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Highlights

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Discovering Thoughts, Inventing Future

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A New Design of Experiment Method for Trim Dies Considering Fatigue Failure

By Pengyan Lu, Qingyu Yang & Xin Wu
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A New Design of Experiment Method for Trim Dies Considering Fatigue Failure

Pengyan Lu [α], Qingyu Yang [σ] & Xin Wu [ρ]

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I. Introduction

In recent decades advanced high-strength steels (AHSS) have been rapidly developed and widely applied in automotive industry to reduce vehicle weight, improve sustainability, and increase fuel efficiency and safety at an affordable cost. However, as the strength of AHSS continues to increase, the service life of existing dies, especially trim dies, is rapidly declining. This is due to the high impact stresses at the trim die cutting edges and the absence of adequate backing material to support the cutting edge.

The performance of trim dies, especially their fatigue life, directly impacts tooling cost and the occurrence of edge cracking in stamped parts. The theoretical study and experimental foundation on fatigue damage of materials were established over a century ago, with the discovery of fatigue failure in railway car axles reported as early as the 19th century [1]. Wöhler [2-4] initiated the early concepts of allowable load, metallurgical size effect, crack propagation, and finite life design based on both static strength and allowable stress amplitude, i.e., the two corresponding safety factors for static and cyclic. The S-N curve was also called “Wöhler curve” after 1936. Eshelby [5] (in 1898) firstly utilized the stress concentration factor of 3.0 for a cylindrical hole in an infinite plate for an explanation of failure at low applied stress. For the reverse loading effect, Bauschinger [6-8] reported that the material elastic limit would be changed after repeated stress cycles”. Basquin [9] stated that the fatigue life has a power-law dependence on the external load amplitude. Soderberg [10], Goodman [11], and Gerber [12] modeled the effect of cyclic stress amplitude on fatigue life with different treatments. Haigh [13-15] studied the stress ratio effect on fatigue life. From a long history of fatigue study on the mechanics and physical damage mechanisms, it is generally agreed that the fatigue failure experiences crack initiation and propagation stages until a critical crack length is reached. Coffin [16] and Manson [17] developed the strain-based low cycle fatigue (LCF) model by correlating strain amplitude to crack initiation. Based on linear elastic fracture mechanics initiated by Griffith [18, 19], the mechanics of fatigue crack growth was established and later extended to ductile materials with crack-tip plastic zone. Paris and Erdogan found that the crack propagate rate, da/dN, is driven by ΔK (where K is the stress intensity factor) in a power-law relation, leading to Paris Law and the S-N curve for fatigue life prediction. A mass of comprehensive review articles and books are available, with representative ones by Schutz [20] and Suresh [21]. Figure 1 summarizes the fatigue damage mechanisms and three regimes. A variety of fatigue testing methods have been developed, with some becoming material testing standards."

Design of Experiments (DOE) is a powerful statistical method that optimizes a system or process by identifying key variables and their interactions [22, 23]. Sir Ronald A. Fisher first developed DOE methods in 1920 for agricultural research [24]. Later, factorial design [25] and fractional factorial designs [26] were developed, which require only a fraction of the runs of a full combination of variables. Classic designs used to detect interactions and quadratic effects include the Central Composite Design (CCD) and Box-Behnken Design (BBD) [23].Taguchi [27, 28]developed robust parameter design methods that emphasize robustness and quality in the design process. Box and Wilson further developed Response Surface Methodology (RSM) [29], which models and optimizes response

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variables over a range of input variables. Space-filling designs are another relevant family of DOE designs. The space-filling designs select a set of experimental conditions that cover the entire range of input variables or factors while minimizing the number of experiments required. Examples of space-filling designs include Latin Hypercube Sampling, Orthogonal Arrays, and Sobol Sequences [30].

The DOE method have made significant progress and has been widely used in many fields, including engineering, manufacturing, healthcare, and agriculture [31]. However, most of the existing research on DOE focuses on a scalar performance variable or a vector of performance variables. Little research studied the DOE method when the performance is high dimensional data such as time series, or images.

This research investigates the impact of trim die repair/reconditioning processes on trim die performance in automotive body manufacturing. In the automotive sheet metal stamping process, trim dies may become damaged due to wear or edge chipping during production. To remedy this, trim dies can either be repaired/reconditioned on-site through welding, grinding, and induction hardening in the tool maintenance division, or repaired/reproduced off-line using different manufacturing methods such as machining, welding, and furnace through-hardening in a more controlled environment.

The objective of this study is to compare these competing manufacturing routes and their effect on trim die performance through simulated and accelerated fatigue testing and microstructure analysis. Because the trim die performance degradation over time can be treated as a time series process over time, the traditional DOE method cannot be directly applied. To overcome this difficulty, we developed a new DOE method when the output performance is a time series. The results and insights gained from this study will provide valuable guidance for future process selection and performance improvement.

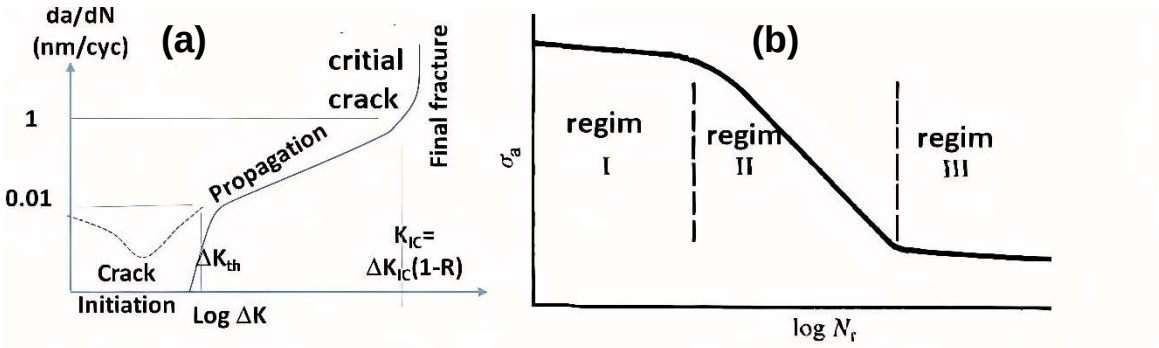


Figure 1: (a) Mechanisms of crack initiation and propagation fatigue failure development; (b) S-N curve showing three regimes of fatigue damage (regenerated schematically based on [21])

II. Experimental Methods

a) Test Material and Matrix

There exist various tool steels, and one such steel utilized in this study is Caldie™, a trademarked grade of Uddeholm [32]. Caldie™ is a chromium-molybdenum-vanadium alloyed tool steel developed by Uddeholms AB for use in tools operating under high compressive pressure, where Rockwell hardness 58-62 HRC is required, and where chipping and/or cracking are the predominant failure mechanisms. Its chemical composition, given by [33], is (in wt%): C 0.7, Si 0.2, Mn 0.5, Cr 5.0, Mo 2.3, and V 0.5.

This study compares three pairs of competing manufacturing methods: raw material process (cast versus wrought), heat treating method (induction heating versus furnace through heating), and repair status (edge welded with Caldie™ filler wires versus base metal-not welded). Each route undergoes two repeated tests, resulting in a total of 16 fatigue tests for eight manufacturing routes. The routes are labeled with abbreviations using the abrasives used in testing, such as "C-TH-w," which stands for the Cast-Through Heating-welded route. To distinguish between repeated tests, a tail "-t1", "-t2", etc., is added, such as "W-IH-b-t2," which represents the Wrought-Induction Heating-bulk-test #2 route. The provider did not perform any heat treatment after a stand TIG welding process using Caldie™ wire. For all IH coupons, the original Caldie™ blocks' hardness is improved from 20HRc to 36-42HRc through a pre-hardening process using the TH method.

b) Simulated Trim Die Edge Fatigue Set-up

We designed and fabricated a trimming simulator, as shown in Figure 2, to assess the die life and relative damage evolution of a trim die specimen. The cube-shaped specimen measures ¾" on each side, with two cutting edges subjected to a concentrated sinewave load through a WC pin. The applied force is equally carried by two specimens using a self-alignment block, allowing the loading train to pass through the edge center. The higher force applied accelerates the edge damage, enabling a quick assessment and comparison of the relative die damage evolution and die life, compared to that observed in real sheet metal

trimming processes. The similarity and difference of the loading conditions between this test and real sheet metal trimming process are explained in detail in another paper published by the present author [34]."

Fatigue loading was operated under a constant cyclic compressive force for remaining WC pin in contact with the die edge. The waveform is given as

$$F(t) = \frac{(F_{max} + F_{min})}{2} sin(2\pi ft) = \frac{F_{max}}{2} (1\text{-}R)\, sin(2\pi ft) \quad (1)$$

where R= F_{min} / F_{max} , F_{max} = 60kN, and R=F_{min} /F_{max} =0.1, and f=10Hz for all the tests. The load wavefunction was provided by a standard material tester (Instron model 8801) with a servo-hydraulic actuator and digital controller.

