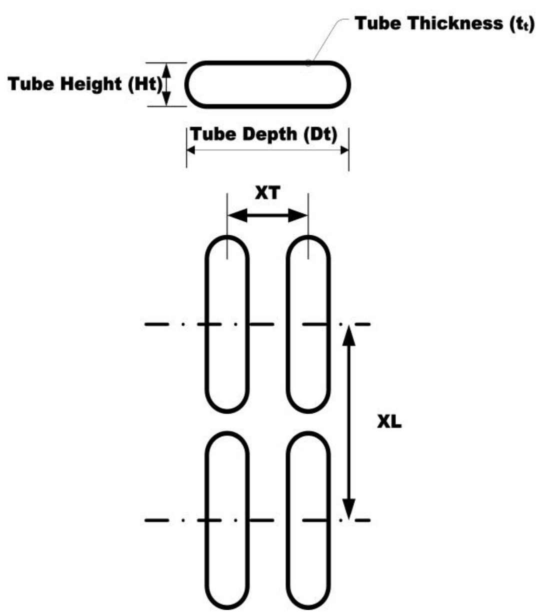

Figure (2.b) : tube layout

Figure (2.c) : Tube shape

Figure (2) : Physical geometry of heat exchanger, Altameemi [10]

The fins are constructed to the tubes so each fins row contains (70) fins attached to tube in equal pitch about (4.18) mm.The fins material is a copper, the physical characteristicand dimensions are listed in table (1).

Table (1) : Geometry and physical characteristic of heat exchanger

Parameter		Value
Core	Width (W), mm	590
	Depth (D), mm	30
	Height (H), mm	320
	No. of Tubes	110
	No. of Tubes/Row	55
	No. of Rows	2
	No. of fins/ Tube (on both sides)	140
	Transverse Distance (X_T) to flow, mm	11.25
	Longitudinal Distance (X_L) to flow, mm	15
	Frontal Area (A_{face}), m^2	0.1888
Fin	Pitch (f_P), mm	4.18
	Length (l_f), mm	8.05
	Thickness(t_f), mm	0.18
	Area of a Single Fin (A_f), mm^2	36.12
	Material	Copper
	Thermal Conductivity (W/m.C), [12]	388
Tube	Height (H_t), mm	2.35
	Depth (D_t), mm	12
	Thickness (t_t), mm	0.24
	Material	Brass
	Inner tube surface	Smooth
	Thermal Conductivity (W/m.°C), [12]	119
Area	Total Surface Area (A_{total}), m^2	3.935
	Total Fin Surface Area, m^2	3.029
	Total Bare Tube Area, m^2	0.906

The whole assembly is mounted on legs with a rubber and fasteners to well-set during operation.

The uncertainty percentage for the measurement was estimated to be within (± 2 %) for the whole tests range in this work, Altameemi [10].

III. Model Methodology

a) Model Technique and Assumptions

The air cooled steam condenser is shown in figure (3).The steam flows inside the flat tube. The air flow is perpendicular to the tubes across the fins so that both process and service fluids pass in a cross flow pattern on both sides of the exchanger wall. A row by row technique was implemented and each row in the single pass condenser is subdivided into segments in the height direction of the heat exchanger, figure (3). Each segment is treated as a small condenser with a specified geometry. It is associated with steam parameters such as mass flow rate, pressure and temperature. The air side has also specific air mass flow rate and inlet air temperature.

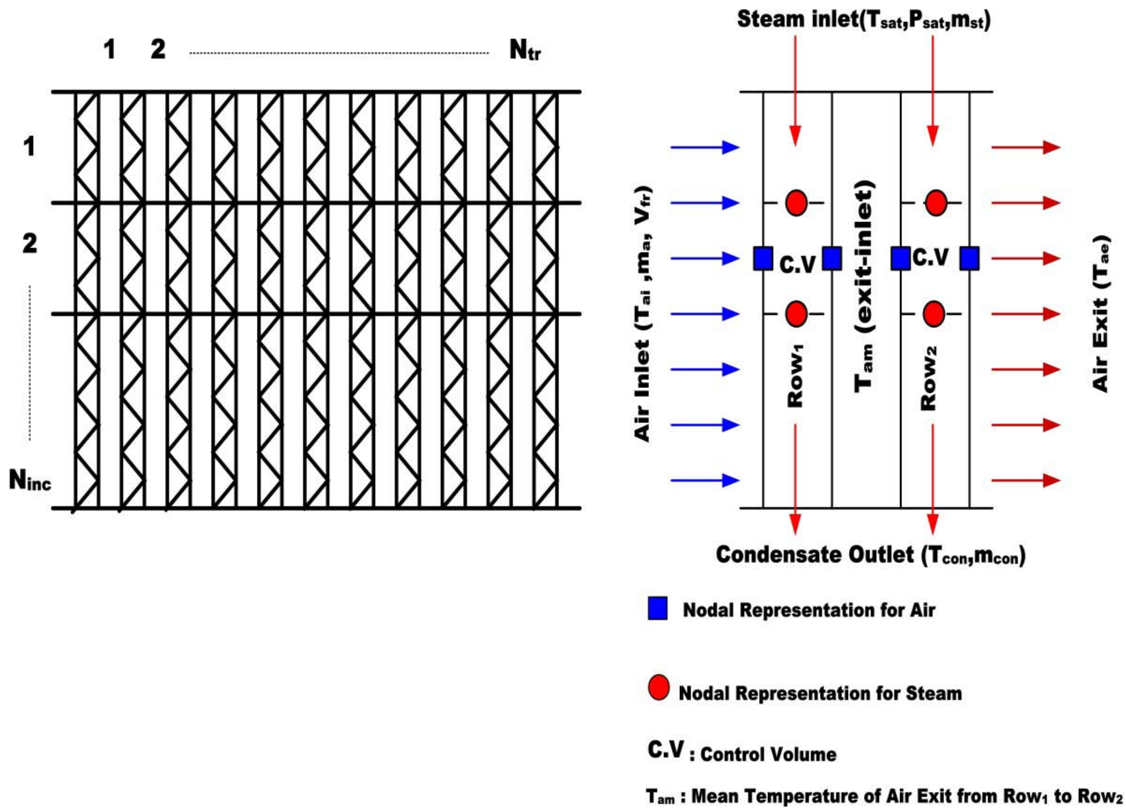

Figure (3) : A step by step modeling representation

The assumptions of the ACC modeling are:

1. The air mass flow rate is assumed to be distributed uniformly over the whole face of the air cooled steam condenser. To ensure this assumption, the inlet duct configuration and mal-distribution was checked.
2. Homogenous temperature distribution of air all over the frontal face area of the heat exchanger and hence for each segment.
3. The mean air exit temperature of each row is considered to be the inlet to the next row.
4. The steam temperature variations between the rows were assumed to be negligible.
5. The inlet air velocity for each row was assumed to be uniform and is represented by a specified value.
6. The steam mass flow rate from the main header is divided equally for each row.
7. Heat transferred away by convection and radiation is neglected.
8. Material properties of the finned tube bundle are constant with temperature variations.

The air side dry-bulb exit temperature that leaves the condenser is considered as the target parameter of the present model.

b) Steam Side Heat Transfer Coefficient

i. Condensation Mode

When the vapor velocity is high, the vapor will pull the liquid along the interface. This is because the vapor velocity at the interface must drop to the value of the liquid velocity. If the vapor flows downward this addition force will increase the average velocity of the liquid and thus the film thickness is decreased. This in turn, will decrease the thermal resistance of the liquid film and thus increasing heat transfer. For condensation inside tubes in air cooled condenser model the tube inside diameter is very small and the influence of tube wall curvature is important in condensation phenomenon. The correlation postulated by Boyko-Kruzhilin (1967) [13] was used to estimate the mean condensing coefficient for a steam between inlet quality x_i and outlet quality x_o inside tubes as below:

$$h_{c,BK} = h_{lo}\left[\frac{\sqrt{\left(\frac{\rho}{\rho_m}\right)_i}+\sqrt{\left(\frac{\rho}{\rho_m}\right)_o}}{2}\right] \quad (1)$$

Where:

$$\left(\frac{\rho}{\rho_m}\right)_i = 1+\frac{\rho_l-\rho_v}{\rho_v}x_i \quad (2.a)$$

$$\left(\frac{\rho}{\rho_m}\right)_o = 1+\frac{\rho_l-\rho_v}{\rho_v}x_o \quad (2.b)$$

h_{lo} is the sensible heat transfer coefficient assuming that the total fluid is flowing with condensate properties (condensate filled the tube and was flowing alone). This can be evaluated with the implementation of any available correlation for forced convection in tubes.

Boyko and kruzhilin [13]suggested the following correlation:

$$h_{lo} = 0.021 \left(\frac{k_l}{D_i}\right) {Re_{lo}}^{0.8} {Pr_l}^{0.43} \quad (3)$$

In a condenser, where the inlet stream was assumed to be saturated vapor and the vapor will be totally condensed,for these conditions equation (1) becomes, Sinnott (2005) [14]:

$$h_{c,BK} = h_{lo}\left[\frac{1+\sqrt{\frac{\rho_l}{\rho_v}}}{2}\right] \quad (4)$$

In the present work it is suggested to divide the tube length into equal increments. The quality change across each increment of length (Δz) is calculated to be (Δx),(x_i –x_e). The heat transfer of steam in two phase region depends on the quality change as a demonstrative factor to describe the amount of heat released at constant temperature. After the determination of the quality limits at each increment, it was utilized to calculate the local condensing heat transfer coefficient at the mid-quality magnitude of each (Δx). Assuming that the local value is constant over particular quality range (Δx), then:

$$\left(\frac{\rho}{\rho_m}\right)_{eq} = \frac{1}{2}\left[\left(\frac{\rho}{\rho_m}\right)_i + \left(\frac{\rho}{\rho_m}\right)_o\right] \quad (5.a)$$

$$\left(\frac{\rho}{\rho_m}\right)_{eq} = \frac{1}{2}\left[1 + \left(\frac{\rho_l-\rho_v}{\rho_v}\right)x_i + 1 + \left(\frac{\rho_l-\rho_v}{\rho_v}\right)x_o\right] \quad (5.b)$$

$$\left(\frac{\rho}{\rho_m}\right)_{eq} = \left[1 + \left(\frac{\rho_l-\rho_v}{\rho_v}\right)x_{eq}\right] \quad (5.c)$$

Where x_{eq} represents the mid-quality which is equal:

$$x_{eq} = \frac{(x_i + x_o)}{2} \quad (5.d)$$

So that equation (1) becomes:

$$h_{c,BK} = h_{lo}\left[\sqrt{1 + \left(\frac{\rho_l-\rho_v}{\rho_v}\right)x_{eq}}\right] \quad (6)$$

At high condensing loads, with vapor shear dominating, tube orientation has no effect, and equation (1) may also be utilized for horizontaltubes, Perry (1999) [15].

ii. *Single Phase Forced Convection*

Turbulent flow:

Numerous relations have been proposed for predicting fully developed turbulent flow in uniform cross-section tubes. The Dittus and Boelter correlation is suitable for moderate temperature variation,Incropera and Dewitt (1996) [16]. TheDittus-Boelter is usually given in the form:

$$h = 0.023 \left(\frac{k_f}{D_i}\right) Re^{0.8} Pr^n \quad (7)$$

Where Reynolds and Prandtl numbers are estimated from:

$$Re = \frac{\rho\, u_t D_i}{\mu} = \frac{G\, D_i}{\mu} \quad (8.a)$$

$$Pr = \frac{\mu\, cp}{k_f} \quad (8.b)$$

And $n = 0.4$ for heating ($T_s > T_m$) and $n = 0.3$ for cooling ($T_s < T_m$).

This mathematical relation has been confirmed experimentally for the following ranges of conditions:

$0.7 \le Pr \le 160$ $Re_D \ge 10{,}000$ and $L/D_i \ge 10$

For the case where the condensing load is small, vertical tube condenser may maintain sub-cooling in the bottom end of the tube. For this condition, if the temperature difference at the inlet and exit is greater than 10° C, then the moderate temperature variation assumption is invalid. However, for flows characterized by large property variations, Sieder and Tate correlation was used to calculate the heat transfer coefficient. Incropera and Dewitt (2006) [17] recommends:

$$h = 0.027 \left(\frac{k_f}{D_i}\right) Re^{0.8} Pr^{1/3} \left(\frac{\mu}{\mu_s}\right)^{0.14} \quad (9)$$

$0.7 \le Pr \le 16{,}700$ $Re_D \ge 10{,}000$ and $L/D_i \ge 10$

Laminar flow:

Below a Reynolds number of about (2000), the flow in pipes will be considered to fall in the laminar region. Sieder and Tate (1930) [18] recommends the following simple correlation:

$$h = 1.86\,(Re\,Pr)^{0.33} \left(\frac{D_i}{L}\right)^{0.33} \left(\frac{\mu}{\mu_s}\right)^{0.14} \quad (10)$$

Here (L) is the length of the tube or conduits.

For steam condensation where the condensed fluid is water, a special correlation for water could be used for more accurate estimation for inside coefficient. Eagle and Ferguson (1930)[19] data bank was adapted by Sinnott (1999) [20] to develop specifically correlation for water as follows:

$$h_i = 4200\,(1.35 + 0.02\,t_m)\left(\frac{{u_t}^{0.8}}{{D_i}^{0.2}}\right) \quad (11)$$

Equation (11) is applicable for all range of Reynolds number. However, if the estimated inside heat transfer coefficient by this equation is large compared with another used correlation, as described above, the smallest value will be taken.

For noncircular tubes all the above equations may be applied by using an effective diameter as a characteristics length. It is termed as the hydraulic diameter and is defined as:

$$D_h = \frac{4\,A_c}{P} \quad (12)$$

Where A_c and P are the flow cross sectional area and wetted perimeter.

c) Air Side Heat Transfer

i. *Heat Transfer Coefficient*

Heat transfer performance of the tube bank is determined by flow pattern, which is strongly dependent on the arrangement of the tubes. The longitudinal tube spacing and transverse tube spacing could influence the thermal characteristics performance of heat exchanger. This has been studies by Tarrad et al. [6], Grame [21] and Jones [22].On the other hand fin spacing, fin thickness and fin height also affect the performance of finned tube heat exchangers as reported by Briggs (1963) [23] and Tarrad and Khodur(2015) [8]. In the present work, the forced convection heat transfer coefficient for the triangular fins could be predicted approximately using correlation of internal flow in ducts for laminar or turbulent flow as stated above. Reynolds number for air flow inside a triangle fin with using a hydraulic diameter approach is calculated as below:

$$Re = \frac{\rho\, u_{max}\, D_h}{\mu} \quad (13.a)$$

The velocity $u_{max}$is calculated at the minimum cross flow area S_m in tube bundle, hence:

$$u_{max} = \frac{\dot{m}_a}{S_m\, \rho_a} \quad (13.b)$$

In the present work minimum cross flow area was calculated according to the air side geometry as:

$$S_m = \frac{1}{2} F_p (X_T - H_t) \quad (13.c)$$

$$\dot{m}_{a,inc} = \frac{\dot{m}_a}{H_{inc}} \quad (13.d)$$

ii. *Steam Side Tube Characteristics*

The cross section of the ACC tube is as shown in figure (4.a).The sides of the tube are assumed to be semicircular with a diameter equal to the tube height.

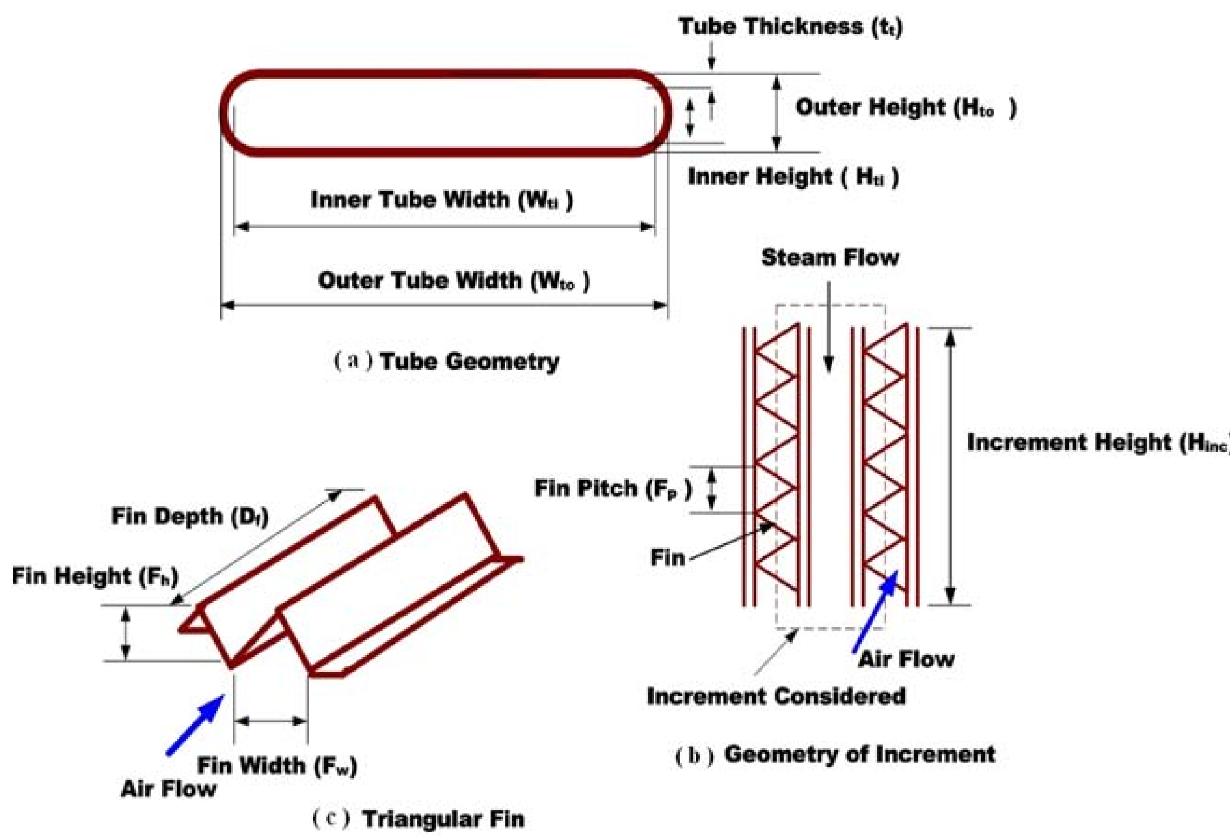

Figure (4) : Geometrical details of air cooled condenser

Therefore, the tube cross-sectional area is calculated as follows:

$$A_t = H_{t,i}(W_{t,i} - H_{t,i}) + \frac{\pi}{4} H_{t,i}^{\;2} \quad (14)$$

The tube wetted perimeter is the total tube perimeter in contact with the steam. It is given by:

$$P_t = \pi\, H_{t,i} + 2\,(W_{t,i} - H_{t,i}) \quad (15)$$

The hydraulic diameter is given by:

$$D_{h,t} = \frac{4\,A_t}{P_t} \quad (16)$$

The tube walls wetted by direct contact with steam transfer heat directly from the steam side to the outside air,hence the heat transfer area:

$$A_s = 2\left(W_{t,i} - H_{t,i}\right)L_t + \pi\, H_{t,i} L_t \tag{17}$$

Each fin attached to the tube with approximately (1 mm) thickness along the depth. The contact area is calculated as:

$$A_{att} = t_{att}\, D_{tube} \tag{18}$$

The total heat transfer area is given by:

$$A_{o,t} = A_s - A_{att} \tag{19}$$

iii. *Air Side Tube Characteristics*

The cross section of the tube outer surface is shown in figure (4.b). The face area of one tube and fin set in one increment, figure (4.c) is defined as:

$$A_{fa,inc} = \left(H_{tube\,,o} + F_h\right)H_{inc} \tag{20}$$

Therefore, the area blocked by the fins is given by:

$$A_{ba} = \frac{H_{inc}}{F_p}\left(l_f t_f + l_f t_f\right) \tag{21}$$

The area available for air flow is represented as the total area less than the area blocked by the fins together with the area occupied by the tube for steam flow as follows:

$$A_a = A_{fa,inc} - \left(A_{ba} + H_{tube\,,o} H_{inc}\right) \tag{22}$$

The perimeter of the tube which is directly in contact with air is given by:

$$P_a = \left[2\,\frac{H_{inc}}{F_p}\left(l_f - t_f\right) + \left(H_{inc} - H_{inc}\,\frac{t_f}{F_p}\right)\right] \tag{23}$$

The hydraulic diameter is:

$$D_{h,a} = \frac{4\,A_a}{P_a} \tag{24}$$

The tube wall which is in contact with steam on the inside surface and with air on the outside surface directly transfers heat from the steam to the outside air. This constitutes the heat transfer area:

$$A_{a,s} = \left[2\left(D_{t,o} - H_{t,o}\right)\left(1 - \frac{t_f}{F_p}\right) + \pi\, H_{t,o}\right] H_{inc} \tag{25}$$

The fins also confirm the heat transfer from the steam to air. Therefore fin surface area is defined as follows:

$$A_{f,s} = 2\,\frac{H_{inc}}{F_p}\left(l_f D_f\right) \tag{26}$$

The total heat transfer area become:

$$A_o = A_{a,s} + \eta_f A_{f,s} \tag{27}$$

Here η_f *is* the fin efficiency, when $\left(\frac{dT}{dx} = 0, x = l\right)$ then the efficiency is given by, Kreith (1999) [24]. In the present work, the fin is represented by a schematic diagram shown in figure (5), hence:

$$\eta_f = \frac{\tanh\, ml}{ml} \tag{28.a}$$

$$m = \sqrt{\frac{h_a P_a}{k_a A_a}} \tag{28.b}$$

Therefore, the total surface efficiency of the fin, η_o is therefore expressed as below:

$$\eta_o = 1 - \frac{A_f}{A_o}\left(1 - \eta_f\right) \tag{29}$$

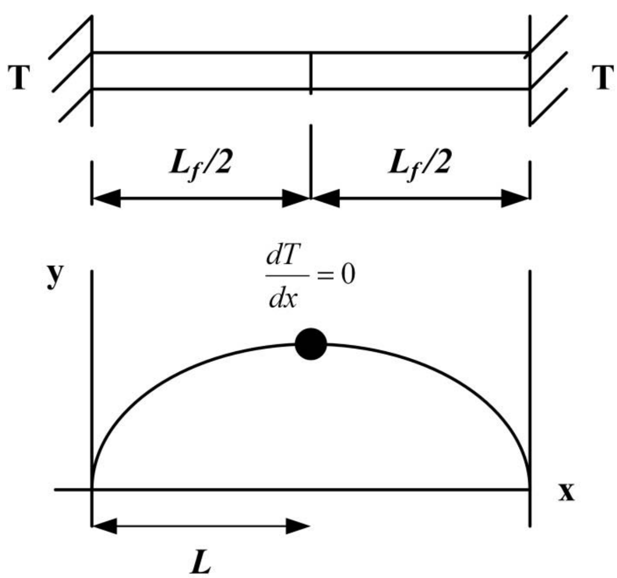

Figure (5) : Representation of fin midpoint temperature variation *d) NTU Effectiveness Relations:*

The NTU method offers more advantages for analyzing heat exchangers. It shows that iterative procedure is not required when inlet and outlet temperatures are unknown. For any heat exchanger, the total heat rejected from the hot fluid to the cold fluid is dependent on the heat exchanger effectiveness and also on the heat capacity of each fluid. This can be calculated as follows:

$$Q = \varepsilon\, c_{min}\left(T_{h,i} - T_{c,i}\right) \quad (30.a)$$

The heat capacity, c, the extensive equivalent of the specific heat, determines the amount of heat a substance absorbs or rejects per unit temperature change, where:

$$c = \dot{m}\, cp \quad (30.b)$$

The effectiveness is the ratio of the actual amount of heat transferred to the maximum possible amount of heat transferred and defined as:

$$\varepsilon = \frac{Q}{Q_{max}} \quad (31.a)$$

In the present work, the heat duty of each increment is calculated by the effectiveness-NTU method. The effectiveness relation for single-phase fluid cross flow is given below, Holman (2002) [25]:

$$\varepsilon = 1 - exp\left[\frac{exp\,(-N\, C_r\, n) - 1}{C_r\, n}\right] \quad (31.b)$$

And for Counter flow:

$$\varepsilon = \frac{1 - exp\,[-N\,(1 - C_r)]}{1 - C_r\, exp\,[-N\,(1 - C_r)]} \quad (32.a)$$

Where:

$$n = N^{-0.22} \quad (32.b)$$

$$C_r = \frac{c_{min}}{c_{max}} \quad (32.c)$$

$$N = NTU = \frac{UA}{c_{min}} \quad (32.d)$$

This is the effectiveness relationship for a cross flow, single-pass heat exchanger with both fluid unmixed. For tow-phase fluid flow, the effectiveness relation is:

$$\varepsilon = 1 - exp(-NTU) \quad (33)$$

The overall heat transfer coefficient (U), takes into consideration the total thermal resistance to heat transfer between two fluids. Even though the convective heat transfer coefficients may be different on the two sides of the heat exchanger, the (UA) product is the same on either side. This is because all of heat taken from hot side must be transferred to the cold side. Overall heat transfer coefficient defined as,Sinnott (1999) [20]:

$$\frac{1}{U_o} = \frac{1}{h_o \eta_o} + \frac{1}{h_{fo,o}\eta_o} + \frac{D_o \ln\left(\frac{D_o}{D_i}\right)}{2\, k_{wall}} + \left(\frac{A_o}{A_i}\frac{1}{h_{fo\ i}\eta_i}\right) + \left(\frac{A_o}{A_i}\frac{1}{h_i \eta_i}\right) \quad (34.a)$$

By neglecting the effect of fouling on both sides of the heat exchanger, and inside surface efficiency, the overall heat transfer coefficient is reduced to:

$$\frac{1}{U_o} = \frac{1}{h_o \eta_o} + \frac{D_o \ln\left(\frac{D_o}{D_i}\right)}{2\, k_{wall}} + \left(\frac{A_o}{A_i}\frac{1}{h_i}\right) \quad (34.b)$$

e) Model Scheme

The suggested model in the present work was prepared in the form of a computer program designated as ACCRP. It was written with the aid of Liberty Basic Language, [26]. Multi iteration schemes were implemented to obtain the final rating data of the air cooled condenser. These were related to the air stream side and steam flow inside the tubes. A complete description and flow diagram of this code could be found in Altameemi [10].

IV. Model Verification

The experimental results are compared to the theoretical simulation results using the ACCRP computer program. The results showed a good agreement with the experimental data.The present model was verified by the implementation of the experimental data collected from [10] at atmospheric pressure. The model calculation scheme depends on the prediction of the air exit dry bulb temperature that on the lee side of the condenser under steady state conditions. Hence, this parameter was considered as an indication for the uncertainty percentage of the simulation process of the present model. Accordingly, the accuracy of the present row by row and step by step strategy is related to how far be the predicted air temperature and the condenser load from the experimental data. The uncertainty of each parameter and its discrepancy or scatter from the experimental data was estimated from:

$$\Phi^{\pm} = \frac{\Phi_{theoretical} - \Phi_{experimental}}{\Phi_{experimental}} \quad (35)$$

Here Φ represents either the exit air temperature or the heat duty of the condenser.

a) Thermal Load

The experimental data collected in the present work showed its dependency on the air velocity and its temperature. Figure (6) shows the variation of the condenser load with entering temperature at two different velocities for a steam mass flow rate of (33.5) kg/hr. It is obvious that increasing air velocity or reducing the entering condenser air temperature will enhance the condenser load.Increasing the air velocity showed an increase in the condenser steam mass flow rate of about (17.3 %) and (14 %) at entering air dry-bulb temperature of (20.7°C) and (42°C) respectively. The corresponding condenser thermal load was improved by (1.21) and (1.18) times as shown in figure (6).