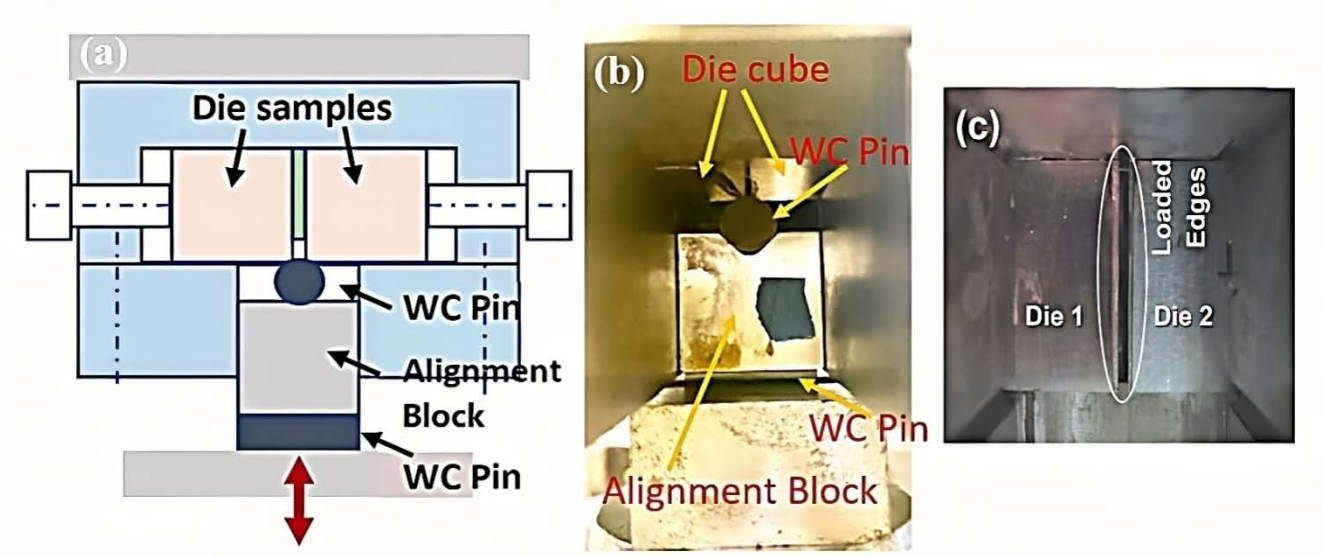


Figure 2: (a) The concept design of simulated trim die edge loading; (b) Self-aligned loading train configuration; (c) Image of specimen damaged edges viewed from fixture opening

c) Edge Damage Characterization and Measurement

The die holding fixture has an open window to allow a front view and bottom view of mounted two die cubes (at the die loaded edges), and the WC pin can be removed and remounted to the die edge from bottom window, as shown in Figure 2(c). This allows the fatigue test to be interrupted at any specified cycles (at about half of the order of magnitude, i.e., 1, 300, 1000, 3000, 10000, 30000…) while the die edge damage needs to be photographed for measurement. All the specimen were gradually and statically loaded to the peak force before applying cyclic load, which is counted as the first fatigue cycle. Upon completion of the fatigue testing, the recorded edge images were analyzed by image processing, to identify the pin contacted edge areas. As shown in Figure 3(a), the 2D projected damage areas were recorded using a digital camera, and the projected edge damage areas were obtained from the number of pixels and the calibrated magnifications for individual images with the known cube edge length on the image.

The edges, under compressive load from round WC bar, will be plastically deformed under static load up to F_{max} i.e. the fatigue peak load, then the edge will continually deform under cyclic loading, during which micro-cracks are initiated, and propagated to meso- or macro-scale cracks. When WC pin is pushed down from H_0 (initial corner contact) to H_1 and H_2, the pin-corner contact arc length (projected) increases from zero to L_1 and L_2; the corresponding volume V_1 and V_2 of the die material is moved from original top surface to side wall, as shown in Figure 3(b), where t is the initial gap between two die cubs. Based on the geometrical relationship, the projected edge damage area can be converted to the corresponding volume of materials. Both of them are used to evaluate the edge damage evolution along with the number of cycles.

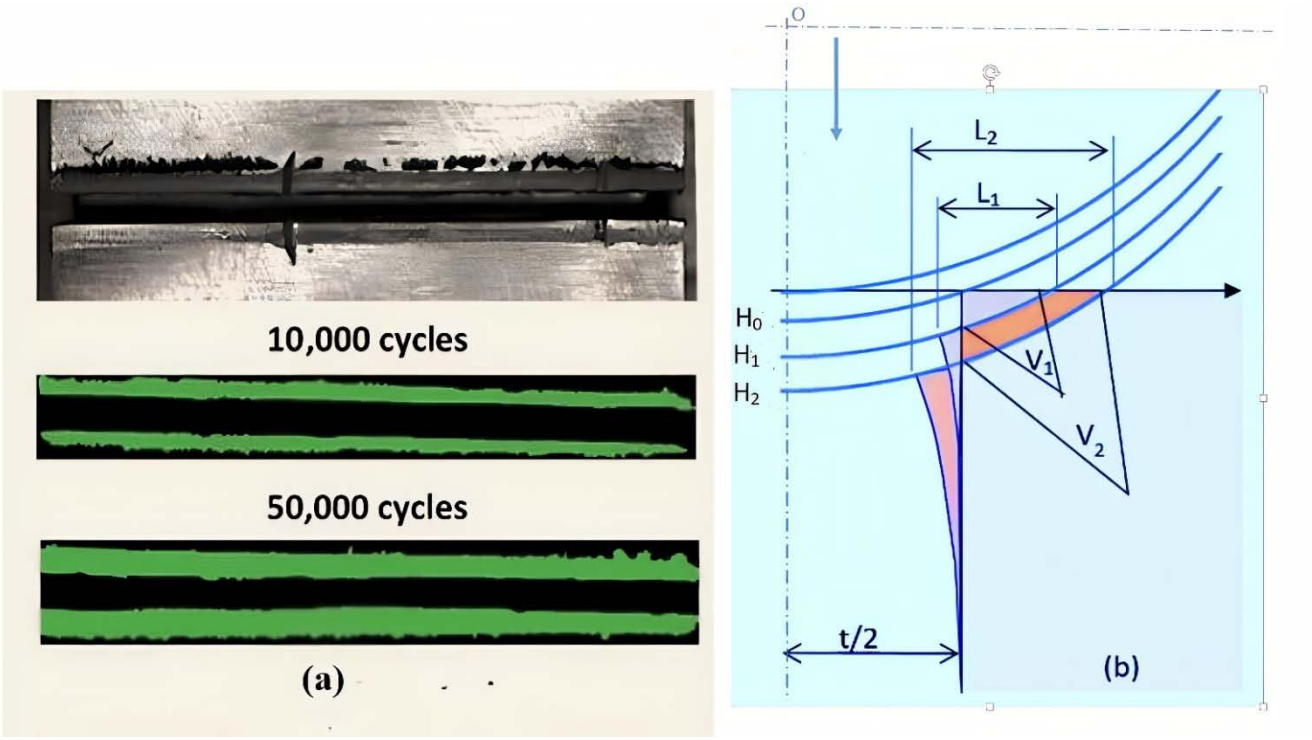


Figure 3: (a) The damaged edge, with the projected damage area highlighted; (b) the schematic of edge profile evolution

d) Results of Mechanical Testing

Figure 4 plots the projected edge damage area (A) and volume (V) of metal removed from the die corner against $\log_{10}(N)$ for all 16 fatigue tests. In this semi-log plot, it can be observed that all of the A-N curves exhibit a sigmoidal shape. The initial and final portions of the curves exhibit a lower growth rate, while the middle portion of the curves displays a more linear increase at a higher rate. The V-N curves follow the same trend as the A-N curves, so in subsequent analysis, only the edge damage area (A) is used to represent the degree of damage.

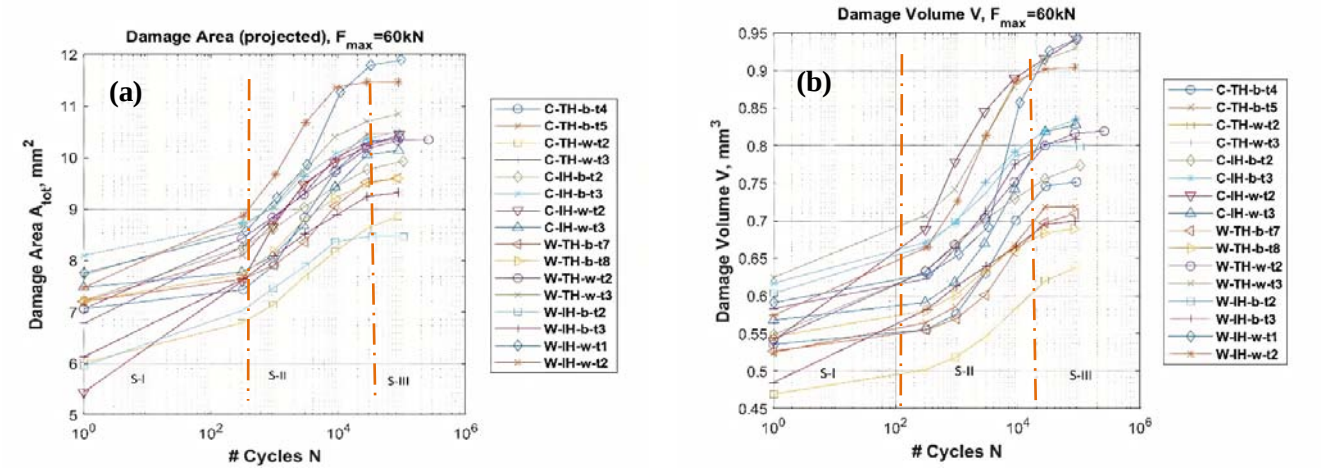


Figure 4: (a) Edge projected damage area vs number of cycles, (b) volume of metal vs number of cycles, showing there are three regimes over tested cycle range

Based on the observed data, we can categorize the A-N curves into three stages of damaging development, namely Stage I (S-I), Stage II (S-II), and Stage III (S-III). These stages are depicted in Figure 4 and are defined as follows: N ~ [1,300] for S-I, N ~(300,30,000) for S-II, and N>30,000 for S-III. In this research, we focus on evaluating the fatigue performance is Stage II (S-II).

e) Hardness Measurement and Microstructure Examination

The hardness of the as-received specimens from various process routes was measured. For each

manufacturing route, a representative metallographic specimen was prepared through standard grinding, polishing, and etching. The microstructures of the specimens were then scanned and photographed using the microscopy.

Figure 5 (a) displays the hardness for each process route and the solid line represents the mean hardness. It can be seen that half of the C-IH-b coupons did not meet the minimum required hardness value of 58 HRC, resulting in the highest static damage area (refer to Table 1). As a general trend, a higher hardness value results in a lower static damage area (Astat). For example, the W-IH-b route shows the lowest static damage area with the highest hardness value. In terms of the standard deviation, which is shown in Figure 5 (b), the top 3 routes with high variation are: (1) C-IH-b, (2) W-IH-b, and (3) C-TH-w. These routes are either from induction hardening or welding, and the larger variations are introduced from manual operation.