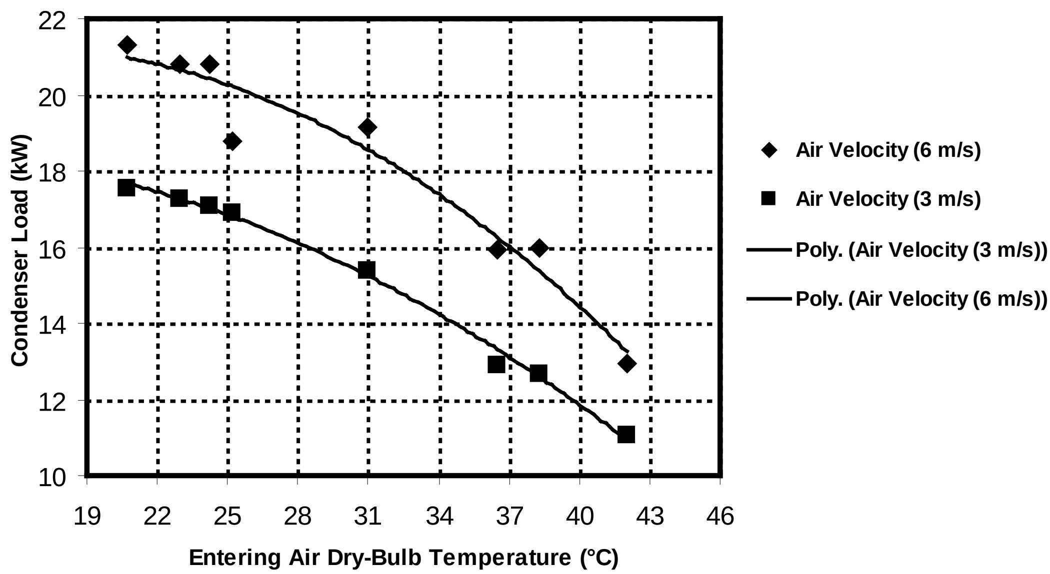

Figure (6) : Air cooled condenser load variation with entering air dry-bulb temperature

The ACC thermal loads for different experimental conditions exhibited a maximum deviation of (+8 %), and a minimum deviation of (-5 %) for air velocity of (3) m/s.The corresponding values for (6) m/s, the maximum discrepancy of (+ 11 %), as shown in figures (7) and (8). It is quite clear that the uncertainty in the model prediction was better at the low air velocity than that at the higher one.

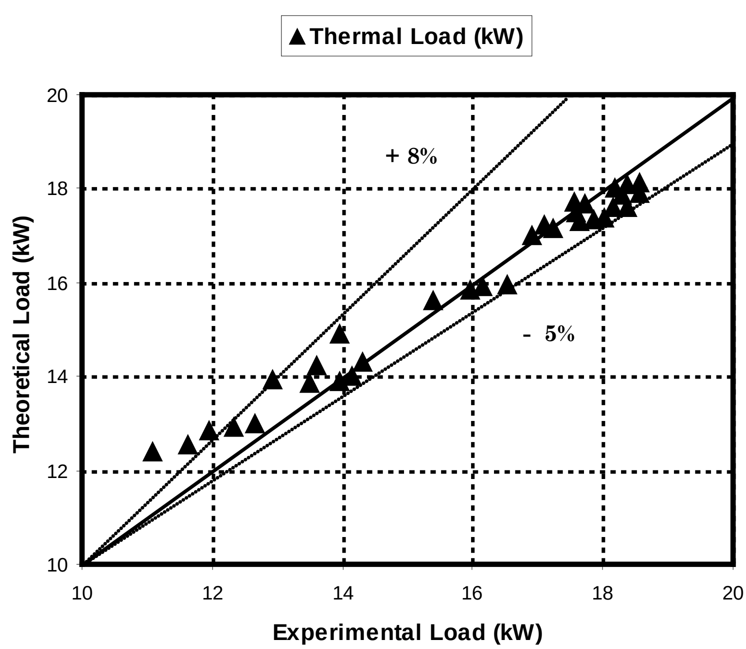

Figure (7) : Comparison of experimental and theoretical ACC thermal load at air velocity of (3) m/s

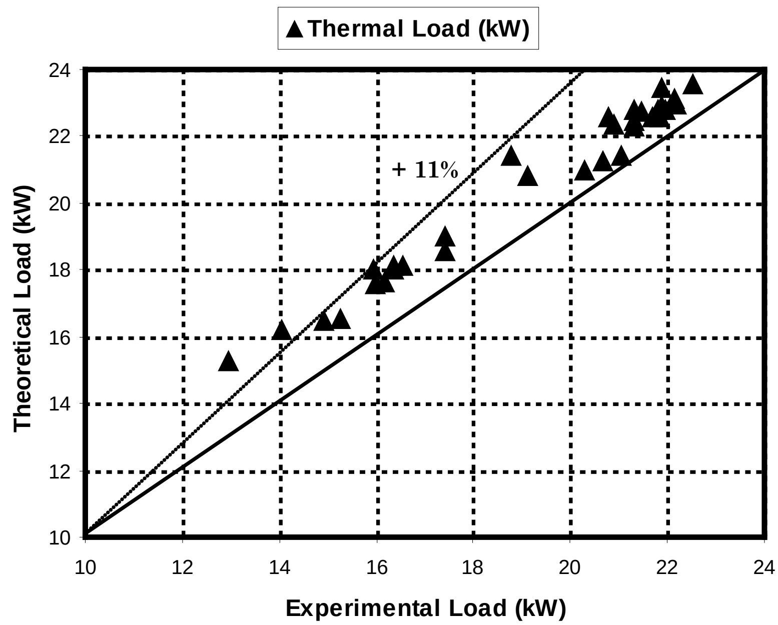

Figure (8) : Comparison of experimental and theoretical ACC thermal load at air velocity of (6) m/s

Figure (9) shows the comparison between the measured experimental heat duty and that predicted by the present modal for the entire operating conditions considered in the present work. The model predicted the condensation load with a high confidence and it lies with a scatter of (+12) % and (-5) % for more than (98) % of the data points.

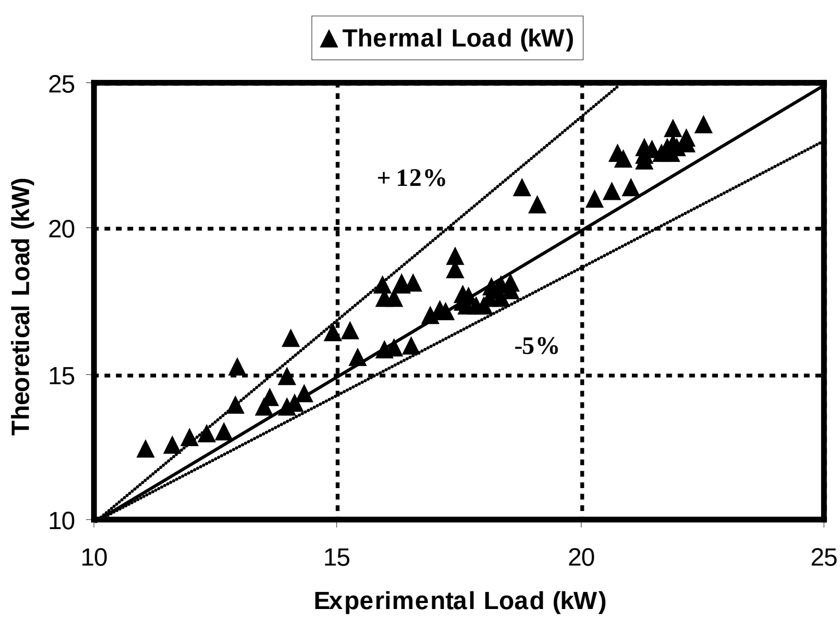

Figure (9) : Comparison of experimental and theoretical ACC thermal load at air velocity of (3) m/s and (6) m/s

b) Exit Air Temperature

Verification of the air exit temperature samples for (3 and 6) m/s are shown in figure (10). It is obvious that all of the results are under predicted by (5 %). The most attractive feature of the present model is its response to the variation of the operating conditions. These conditions are related to the condensation loading, air temperature and its flow rate.