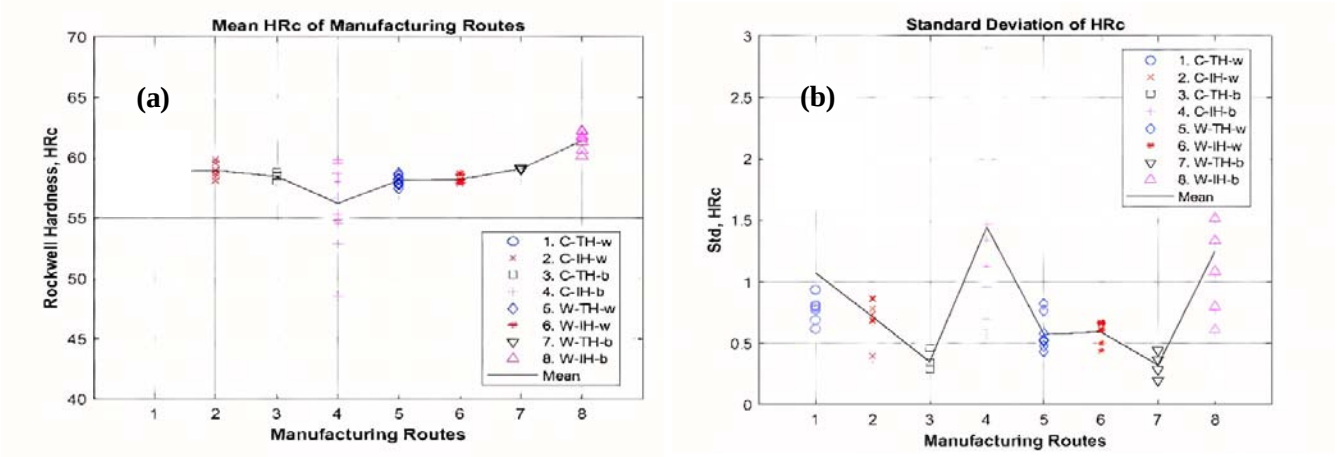
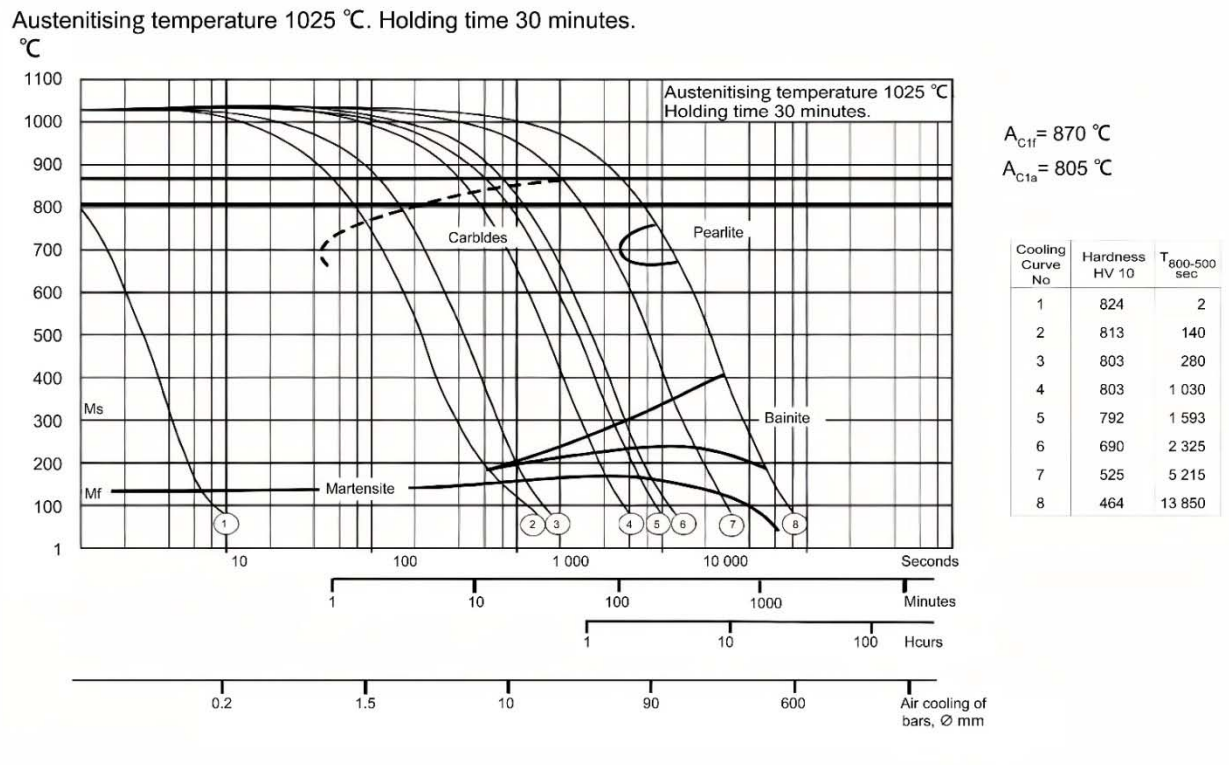


Figure 5: Mean(a) and standard(b) deviation of Rockwell hardness for 8 manufacturing routes. Note that each plotted data point is the mean of 18 measurements (repeats) from one specimen, and about half of these specimens were used for fatigue testing

Based on its chemical composition, the investigated material can be classified as hyper-eutectoid steel [33, 35]. When subjected to equilibrium conditions, heating the material to temperatures ranging from 805-875°C causes the carbide (cementite) to dissolve and transform into austenite. At room temperature, the microstructural phases present may consist of tempered martensite, or a combination of carbide and martensite, bainite, and/or pearlite, depending on the cooling rate depicted in Figure 6. Additionally, the cooling rate has an impact on both the grain size and the size of the phase particles.

The microstructure produced directly influences the static and dynamic characteristics of the material [36]. No further heat treatment was carried out after TIG welding, and therefore, the welded specimens are only meaningful for comparison between the bulk and weld materials as the previous heat treatment history will be overridden by the welding process. Figure 7 shows the microstructures of unrepaired dies manufactured using four different methods without welding, while Figure 8 displays the microstructures of four repaired dies produced using TIG welding. Based on information provided by the material supplier, all eight manufacturing routes will result in tempered martensite with some retained austenite, which is also confirmed by the microstructure images shown in Figure 7 and Figure 8.



Cooling Curve No	Hardness HV 10	$T_{800-500}$ sec
1	824	2
2	813	140
3	803	280
4	803	1 030
5	792	1 593
6	690	2 325
7	525	5 215
8	464	13 850

Figure 6: Continuous cooling transformation (CCT) diagram of CaldieTM [23]

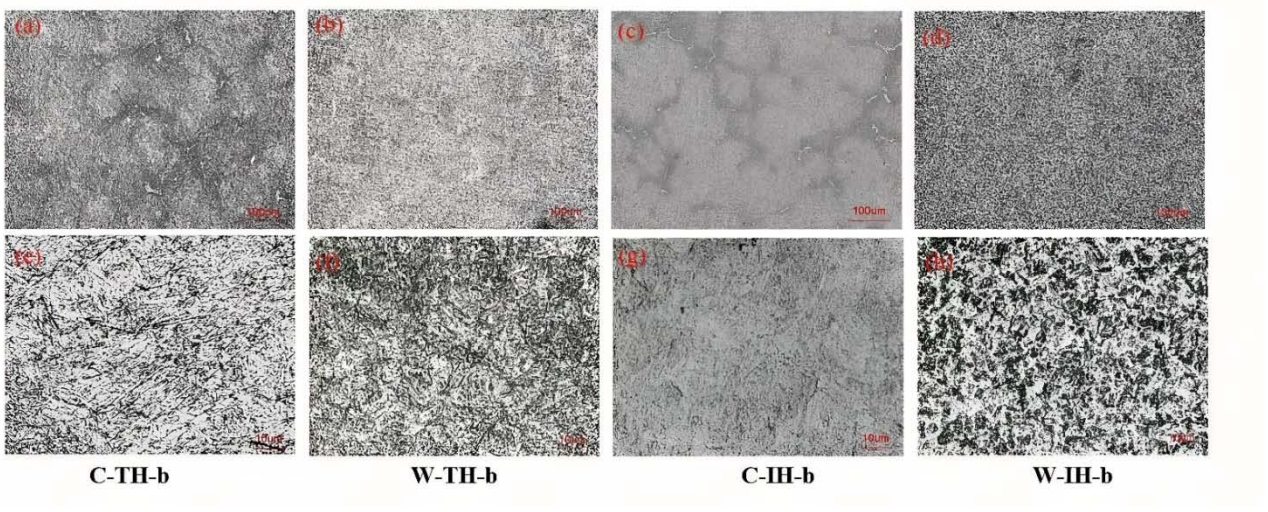


Figure 7: Microstructures of four different kinds of unrepaired dies. For each case two images are given at low (upper) and high (bottom) magnifications, with scale bars at 100μm and 10μm, respectively; C-TH-b: (a) & (e), W-TH-b: (b) & (f), C-IH-b: (c) & (g), W-IH-b: (d) & (h)