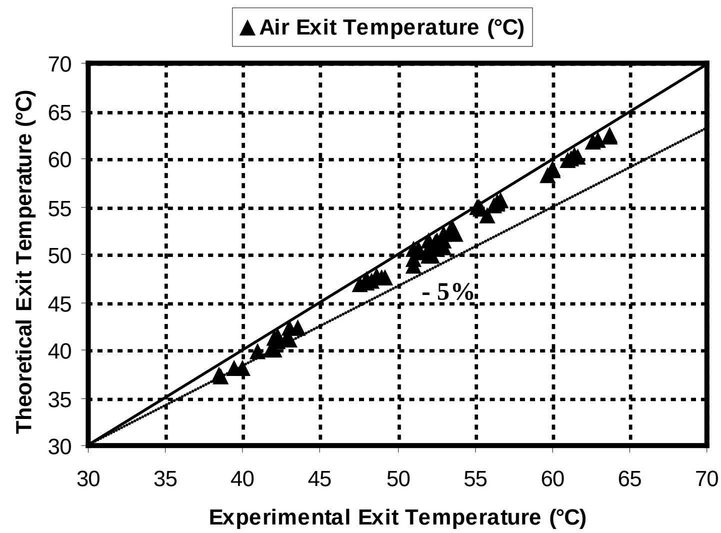

Figure (10) : Comparison of experimental and theoretical ACC exit dry-bulb temperature for both test air velocities at different steam flow rates

c) Overall Heat Transfer Coefficient Distribution

The distribution of the overall heat transfer coefficient with the tube length is illustrated in figures (11),(12) for the ACC under low and high air velocity respectively. The present model showed that the local overall heat transfer coefficient for air cooled condenser varies with increment and row position in the air direction towards the exit side of the condenser. The variation with increment position is due to the condensation heat transfer variation with vapor fraction at each section. The variation with row position is due to the variation in air side heattransfer coefficient in the air direction.

It is obvious that the choice of increasing the air flow rate and flow velocities with (100%) by fanning a higher air volumetric flow may be considered to achieve high heat transfer. This is due to the increaseof air side heat transfer coefficient, especially for hot ambient condition when performance in a credible manner was required.The air velocity is an important character in air cooled condenser overall design and determination of the face velocity. However it is usually falls within the range of (1.5) to (4) m/s, Tarrad (2010) [7]. It is recommended for the face velocity of the air a value which is not exceeding (3) m/s, for pressure drop consideration, Wilber and Zammit (2005) [27].

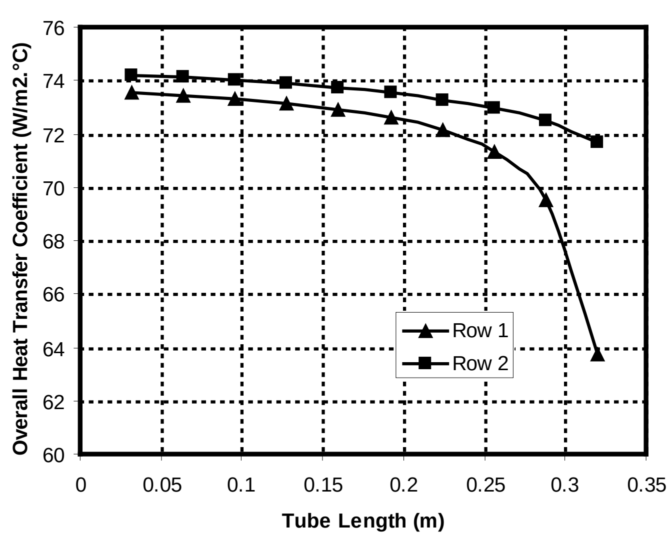

Figure (11) : Overall heat transfer coefficient distribution for ACC under air flow velocity of (3) m/s at inlet air temperature of (31°C) and steam flow rate of (33.4) kg/hr

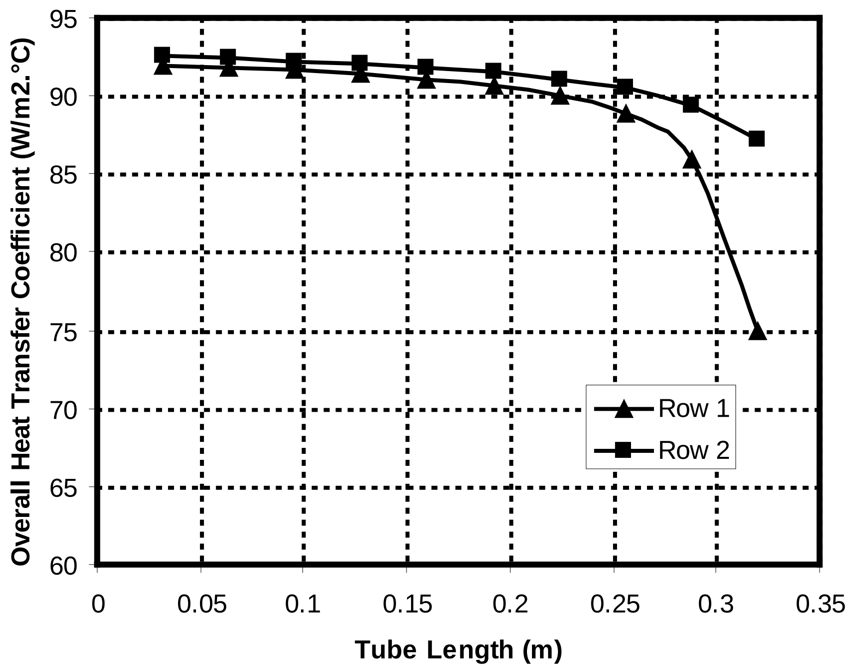

Figure (12) : Overall heat transfer coefficient distribution for ACC under air flow velocity of (6) m/s at inlet air temperature of (31 °C) and steam flow rate of (33.4) kg/hr

V. Conclusions

The present work revealed the following findings:

1. Thermal rating model for the ACC has been built successfully to predict the thermal load and temperature distributions across the heat exchanger. It showed excellent agreement between the experimental and predicted data of the exit air dry bulb temperature and condensation load.
2. The simulation model results showed that the local overall heat transfer coefficient (U_o) is changed slightly with the increment and row position. It is conservative to assume that (U_o) is of a constant value for each row.
3. When the air flow rate was doubled, the ACC average steam mass flow rate is increased by (17.5%) and the average condenser thermal load is increased by (17.6%) with air dry-bulb temperature reduction of (42 to 20.7) °C.

Nomenclature

A	Area	m^2
C_r	Heat Capacity Ratio	-
cp	Specific Heat at Constant Pressure	J/kg.°C
D	Diameter or Depth	m
F_p	Fin Pitch	m
g	Gravitational Acceleration	m/s^2
h	Specific Enthalpy	kJ/kg
h_c	Steam Condensing Heat Transfer Coefficient	W/m^2 °C
h_o	Outside Heat Transfer Coefficient	W/m^2 °C
H	Height	m
k	Thermal Conductivity	W/m °C
L	Tube Length	m
l_f	Fin Length	m
$\dot{m}$	Fluid Mass Flow Rate	kg/s
n	Parameter Defined by Equation (32.b), Correlation index	-
N	Number	-
Nu	Nusselt Number	-
p	Operating Absolute Pressure of Steam	bar
P	Perimeter of Tube	m
Pr	Prandtle Number	-
$\dot{Q}$	Condensation Load	kW
Re	Reynolds Number	-
S_m	Hollow Fin Cross Sectional Area	m^2
t	Thickness	m
T	Fluid Temperature	°C or K
ΔT	Temperature Difference	°C
u	Fluid Velocity	m/s
U_o	Overall Heat Transfer Coefficient	W/m^2 °C
W	Air Cooled Condenser Width	m
x_{eq}	Steam Local Quality	-
X_T	Transverse Tube Pitch to the Flow Direction	m
X_L	Longitudinal Tube Pith in Flow Direction	m
z	Heat Exchanger Cooled Length	m

Greek Symbols

η_f	Fin Efficiency
η_o	Total Surface efficiency
ε	Effectiveness of the Condenser
ρ	Density (kg/m^3)
μ	Viscosity (kg/m.s)
Φ	Parameter defined by eq. (35)

Subscripts

a	Air
ass.	Assumed Value
att.	Attached
c	Condensate , cold
cBK	Boyko-Kruzhilin condensation coefficient
cal.	Calculated Value
cond	Condenser, Condensation
e	Exit or Equivalent
eff.	Effective
eq.	Equivalent
est.	Estimated Value
f	Fouling , Fin or fluid
g	gas
h	Hydraulic diameter, hot fluid
i	Inside or Inlet
inc	increment
l	Liquid
lo	Liquid Only
m	mean
max	maximum
min	minimum
o	Outside
r	ratio,row
row	Row Value
s	Steam Value or Surface
t	Tube
tr	tube per row
Tube	Tube Value
ν	Vapor
w	Wall Value

Abbreviations

ACC	Air Cooled Condenser
ACCRP	Air Cooled Condenser Rating Program
NTU	Number of Heat Transfer Unit
OHTC	Overall Heat Transfer Coefficient

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Experimental Investigation of Magnetic Field Assisted on Edm Process By using Taguchi Method on En-19 Tool Steel

By Krishan Kant
Chandigarh University, India

Abstract- Electric discharge machining (EDM) is one of the maximum commonly used nontraditional processes for making accurate intricate shapes on hard materials like die steels and is most preferred process to be followed for die and mold making. In this research work, an attempt has been made to machining the En-19 tool steel by using copper electrode performer on electrical discharge machine. Experiment plan has been designed using Taguchi technique to study the effect of different parameters and their levels by conducting least number of experiments. Based on this L18 orthogonal array is been used, Where Diameter of U-shaped electrode, Current and Pulse on time are taken as process input parameters and material removal rate, tool wear rate, Overcut on surface of work piece are taken as output parameters. Effort has been made to find out the optimum machining conditions by varying process parameters like current, powder to be suspended in dielectric, its concentration, tool material and pulse-on duration at three levels with and without using external magnetic field.