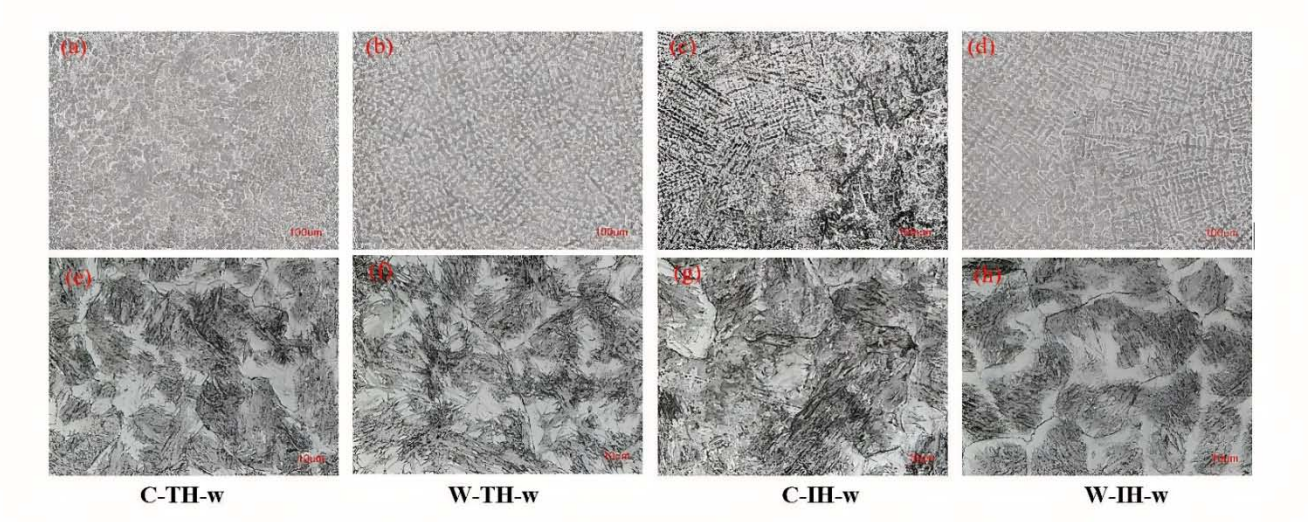


Figure 8: Microstructures of four different kinds of repaired dies by welding. For each case two images are given at low (upper) and high (bottom) magnifications, with scale bars at 100μm and 10μm, respectively; C-TH-w: (a) & (e), W-TH-w: (b) & (f), C-IH-w: (c) & (g), W-IH-w: (d) & (h)

f) A Two-Stage Design of Experiment Method

The DOE is a methodology for systematically applying statistics to experimentation by considering variation due to the experiment replication. In this study, the DOE method is used to compare the effect of competing manufacturing routes on trim die performance -- fatigue degradation (fatigue damage area over time), denoted by $y_{ijkl}(t)$, where i,j,k,l represent material process, heating method, repair status, and replication, respectively, and t denotes the number of cycles. As $y_{ijklt}(t)$ is a time series data that typically have a temporal dependency, the traditional multi-variable based method cannot be directly applied. In this research, we developed a new two-stage statistical model to analyze the fatigue degradation process over different routes.

In stage 1, the time series data $y_{ijkl}(t)$ is modeled by using a parametric model $f(\boldsymbol{\theta};t)$, where $\boldsymbol{\theta}$ is the model parameters and t is the time represented by the number of cycles (for a given frequency); In this research, linear regression is chosen as the parametric model. Specifically, the total edge damage area for this stage can be expressed as follows:

$$y_{ijkl}(t) = A_{tot} = A_{stat} + A_{cyc} = \begin{cases} A_{stat}, & t = 1 \\ A_{stat} + B_2\, log_{10}(t), & t = 300\sim30{,}000 \end{cases} \quad (2)$$

where the two model parameters, A_{stat} and B_2, are used to evaluate and compare the performances of different tests or process routes. Specifically, A_{stat} represents the edge damage under static test when number of cycle $t = 1$, and β represents the slope of the damage evolution curve, or dynamic damage rate. In this research, we focus on regime S-II where the number of cycles $t = 300\sim30{,}000$. The B_2 vs. $log_{10}(t)$ data show a linear relationship in the semi-log plot, which justify the usage the linear regression model.

To calculate and compare the damage severity of the eight process routes, the tested data was grouped for each route (which includes two tests of four specimens each), and the results were plotted in Figure 9 and listed in Table 1.

In Table 1, the power-law fitting error for parameter B_2 is estimated by the p-value, which represents the probability of obtaining a correlation as large as the observed value. A small p-value, such as less than 0.05, indicates that the correlation between the experimental data and the fitted curve is significant. The fitting errors for all routes are below the 5% threshold.

The errors in the data are composed of two parts: (1) material processing/operation error, which is dependent on process route, and (2) mechanical testing/measurement error, which is random over different process route. High error cases are often observed in induction hardening (IH) or in welded (w) specimen, due to the manual operation that introduced higher test-to-test variation and specimen-to-specimen variation. This is evident from the hardness measurement of the as-received cube specimens before fatigue testing, as shown in Figure 5.

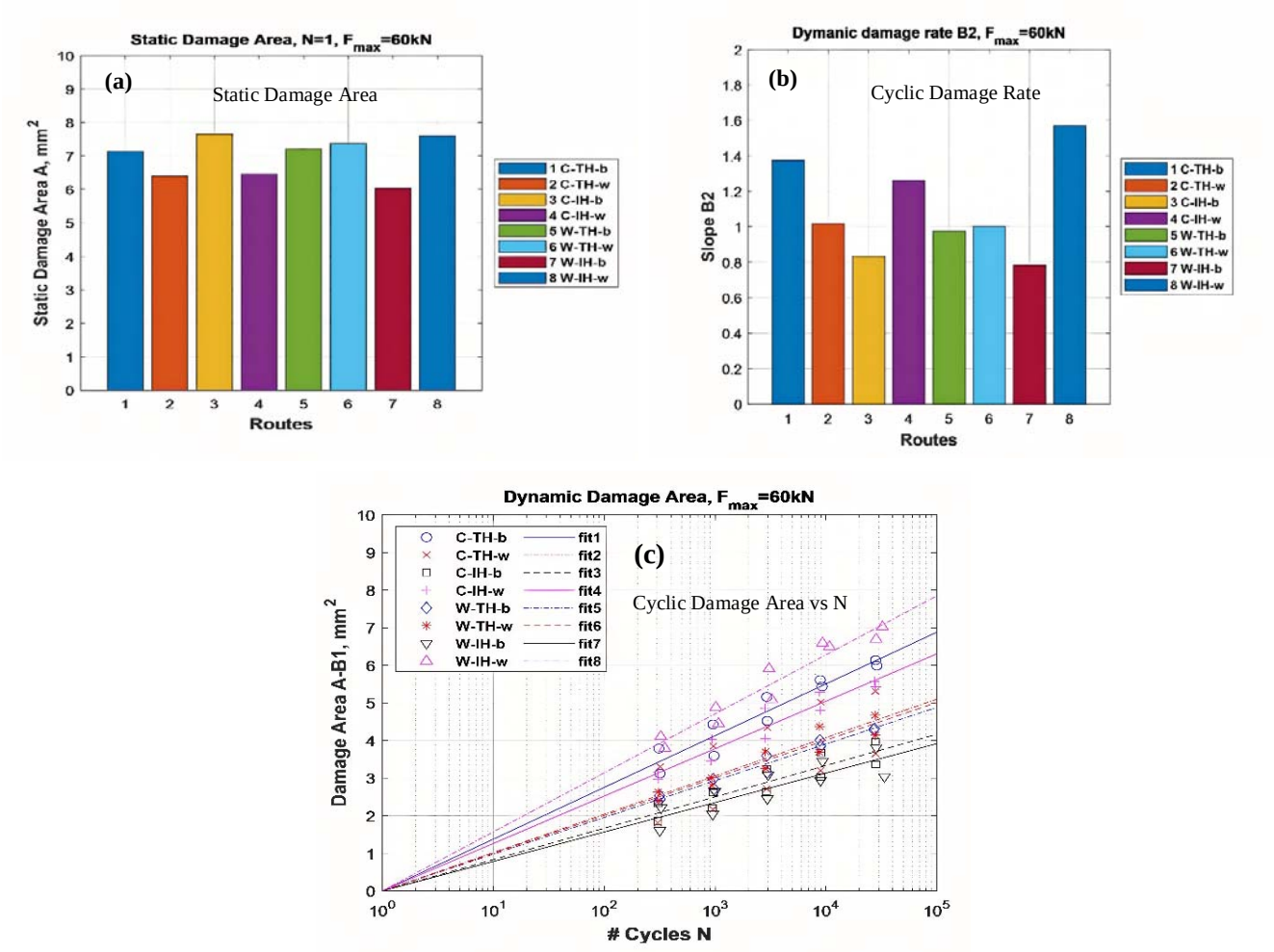


Figure 9: (a) The static projected damage area A_{stat}, (b) the dynamic damage rate B2, and (c) the dynamic damage evolution over cycles (with the fitted slopes given in b), for 8 manufacturing routes tested at F_{max} =60kN

Table 1: Measured damages for each process route with error estimate and ranking (a higher score has a lower rank number)

#	ID	Static		Cyclic			Sum	
		A_{stat},mm²	Score	B_2	p-value	Score	Mean Score	Rank
1	C-TH-b	7.137	5	1.377	1.72E-05	2	3.5	7
2	C-TH-w	6.397	7	1.020	4.30E-02	4	5.5	2
3	C-IH-b	7.663	1	0.833	3.69E-04	7	4.0	5
4	C-IH-w	6.461	6	1.261	1.39E-05	3	4.5	4
5	W-TH-b	7.206	4	0.976	6.66E-07	6	5.0	3
6	W-TH-w	7.385	3	1.003	3.13E-05	5	4.0	5
7	W-IH-b	6.041	8	0.784	1.48E-03	8	8.0	1
8	W-IH-w	7.615	2	1.570	4.9E-06	1	1.5	8

In Stage 2 of the developed DOE method, after time series data is modeled by parameters, $y_{ijkl}(t) = \{A_{stat}, B_2\}$, the fatigue damage for different process routescan be analyzed by DOE methods with three factors (the two input variables and their interaction). However, during the welded repair process, the welded material overlays the base material, and all the workpieces are cooled in the air, eliminating the effects of considered raw material process and heat treating methods. Thus, the traditional DOE method with three factors, e.g., factorial design or fractional factorial designs, cannot be directly applied. The new statistical analysis needs to consider the different repair status individually.