Keywords: electric discharge machining, taguchi technique, l18 orthogonal array, En-19 tool steel.

GJRE-A Classification : *FOR Code: 091399*

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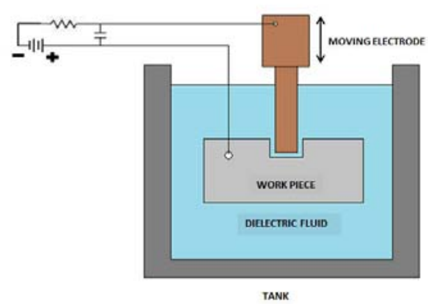
In the case of Tool wear rate the most important factor is discharge current then pulse on time and after that diameter of tool. From the experimental investigation copper tool followed by C18000 tool has been found to give the best MRR results and high tool wear, whereas tungsten tool has been found to give the least MRR accompanied by least tool wear. The dimensional accuracy of the tools in terms of corner wear, side wear and overcut has also been studied.

Keywords: electric discharge machining, taguchi technique, l18 orthogonal array, En-19 tool steel.

I. Introduction

It is clear that the past few years have seen an increasing interest in the novel applications of electrical discharge machining to see the potential of this technique for better process performances it is obvious that lot of work has been done to optimize the EDM process and the work related to finding the feasibility of harder material. The correct selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of manufacturing processes and, particularly, in processes related to Electrical Discharge Machining (EDM). It is a capable of machining geometrically complex or hard material components, that are precise and tool steels, composites, super alloys, ceramics, carbides, heat resistant steelspulse on time and diameter of tool of En-19 tool steel material.



Parts of the experiment were conducted with the L18 orthogonal array based on the Taguchi method . And non- conventional machining. The Electric discharge machining process is finding out the effect of machining parameter such as discharge current, materials, posses greater strength and toughness are usually known to create major challenges during conventional forming tools. These steel are categorized as difficult to machine rang of application in Plastic moulds, frames for plastic pressure dies, hydro better polish ability, it has a grooving tempered condition. Good mach inability, hardened and as preferred particle size, sintering temperatures and pressures. Despite the promising results, electric discharge and nuclear industries. En-19 Plastic mould steel that is usually supplied in a making industries, aerospace, aeronautics etc. being widely used in die and mold.

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a) Objective of the present work

1. To find feasibility of machining EN-19 tool steel using U-shaped tubular copper electrode and internal flushing.
2. To analyze the responses MRR, TWR, and over cut by using the machining parameter selected for discharge current, pulse on time, and diameter of the tool using Taguchi design approach.
3. To Find the influence of MRR With discharge current, pulse duration time, and diameter of the tool. To find the influence tool wear rate with discharge current, pulse on time and diameter of tool.
4. To find the influence on over cut with discharge current, diameter of the tool and, pulse on time.
5. To investigate the machining parameters for EDM using shaped electrode of EN-19 tool steel.

II. Parameters Affecting Performance of Edm

a) Discharge Voltage

Discharge voltage in EDM is related to the spark gap and breakdown strength of the dielectric.Before current flows, open gap voltage increases until it creates an ionization path through the dielectric. Once the current starts flowing, voltage drops and gets stabilized at the working gap level. Higher is the voltage, more is the gap, that improves the flushing conditions and helps to stabilize the cut. MRR, tool wear rate (TWR) and surface roughness increases, by increasing open circuit voltage, because electric field strength increases [Fuller, 1996].

b) Peak Current

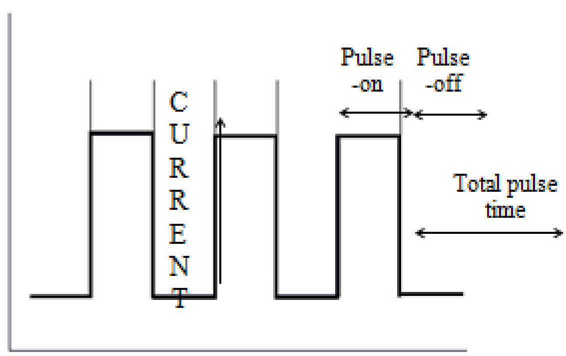
Higher amperage is used in roughing operations and in cavities or details with large surface areas. Machined cavity is a replica of tool electrode and excessive wear will affect the accuracy of machining.

c) Pulse Duration and Pulse Interval

Each cycle has an on-time and off-time that is expressed in units of microseconds. Since all the work is done during on-time, the duration of these pulses and the number of cycles per second (frequency) are important. Pulse on-time is commonly referred to as pulse duration and pulse off-time is called pulse interval. When the optimum pulse duration for each electrode—work material combination is exceeded, material removal rate starts to decrease.

d) Polarity

Polarity determines the direction of current flow relative to electrode; it can be either positive or negative depending on applications. In positive or normal polarity workpiece is positive and tool is negative and in reverse or negative polarity workpiece is negative and tool is positive.



Pulse waveform of controlled pulse generator

e) Dielectric

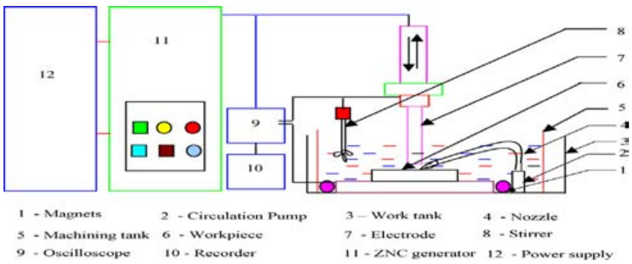
Basic characteristics necessary for a dielectric in EDM are high dielectric strength and quick recovery after breakdown, effective quenching and flushing ability. TWR and MRR are affected by the type of dielectric and the method of its flushing. Generally kerosene and deionized water is used as dielectric fluid in EDM. Tap water cannot be used as it ionizes too early and thus breakdown due to presence of salts as impurities occur. Dielectric medium is generally flushed around the spark zone. It is also applied through the tool to achieve efficient removal of molten material.

f) Pulse-on Time

This is time period during which machining is performed. As the 'pulse on' time increases, machining will perform at faster rate and craters will be broader and deeper thereby resulting in poor surface finish and high MRR. Larger the pulse on times means larger is the recast layer and more are the heat affected zones.

g) Pulse-off Time

The 'pulse off' is the time during which re-ionization of the dielectric takes place. The more is the off time, the greater will be the machining time. The off time governs the stability of the process. An insufficient off time can lead to erratic cycling and retraction of the advancing servo thereby slowing down the operation cycle.



The experimental set up consists of transparent container in which machining is performed called machining tank, placed in the work tank of EDM. Fixture assembly is used to hold the work piece. Dielectric (kerosene oil) fluid is filled in machining tank. A stirrer system is used to avoid particle setting. Small dielectric circulation pump is used. Pump and stirrer assembly are placed in same tank in which machining is performed. Magnetic forces were used to separate the debris from the dielectric fluid, for these two permanent magnets are placed at the bottom of machining tank.

The spark gap is filled with powder particles. When voltage was applied an electric field was created. The powder particles get charged and act as conductors behaving in zigzag manner.

III. Experimental Design

Designing an experiment is the principle need of any experimentation plan. In present study Taguchi Method is used for preparing experimental design. Main steps of experiment plan are listed below.

- Defining objective function
- Selecting an appropriate OA
    - Selection of factors
    - Pilot Experimentation
    - Finalizing the factors and their levels

a) Defining Objective Function

The main objective of this experimentation is to study the effect of current, powder concentration, type of powder and magnetic strength on tool behavior during macro and micro EDM, PMEDM during slot cutting to analyze output parameters dimensional and profile accuracy of tool.

b) Selecting an Appropriate OA

The Taguchi method involves reducing the variation in a process through robust design of experiments by using a selected set of experimentation plan. Each factor is assigned column(s) depending on its DOF. Each level of a factor has an equal number of occurrences within each column; and for each level within one column, each level within any other column will occur an equal number of times as well.

c) Selection of Factors

Selection of factors is an important task which is to be done carefully to prepare the most effective design of experiment. Brainstorming and pilot experimentations are conducted to decide factors and their levels.

d) Calculation of DOF

DOF denotes the number of the independent comparisons that can be made in any experiment. The number of factors considered for experimentation, their respective levels determine the total degree of freedom required for designing OA. Mathematically, DOF for each factor is calculated as,

DOF= n-1, where n is the level of each factor

e) Selection of OA for PMEDM

Different factors considered for PEDM experiments and their levels are listed in Table 3.2.