We first consider the scenario when the repair status is for the case of base metal not welded. The effects of material process, heat treating method, and their interaction can be modeled as follows.

$$\boldsymbol{\theta}_h = \mu_h + \alpha_{hi} + \beta_{hj} + (\alpha\beta)_{hij} + \varepsilon_{hijl};\ \ i,j,h = 1,2;\ l = 1 \ldots m; \tag{3}$$

Where index *i,j* is the level of the two input variables α and β for raw material processes and heat treatment, respectively, and h is the two levels of response $\boldsymbol{\theta}.\boldsymbol{\theta}_1 = A_{stat}\ and\ \boldsymbol{\theta}_2 = B_2$; μ_h is the global mean of the response. For the two input variables, their value ranges are normalized to be at two levels at -1 and 1. i.e.,$\alpha_{hi} = -1$ is the raw material process for Cast (C), and $\alpha_{hi} = 1$ for Wrought (W). Similarly, β_{hi} =-1 for Induction heat treated (IH) and $\beta_{hj} = 1$ for (TH); $(\alpha\beta)_{hij}$ is the effect of the interaction of raw material process and heat treatment at levels i and j. In this research, $m = 2$, as *two* replication are implemented for each route. ε_{hijl} is the random error component of the model, which are composed of two parts: (1) material processing/operation error, which is dependent on process route, and (2) mechanical testing/measurement error, which is random over different process route.

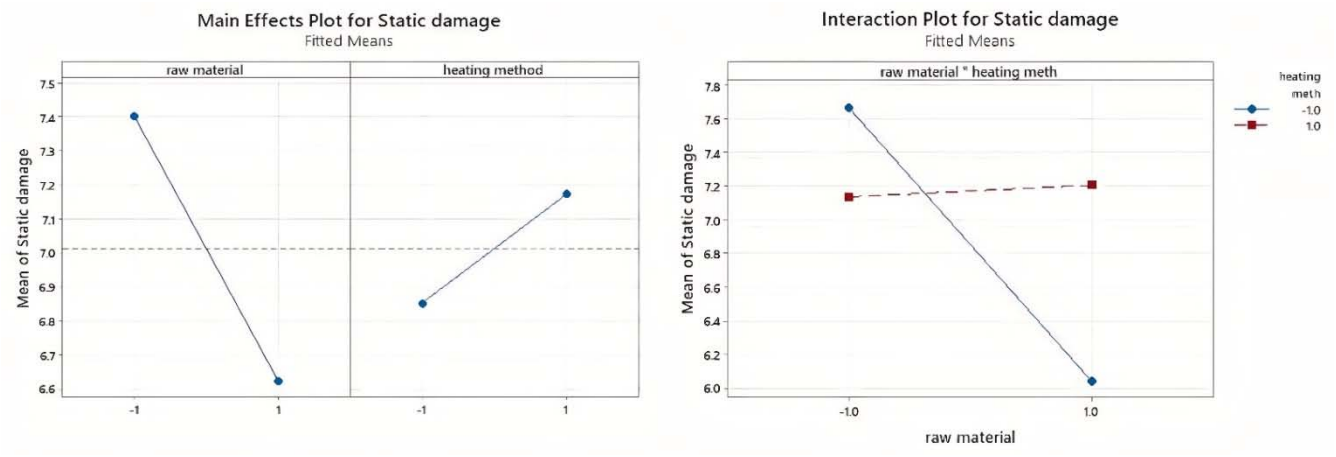
The model is fitted by using the experiment data, and the results are listed in the following Table 2.

Table 2: Summary of the statistical model

	Static damage, A_{stat}				Cyclic damage rate, B_2			
	Estimate	Std. Error	*t*value	P(>|t|)	Estimate	Std. Error	*t*value	P(>|t|)
Raw material process	-0.388	0.113	-3.42	0.027	-0.112	0.0471	-2.38	0.076
heat treatment	0.160	0.113	1.41	0.233	0.184	0.0471	3.91	0.017
raw material process × heat treatment	0.423	0.113	3.72	0.020	-0.089	0.0471	-1.88	0.133

The p-values in Table 2 suggest that both raw material process and heat treatment have a significant impact on static and cyclic damage rates. Specifically, the effects of the raw material process and the 2-way interaction of the raw material process and heat treatment are statistically significant for static damage, as the p-values are smaller than 0.05. While the effects of raw material process and heat treatment are statistically significant for cyclic damage rate. Both models fit the data well, as indicated by their high R-square values of 0.8731 and 0.8597 for static and cyclic damage rates, respectively. These findings provide strong evidence that raw material process and heat treatment are key factors affecting fatigue damage for both static and cyclic tests.

Figure 10 further illustrates the effect of the main factor and 2-way interaction on the static damage. In Figure 10(a), it can be seen that static damage is higher when the raw material process factor is set to the "-" level (*C*) compared to the "+" level (*W*). On the other hand, static damage is lower when the heat treatment factor is set to the "-" level (*IH*) compared to the "+" level (TH), although this effect is not statistically significant. Moreover, Figure 10(b) shows that the combination of raw material process factor C and heat treatment factor IH results in the greatest static damage, while the combination of raw material process factor C and heat treatment factor *TH* results in the lowest static damage.



(a) (b)

Figure 10: Effect of the main factors and factor interaction on the static damage (a) Main effect of raw material process and heating treatment; (b) Interaction effect of raw material process and heating treatment

Figure 11 illustrates the impact of the factors on cyclic damage rate, with only the main factor effects plotted since the interaction effect is not statistically significant. As shown in Figure 11, the cyclic damage rate is observed to be higher, when the raw material process factor is set to the "-" level (C)or the heat treatment factor is set to the "+" level (TH). Figure 12 presents the results of the model checking procedure for both the static damage and cyclic damage rate. As evident from the figure, the model fits the experimental data well.

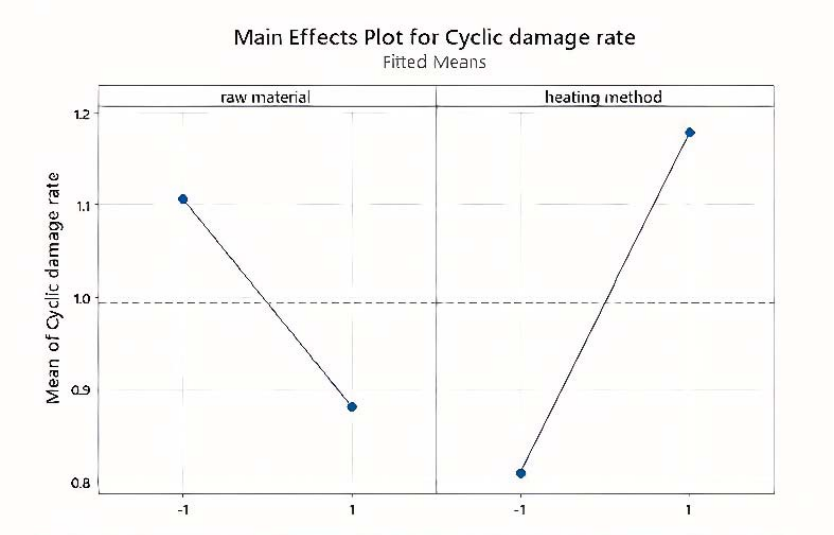


Figure 11: Effect of the main factors and factor interaction on the cyclic damage rate

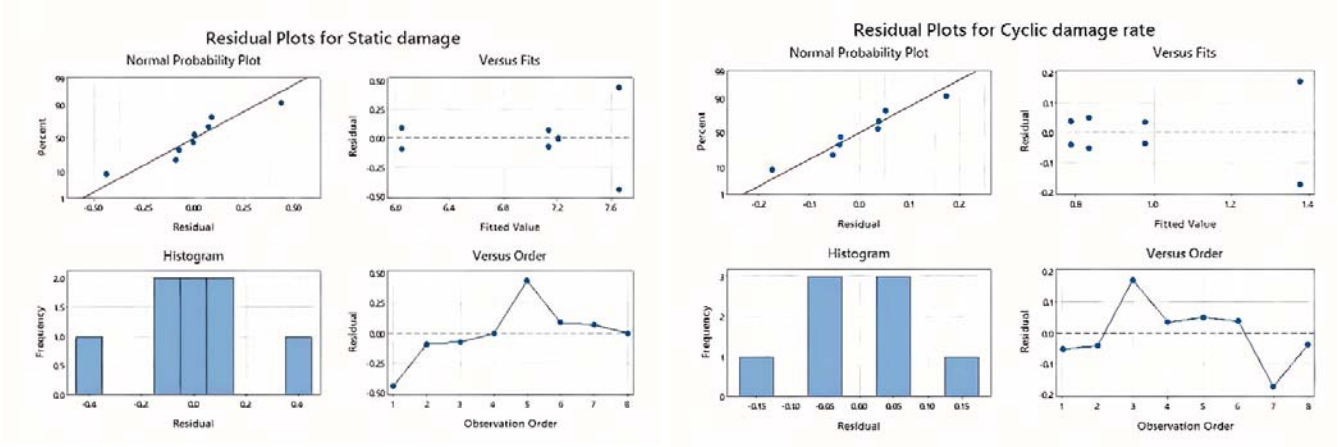


Figure 12: Model checking

In the previous section, the microstructures of the cast and wrought materials, which underwent the same hardening processes, are significantly different. As shown in Figure 7, the cast material has large undissolved eutectic carbides and severe carbon segregation along the grain boundaries of the parent austenite, which are expected to reduce its toughness. On the other hand, the initial coarse dendrite grain structure and large eutectic carbides of the wrought material are broken down by extensive hot plastic deformation, resulting in a refined grain structure and a homogenized distribution of carbon and alloying elements after recrystallization. Additionally, even though both materials may contain similar amounts of martensite after quenching and tempering, the distribution and size of the martensite in the wrought material are much more uniform and smaller than that in the cast material. These two factors explain why the wrought material has a slower dynamic damage rate compared to the cast material.

Furthermore, for TH samples, there are at least two tempering processes according to the recommended heating treatment schedule. This results in a reduction of the retained austenite below 5% [33], which means that the TH sample has significantly less retained austenite compared to the IH sample. Austenite is a soft phase in the matrix, which enhances the material's toughness and slows down fatigue damage. As shown in Figure 7(a) and Figure 7(c), for cast bulk materials, the eutectic carbides located at the initial coarse grain boundaries will not dissolve during the austenization process, The grain size of the parent austenite of C-TH-b and C-IH-b is almost the same under low magnification. However, under high magnification, the martensitic morphology and the amount of retained austenite are clearly different, as seen in Figure 7(e) and Figure 7(g). More lath martensite is generated in C-IH, compared to the needle martensite (or plate martensite) in C-TH. It is well-known that the toughness of lath martensite is better than plate martensite. Therefore, for cast materials, IH results in much better fatigue resistance compared to TH. In addition, for wrought bulk materials, Figure 7(b) and Figure 7(d) show that both heat treatment processes can produce a similar microstructure, i.e., small and uniform tempered martensite with retained austenite. Due to the small starting grain size and homogenized chemical composition in unrepaired wrought dies, IH provides sufficient thermal activation for martensite transformation without coarsening the grain size, unlike TH. Figure 7(h) shows the formation of a cryptocrystalline martensite with a super-fine grain size resulting from the subsequent high cooling rate. As a result, W-IH-b achieved the highest scores in both static and cyclic properties, making it the top-ranked process route among the eight studied in Table 1.

It is also noteworthy that the improved fatigue properties of the IH samples may also be attributed to the pre-hardening process carried out using TH methods. This process increased the original hardness of Caldie from 20 HRc to 36-42 HRc. The tempering curve for Cladie™ is shown in Figure 13, where to obtain 36-42 HRc, the tempering temperature should be around 650°C, which is significantly higher than the standard tempering temperature of 525°C used to achieve 58-62HRc. Hence, this quenching and high-temperature tempering process may provide a more uniform texture for the C-IH-b and W-IH-b samples before induction hardening, which is beneficial for the formation of smaller and more evenly distributed martensite in the matrix. Moreover, high-temperature tempering can cause the participating carbides to grow further, resulting in a larger carbon-depleted area in Cast Caldies, which also explains why more lath martensite is generated in the C-IH samples [37]. Given its crucial role in phase transformation, there seems to be a large scope for improving the heat treatment process.

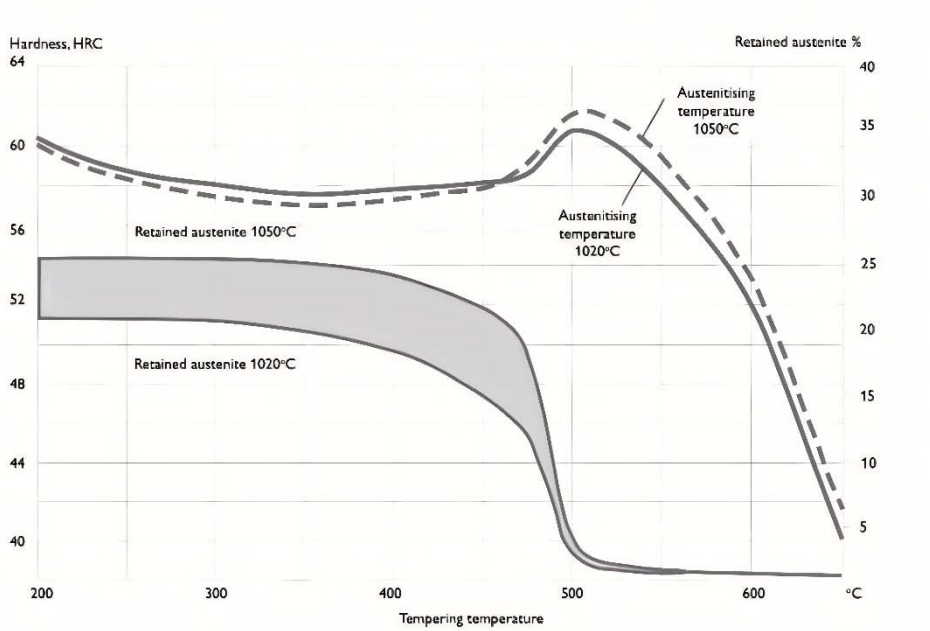


Figure 13: Tempering Graph for Caldie™[33]

Next, we consider the scenario when the repair status is set as (w), i.e. the die edge is welded with Caldie™ filler wires. Under this situation,

$$\boldsymbol{\theta}_h = \xi_h + \tau_{hk}, k = 1 \ldots n; \quad (4)$$

where $h = 1,2. \boldsymbol{\theta}_1 = A_{stat}$ *and* $\boldsymbol{\theta}_2 = B_2$; ξ_h is the mean effect of the response; τ_{hk} is the error term and $n = 4$ as we have four samples.

Tests were conducted to determine the equality of means and variances across different repair statuses for both static damage A_{stat} and cyclic damage rate B_2. The results are presented in Table 3. Since the p-values for the equal mean tests for both static damage and cyclic damage rate are large, we cannot reject the null hypothesis that the means are equal across different repair statuses. Similarly, since the p-values for the equal variance tests for both static damage and cyclic damage rate are large, we cannot reject the null hypothesis that the variances are equal across different repair statuses.

Table 3: Tests for equal mean and variance for different repair status (w v.s.b)

	Static damage, A_{stat}		Cyclic damage rate, B_2	
	F statistics	*p-value*	F statistics	*p-value*
Test for equal mean	0.02	0.90	2.64	0.12
Test for equal variance	0.58	0.46	0.05	0.83

Theoretically, the static damage and cyclic damage rate should be similar for all welded materials, since the welding process is the final procedure and all the workpieces are cooled in the air. However, the results show dramatic variations in response to changes in the substrate metals, which is also consistent with the large variation in the hardness measurement of the welded die.

As seen from Table 1, overall for welded and bulk materials, they have similar static properties, but the welded material has a much higher cyclic damage rate compared to the bulk material. In terms of the individual cases, only in the case of C-TH, the welded die shows a slower accumulation of damage compared to the bulk new die, while in the other three cases, the result is reversed. As observed from the low magnification images in Figure 8(a) through 8(d), all welded samples showed considerable dendrite structures in the matrix, except for C-TH-w, which had very small and uniform grain size. This explains why C-TH-w was ranked second overall in Table 1. The high magnification images, Figures 8(e) through 8(h), reveal the presence of micro-crack defects in all four welded samples that were generated during the welding process. These defects are expected to deteriorate the fatigue resistance of the welded dies. Additionally, manual TIG welding with Caldie wires may also introduce a large heat-affected zone (HAZ), which

further worsens the fatigue properties of the repaired dies.

III. Conclusions and Discussion

In this research, accelerated fatigue testing was performed using a newly designed trim die simulator, with projected edge damage areas being used to quantify cutting-edge damage. Edge damage amounts as a function of the number of cycles were obtained and used to compare and rank the different process routes. a new two-stage statistical model was developed to systematically analyze the effect of different manufacturing routes on fatigue damage path. In addition, microstructures resulting from the various manufacturing routes were also studied, revealing that solidification thermal conditions and heat treatment schedules significantly impact the microstructures produced and subsequent fatigue properties of the trim die. Based on these findings, it can be concluded as follows:

1. Cast material is generally more prone to damage underboth static and cyclic loading compared to wrought metal, because of its more brittle dendritic microstructure and eutectic carbides. This is due to their brittle dendritic microstructure and eutectic carbides. In contrast, wrought metals break down the cast dendrite and primary carbides through hot deformation and recrystallization, resulting in a refined grain structure.
2. The heat treatment history significantly impacts the fatigue performance of tool steel. Overall, the IH heat treatment leads to much better cyclic damage resistance than the TH heat treatment, for both non-welded cast and wrought dies. This could be due to the pre-hardening process and the higher cooling rate, which promotes grain refinement.
3. The welded die edges (with the exception of C-TH) show a higher cyclic damage rate compared to bulk metals in overall comparisons. This can be attributed to the formation of abundant dendrite textures, the heat-affected zone, welding defects, and variations from manual welding operations.
4. The fatigue damage of the trim die over time is a time series data, so the traditional DOE methods are not sufficient to characterize the damage path. To handle this issue, a new two-stage DOE method is developed in this research to describe fatigue damage paths over time. Based on the proposed model, the fatigue damage over time of a new trim die can be predicted.

In the stamping industry, some material processing routes, such as forming and heat treatment, are unavoidable due to industry-wide best practices and time constraints. At times, limitations in material availability also result in suboptimal processing choices. Despite cast material's tendency to be more susceptible to damage compared to conventional wrought bar stock, its design versatility and size capabilities make it a commonly used material in stamping dies. To harden dies, including large cavities and components, various methods such as flame, induction, or through-hardening, are employed in the industry. The choice of hardening method can greatly impact downstream die performance, particularly before other surface applications, such as ion nitride and PVD coatings. It is ideal to control the cooling rate in all hardening processes, whether through optimized quenching mediums or heat retention coverings. Another factor affecting die longevity is its condition. For repair reasons, all stamping dies require subsequent weld overlays in addition to the base material. It is important for die shops to understand crucial factors such as cap and filler weld rod selection, speeds and feeds, and application temperature. Although welds on stamping dies are unavoidable, the material usage can be optimized by using a preferred weld material and minimizing the formation of heat-affected zones.

In this study, the statistical models and analysis are based on fatigue damage information obtained through a pre-processing step using image processing methods. In the future, deep learning models will be developed using deep neural networks, allowing the model and analysis to directly utilize image information. Furthermore, the microstructure information will be quantitatively extracted and incorporated into the statistical learning models and analysis to achieve more accurate damage predictions.