Factors (unit)	Levels		
	Level 1	Level 2	Level 3
Current (A)	2	4	6
Magnetic field (T)	0.1	No	-
Tool material	Copper	C18000	Tungsten
Powder type	Tungsten	Copper	Titanium
Concentration (g/L)	2	4	6
Pulse-on time (μs)	50	100	200

Factors and their levels for magnetic assisted PMEDM

IV. Experimental Set Up

The experimentation work is performed on T-3822 M Electric Discharge Machine of Victory Electromech placed in non-traditional machining lab at Thapar University, Patiala. A separate arrangement is added for performing powder mixed EDM, a mild steel tank with inside dimensions as length 330 mm, breadth 180 mm, height 187 mm and plate thickness 3 mm. Capacity of the used tank is 9 L. A stirrer with the maximum speed of 1400 rpm is used to properly mix the powder in the dielectric medium.

V. Workpiece and Tool Electrode Details

For experimentation, die steel material is used as workpiece. Before machining, workpiece is properly grinded from both the sides for maintain perfect alignment of workpiece with the tool electrode during machining. Three electrode materials used for machining purpose, namely copper, tungsten and C18000 (alloy (Copper, Chromium, Nickel, Silicon (beryllium free)), all with diameter 2.4mm and 30mm length.

Selection of workpiece

S. No	Parameter	Value
1	Voltage	135±5% V
2	Polarity	Positive
3	Machining time	8min
4	Pulse-off time	57µs
5	Dielectric medium	EDM oil

EN-19 tool steel is very hard having the following Mechanical properties.

Mechanical properties of EN-19 steel

Tensile strength	1150N/mm2
Yield stress	850N/mm2
Elongation	14-17%
Modulus of elasticity	210000N/mm2
Density	7.8Kg/m3

Exp. No	Magnetic strength	Powder	Concentration (g/L)	Current (A)	Tool material	Pulse-on (µs)	MRR (g/min)
1	With	W	2	2	Cu	50	0.05200
2	With	W	4	4	W	100	0.00533
3	With	W	6	6	C18000	200	0.01333
4	With	Ti	2	2	W	100	0.01200
5	With	Ti	4	4	C18000	200	0.02733
6	With	Ti	6	6	Cu	50	0.02000
7	With	Gr	2	4	Cu	200	0.06000
8	With	Gr	4	6	W	50	0.00800
9	With	Gr	6	2	C18000	100	0.01000
10	Without	W	2	6	C18000	100	0.01733
11	Without	W	4	2	Cu	200	0.02533
12	Without	W	6	4	W	50	0.00666
13	Without	Ti	2	4	C18000	50	0.03133
14	Without	Ti	4	6	Cu	100	0.02733
15	Without	Ti	6	2	W	200	0.01200
16	Without	Gr	2	6	W	200	0.00533
17	Without	Gr	4	2	C18000	50	0.02466
18	Without	Gr	6	4	Cu	100	0.05866

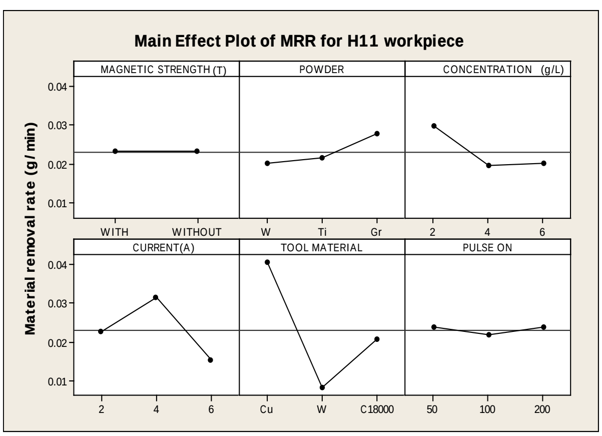
VI. Results

The effect of powder mixed in dielectric, concentration of powder, current, tool material and pulse-on duration is analyzed on MRR and TWR with and without using external magnetic field. Using Taguchi experimental design, L18 orthogonal array is used for the experiments using bar magnets of 0.1 T. Schematic representation of the tool and the workpiece Tool is made in contact with the workpiece up to 10 mm in length and machining duration is kept 10 minutes.

The results are analyzed using ANOVA. It helps in identifying the important process parameters affecting the response. Results for mean of MRR calculated at 90% confidence level ANOVA table for MRR of EN-19 workpiece (Note: For 90% CI, Fcritical(2,6) = 3.46, Fcritical(1,6) = 3.78, PC= percentage contribution)

Parameter	Symbol	DOF	SS	Variance	*F*- value	*p*-value	PC
Magnetic strength (T)	*A*	1	0.00000	0.00000	0.0	0.989	0
Powder	*B*	2	0.000201	0.000101	0.91	0.452	3.822
Concentration (g/L)	*C*	2	0.000383	0.000192	1.73	0.255	7.284
Current (A)	*D*	2	0.000802	0.000401	3.63	0.093	15.252
Tool material	*E*	2	0.003192	0.001596	14.44	0.005	60.707
Pulse-on time (μs)	*F*	2	0.000017	0.000008	0.08	0.927	0.323
Residual error		6	0.000663	0.000111			12.60
Total		17	0.005258				

The principle followed by F-test is that, greater is the F value for an input parameter the larger is its effect on output parameter. ANOVA shows the results of MRR of PMEDM with and without the use of magnetic strength. Under such experimental conditions the two factors i.e. tool material (F value 15.56) and current (F value 4.27) are found to be significant. The value of F is for the concentration 1.58 g/L. MRR is found to decrease with concentration because as the amount of powder suspended in the dielectric increases, the circulation of the powder particles is not enough also with increase in concentration above a certain level arcing occurs as the effective gap between the tool and the workpiece decreases with increase in concentration.



Main effects plot of MRR for EN-19 work piece

The highest MRR is achieved on suspension of graphite powder as its density and electrical resistivity is least among the all three. The MRR obtained by titanium is slightly higher as compared to tungsten but less than graphite as the electrical resistivity and density of titanium is less than tungsten but higher than graphite. Thus less is the density and electrical resistivity of a powder more is the MRR achieved by it till the concentration reaches an optimum level. The effect of pulse on duration and magnetic strength have not been found to be very significant and have been ranked as 5th and 6th respectively based on their F values. The MRR is found to increase on increasing the pulse on duration as more melting and vaporization of workpiece will take place when time for which the energy supplied increases.

Magnetic strength has least effect on the MRR. The MRR obtained under the influence of magnetic field is slightly less than that obtained without the use of magnets but overall the effect of this factor is negligible.

Level	Magnetic strength (T)	Powder	Concentration (g/L)	Current (A)	Tool material	Pulse-on time (μs)
1	0.023110	0.01997	0.029665	0.022665	0.040553	0.023775
2	0.023181	0.021665	0.019663	0.031552	0.008220	0.021775
3		0.027775	0.020108	0.015220	0.020663	0.023887
Delta	0.000071	0.007778	0.010002	0.016332	0.032333	0.002112
Rank	6	4	3	2	1	5

Response table for MRR of EN-19 workpiece

Optimal design

In the experimental study, the mean effect plots is used to evaluate the mean MRR at optimal trial conditions considering higher F-value and corresponding percentage contribution two parameters are found to be significant tool material and current. The level of these factors which gives the maximum MRR are noted from main effect plot and the corresponding MRR for D_2, 〖E〗_1 is directly obtained from Maximum value of these parameters is selected because MRR is the higher the better type of response variable. Desired mean in this case is estimated as:

$$\mu_{D_2,E_1} = \overline{D_2} + \overline{E_1} - \overline{T} = 0.031552 + 0.040553 - 0.0231456 = 0.0489594 \text{ g/min}$$

Confidence interval

$$CI = \sqrt{\frac{F_{\alpha,v_1,v_2} V_e}{n_{eff}}}$$

Where F_{α,v_1,v_2} = F ratio

$\alpha = 0.1$ (risk)

Confidence = $1 - \alpha$

v_1 = DOF for mean (always 1)

v_2 = Total DOF (=17)

$\overline{T}$ = Average of all experimental trials

n_{eff} = Number of tests under that condition using the participating factors

$$n_{eff} = \frac{N}{1+DOF_{D,E}} = \frac{18}{1+4} = 3.6$$

N is the number of trial in the experiment

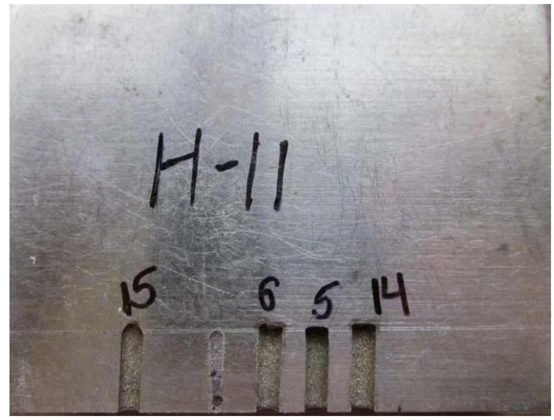
V_e = Variance of error

$$CI = \sqrt{\frac{3.03 \times 0.000111}{3.6}} = \pm 0.00966$$

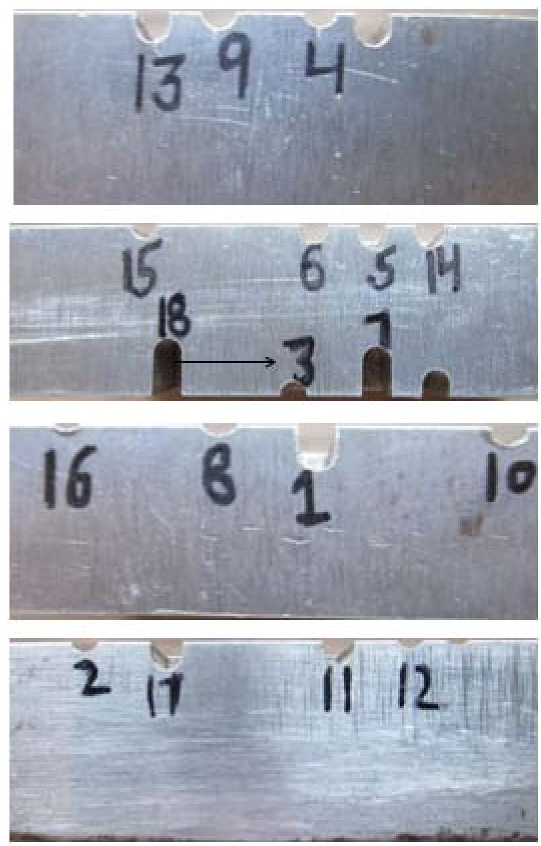
Thus the optimum value of MRR is given by

(0.0489594 ± 0.00966) g/min.