For the purpose of trim die reconditioning, edge welding with high-grade materials followed by rapid cooling can be an effective process route. This can be achieved through the use of an automated welding system. We have tested both MIG welding and laser powder deposition on trim die corners, and found that a portable 3D electrically-driven automated machine for MIG/TIG welding followed by quick cooling, or a special version of a laser additive manufacturing system with a portable diode laser welding unit and powder filler, could be used to achieve superior welding quality. This system eliminates heat-affected zones, refines the microstructure, improves both static and dynamic properties, and strengthens the cutting edge by adding high alloys, making it adaptable to a wide range of base die materials such as cast, wrought, and low-cost base metals. The implementation of such a system will ultimately address concerns regarding trim die performance and sustainability.

Acknowledgement

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Hip Simulator 'Trifemur' Poised for Marathon Tests, can Direcly Guage the Wear-Life Span of Regular Implants and Compare with that of the Dimpled Ball Types

By V. Githaguru

Abstract- Trifemur after augmentation proves as a holistic wear tester, both as ball-on-socket and ball-on-triplate type configuration. Unaccelerated but continuous testing of implants & lubricants just for few months, can characterize their decades long service limited by either wear depth or wear volume. This has to be tested and ascertained, to rank the Trifemur as a standard comparator. As if an island of stability is sighted in the sea of chaos, two pilot experiments confirmed the feasibility of reaching to the practical range of linear wear depth. Those experimental details and results using Trifemur are presented here.

Keywords: *Trifemur, dimpled femur ball, implant life.*

GJRE-A Classification: *LCC: RD 734.T75*

Strictly as per the compliance and regulations of:

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I. Introduction

Trifemur, a patented invention and the simplified three-station wear tester after its realization, successfully tested metallic spherical shells articulating against steel balls of 25mm dia in dry ambient condition as shown in Fig. 1 and Fig. 2[1]. The results of run-in, steady state wear-rate and its dependence on the load as a new finding, are all reported in the author's Doctoral Thesis [1]. The shells are of: Copper, Cast Iron and Bronze. Next the wear-tests of specimen shells under proper lubrication and reaching to the maximum 6 to 10mm linear wear depth had to be ensured. Accordingly, a lubricant container was made with sheet metal, around the shell-holder as shown in Fig. 3. Also, ball-on-triflat wear testing is required for evaluating surface fatigue, special coatings and lubricants. Hence a special octant shaped specimen holder located in a tetrahedral lub-basin was made. Specimen-flat of round discs get laid up as a trifolium on the octant's face snugly, without extra fixtures of any kind as shown in Fig. 3 and Fig. 6. The lubricant of choice can be filled during the experiments.

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Ṙ *Publishing this decade old research due to its growing relevance globally and terming it as "Rubric Report 2023" is explained separately.*

a) Pilot Experiments

i. *Ball-on-socket Test:* With the steel balls of 25mm dia articulating against hemi spherical shells of ABS plastic of 6mm thickness, in distilled water lubricant pool, was conducted for 10 hours duration. Linear wear depth of 4mm was reached and more depth range of ball impinging is just feasible as can be seen in Fig 4a & 4b. This is the nominal depth range of service life mostly, for the hip joint implants which the Trifemur ensured.

ii. *Ball-on-triplate Test:* With steel balls of 25mm dia. articulating against trifolium of teflon discs of 5mm thick and 25mm dia, in the distilled water lubricant pool, was conducted for 10 hours duration. The linear wear depth of 2mm for each disc was noted. The circular wear-scar is sufficient for wear characterization as can be seen in Fig. 5a & 5b. With thicker flat specimens, the impinging ball can reach the trifoliate's vertex. Then the three wear fronts coalaces into a clover shape and keep changing as that of quasi ball-on-socket configuration henceforth.

The wear of steel balls as a counter face is outside the scope of the present experiment. However, the transferred Teflon film onto each ball, as three elliptical patches is noticed. Soft materials of ABS plastic for shells and commercial grade Teflon flat of 5mm thick for discs were deliberately chosen as the tribo pair to reduce the pilot experimental duration for just only 10 hours. Fig 6a & 6b show the worn out discs and transferred film.

b) Characteristic Wear Curves & Life Cycles

Dry Test: The experience gained earlier, while wear testing the metallic dry shells as reported in the Doctoral Thesis [1] of the author is as follows. The typical wear curve is shown in Fig. 7 coasting through the run-in and proceeding considerably into the steady-state wear regime requires about 15 data points. It is about 2 x 10^5 cycles at 1 Hz; which is 9000 minutes, as in the case of ball on socket shell configuration. It is a continual test, unaccelerated one, intermittently stopped for data collection: emanated wear debris quality/quantity.

Lubricated Test: Now, once the data of steady state wear-rate in lubricated condition is obtained and its stability is experimentally confirmed, then the implant specimen wear-life can be estimated by computation and it is a prediction guided by constant wear-rate and limited by the maximum linear wear depth or cumulative wear volume which ever is desired and happen earlier for the tribo pair!.

As for the ball-on-triplate wear test, run-in and steady-state are not distinct at all. The entire wear regime is a non steady state transient regime, and data generation has to be continued till the required wear depth is reached.

Implant Test: Clinical ready hip-joint implants could be put to marathon wear tests, say 5 x 10^7 cycles and beyond, to find out their run-in wear, steady state wear-rate and the resulting wear debris types, continually at 1 Hz level, of unaccelerated operation. Experiments can proceed through the multimillion cycles of the life span, accurate to the last cycle, reaching either the permitted maximum linear wear depth or cumulative wear volume whichever is happening first. Thus, the wear-life determined is the practical gauging approach using Trifemur.

c) Intended Experiments & Protocol

i. Lubricant top-up, change over, recirculation and wear debris collection etc shall be as per the prevailing norms.
ii. Retrofitting of the clinical ready implants needs rectification of the kink of the femur shaft to suit the Trifemur simulator. Special components are needed for the fitment.
iii. Wear test results of each of the three stations can be retained as individual data generated by the experimentation.
iv. Motorised pendulum at 1 Hz level as the actuator and minimalist mechanism of mimicking human walking, using Trifemur, is the twin strengths of this unaccelerated wear test, by a harmonically driven, linearly damped, oscillator.
v. The total number of cycles from the start to reach the tertiary wear regime is termed "Characteristic wear curve", life is limited by wear depth or wear volume.
vi. Dimpling of the ball for better lubrication was suggested by the author first in [2] and then referred in [1] which has been proved effective by Arkansas university, U.S.A [4].

Description of Figures:

Fig. 1. Trifumur a patented invention: Wear tester in the front & pendulum actuator in the behind [3].

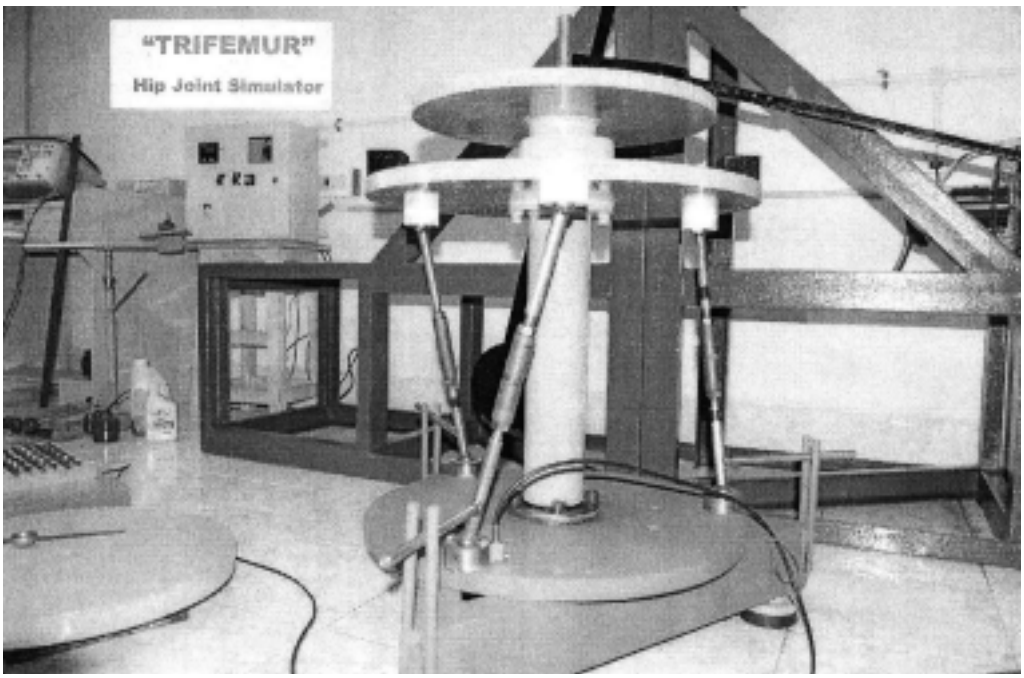
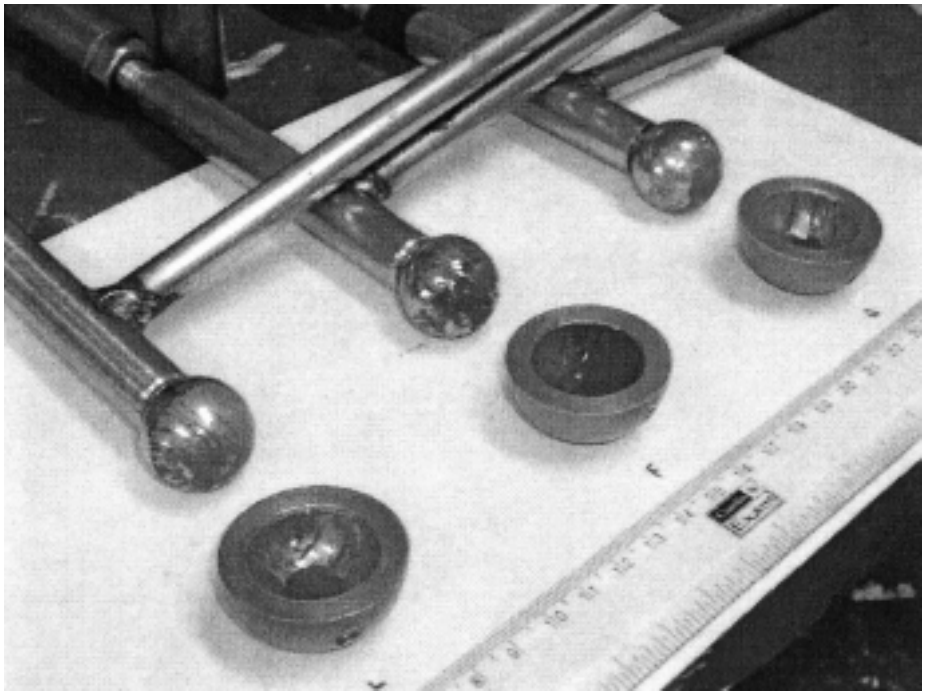


Fig. 1: Close up view of three femurs with A.E sensor on front-socket

Fig. 2. Set of femur balls & copper metallic shells: 25mm dia and 6mm thick.