The workpiece samples from different views of H11 after each cut is shown in Figures shows top view which indicates the length of cut shows the side views where depth till which machining has been completed can be seen.



(a)



(b)

a) Results and Analysis of TWR

The effect of powder mixed in dielectric, concentration of powder, current, tool material and pulse on duration on tool wear rate is analyzed with and without using external magnetic field on tool wear rate, using Taguchi experimental design. L18 orthogonal array is used for the experiments using bar magnets of

0.1 T. It is smaller the better type of response variable. TWR is calculated by measuring the initial and final weight of the tool using a weighing machine with least count of 0.001 g

$$TWR= \frac{W_{i-}W_f}{t} \text{ g/min}$$

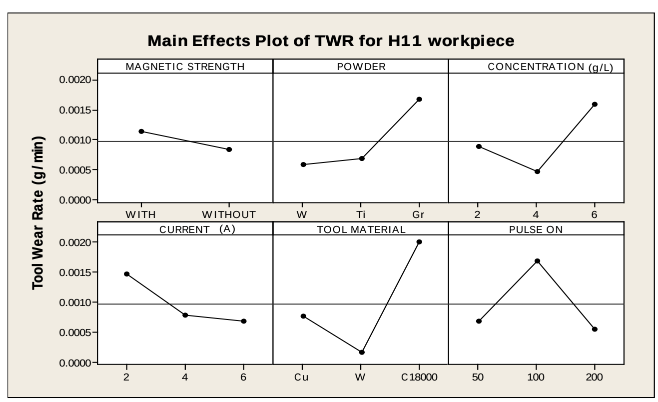
Where Wi = Initial weight of the workpiece (g)
Wf = Final weight of the workpiece after the experimentation (g)
t = Machining time (min)

Expt. No	Magnetic strength (T)	Powder	Concentration (g/L)	Current (A)	Tool material	Pulse-on (µs)	TWR (g/min)
1	With	W	2	2	Cu	50	0.00067
2	With	W	4	4	W	100	0.00006
3	With	W	6	6	C18000	200	0.00066
4	With	Ti	2	2	W	100	0.00006
5	With	Ti	4	4	C18000	200	0.00067
6	With	Ti	6	6	Cu	50	0.00067
7	With	Gr	2	4	Cu	200	0.00060
8	With	Gr	4	6	W	50	0.00067
9	With	Gr	6	2	C18000	100	0.00670
10	Without	W	2	6	C18000	100	0.00133
11	Without	W	4	2	Cu	200	0.00067
12	Without	W	6	4	W	50	0.00006
13	Without	Ti	2	4	C18000	50	0.00200
14	Without	Ti	4	6	Cu	100	0.00067
15	Without	Ti	6	2	W	200	0.00006
16	Without	Gr	2	6	W	200	0.00067
17	Without	Gr	4	2	C18000	50	0.00067
18	Without	Gr	6	4	Cu	100	0.00133

Parameter	Symbol	DOF	SS	Variance	*F*-value	PC
Magnetic strength (T)	*A*	1	0.00000036	0.00000036	0.18	0.914
Powder	*B*	2	0.000004	0.000002	1	10.162
Concentration (g/L)	*C*	2	0.000004	0.000002	0.87	10.162
Current (A)	*D*	2	0.000002	0.000001	0.51	5.081
Tool material	*E*	2	0.000011	0.000005	2.42	27.947
Pulse-on time (µs)	*F*	2	0.000005	0.000002	1.06	12.703
Residual error		6	0.000013	0.000002		33.028
Total		17	0.00003936			

b) Results and analysis of TWR for EN-19 workpiece

Based on this analysis conducted, most significant factor is tool material. The highest tool wear is observed with C18000 alloy followed by copper tool. Tungsten tool has been found to give the least tool wear. This is because of difference in the melting points of the tool materials. Thermal conductivity of copper at 100 °C is about 400 W/m-K and of alloy C18000 is 208 W/m K and that of tungsten is 173 W/m-K although tool wear is found to decrease with increase in thermal conductivity but in this case it is not a dominating factor. Pulse on duration is the second factor affecting the tool wear rate after the tool material. The center line represents mean value of the levels.



Main effect plots of TWR for EN-19 workpiece

Optimal Design

In the experimental study, the mean effect plots. are used to evaluate the mean TWR at optimal trial conditions. From Table considering higher F-value and corresponding percentage contribution three parameters are found to be significant tool material followed by current and type of powder. The level of these factors which gives the minimum TWR are noted from main effect and the corresponding TWR for E_2 and F_3 is directly obtained. Minimum value of these parameters is selected because TWR is the lower the better type of response variable. Desired mean in this case is estimated as:

$\mu_{E_2} = \overline{E_2} + \overline{F_3} - \overline{T}$ = 0.000162 + 0.000555 – 0.0010122

= -0.0002952 ≡ 0

The optimal calculation for population mean (μ) gives negative value. This situation may appear for responses which are lower the better type and where the optimum/target value is zero. For such case negative value of μ may not have any physical significance and is to be considered as zero.

Confidence interval

$$CI = \sqrt{\frac{F_{\alpha,\nu_1,\nu_2} V_e}{n_{eff}}} \quad (\mu s)$$

Where $F_{\alpha,\nu_1,\nu_2} = F$ ratio

$\alpha = 0.1$ (risk)

Confidence = 1 – α

ν_1 = DF for mean (always 1)

ν_2 = Total DOF (=17)

$\overline{T}$ = Average of all experimental trials

n_{eff} = Number of tests under that condition using the participating factors

$$n_{eff} = \frac{N}{1+DOF_{E,F}} = \frac{18}{1+4} = 3.6$$

N is the number of trial in the experiment

V_e = Variance of error

$$CI = \sqrt{\frac{3.03 \times 0.000002}{3.6}} = \pm\, 0.001297$$

This experimental investigation was mainly aimed at comparing the tool wear behavior of the three tool material copper, C18000 and tungsten with and without using the external magnetic field. Different process parameters like current, pulse-on time, powder suspended in dielectric (tungsten, titanium and graphite) was varied at three levels with and without using magnetic field. Different output parameters measured are MRR, TWR, geometrical tool wear characteristics (corner wear, side wear), overcut. Some significant conclusions drawn on the basis of analysis of results

- Tool material is found to be the most significant factor in case of all the response variables measured with copper giving the highest MRR and TWR followed by C18000 alloy and tungsten.
- Besides tool material current is found to be the significant factor in affecting MRR for EN-19 workpiece materials, type of powder suspended in dielectric is found to affect the MRR for EN-19 workpiece materials.
- Including the tool material factor TWR is affected by pulse-on duration for EN-19 workpiece, by magnetic strength for EN-19 workpiece.
- EN-19 workpiece material is found to have maximum MRR and Graphite powder has reported better MRR compared to the two other powders used.
- Trials conducted in the presence of external magnetic field have reported to show better MRR and less TWR.
- Maximum MRR is achieved at the powder concentration of 2g/L.
- Maximum corner wear is reported in tool material C18000 alloy while maximum side wear is shown in tungsten tool.
- Overcut is found to decrease with increase in pulse-on duration, presence of magnetic strength is also found to decrease the overcut.
- Maximum depth of cuts is achieved using copper as a tool material and using 4 A of current setting.

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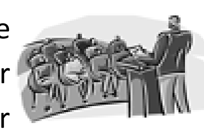

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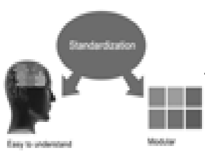

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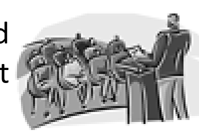

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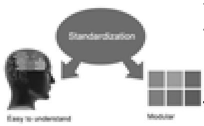

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2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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- Exact spelling, clearness 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

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The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled 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 with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose 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 sound written Procedures segment allows a capable scientist to replacement 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 for the least amount of information that would permit another capable scientist to spare 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 object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text 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:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not 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 - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in 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 a 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. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise 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 in manuscript form.

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- Never confuse figures with tables - there is a difference.

Approach

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- Give details all of your remarks as much as possible, focus on mechanisms.
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Approach:

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References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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