[These above two photos are taken from the Doctoral Thesis of the author]. [1]

Fig. 2: Copper shells and stainless steel ball showing wear debris, track and transferred film

Fig. 3. Specimen holders & lubricant containers: cylindrical for shells, in the front row; octant for circular discs, in the rear row.

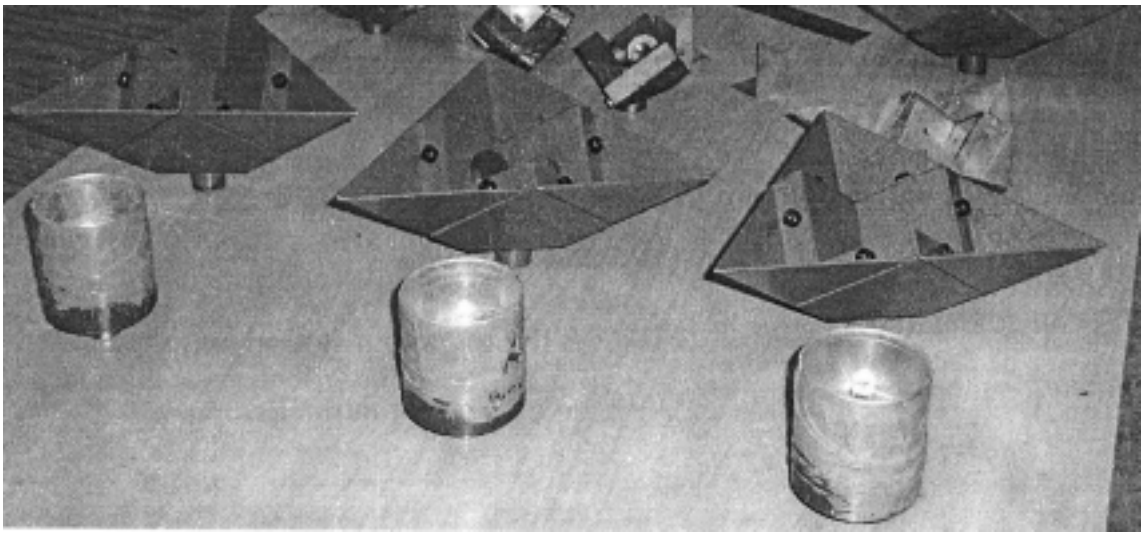


Fig. 3: Specimen holders & lubricant containers
Front row: Cylintrical shape Rear row: Octant shape

Fig. 4a. Close-up at a wear station: Ball-on-socket; ABS plastic shell in distilled water pool lubricant against steel ball.
Fig. 4b. Set of three shells simultaneously tested; worn out shells after washing.

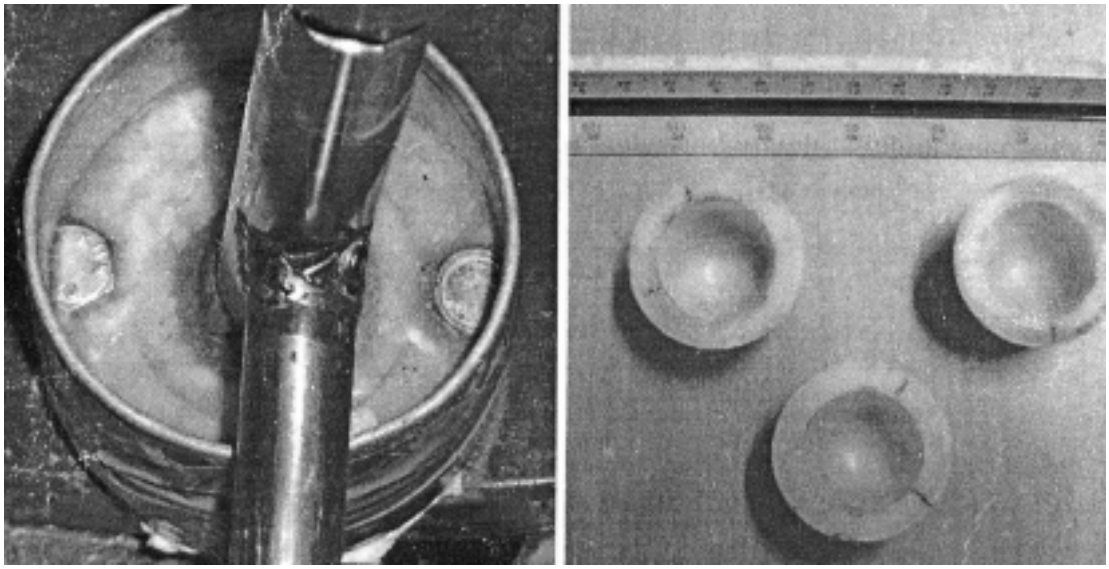


Fig. 4a: Ball-on-soket wear test Fig. 4b. ABS plastic specimen shells Water as lubricant worn out and washed

Fig. 5a. Close-up at wear station: ball-on-triplates; Trifollium of teflon discs in the water lubricant basin.
Fig. 5b. Set of nine specimen discs simultaneously tested, worn out discs after washing.

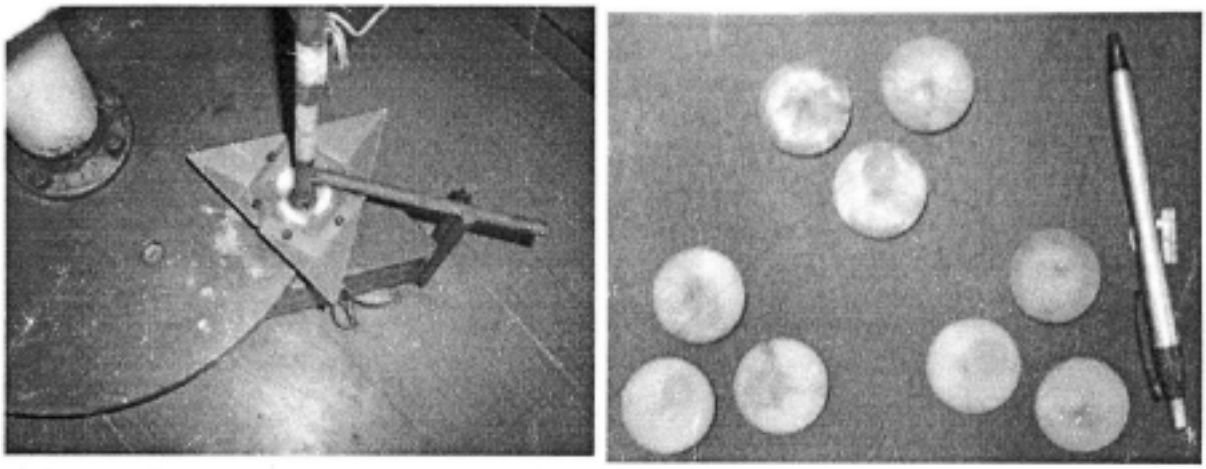
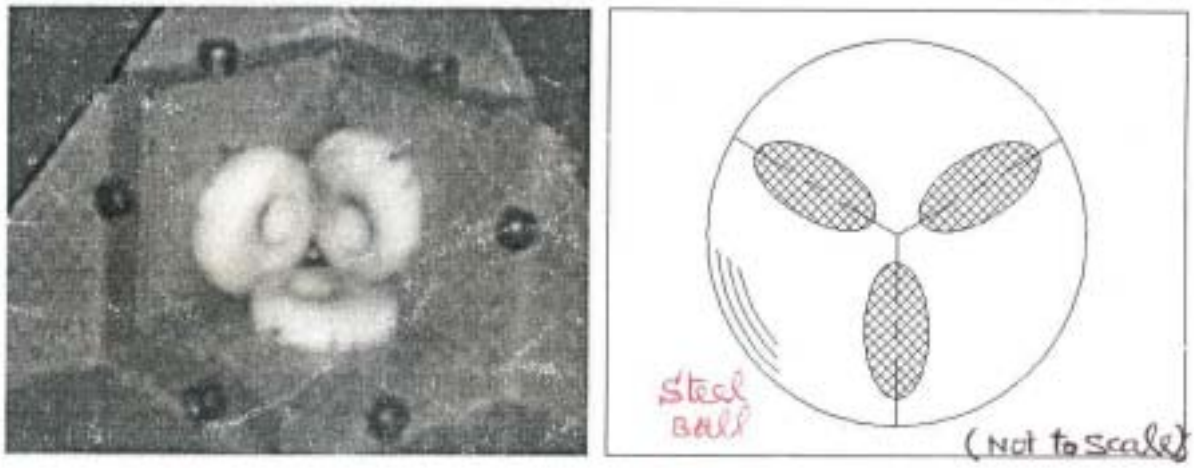


Fig. 5a: Ball-on-triflats test Fig. 5b. Set of nine discs as With water as lubricant test specimen / ABS plastic

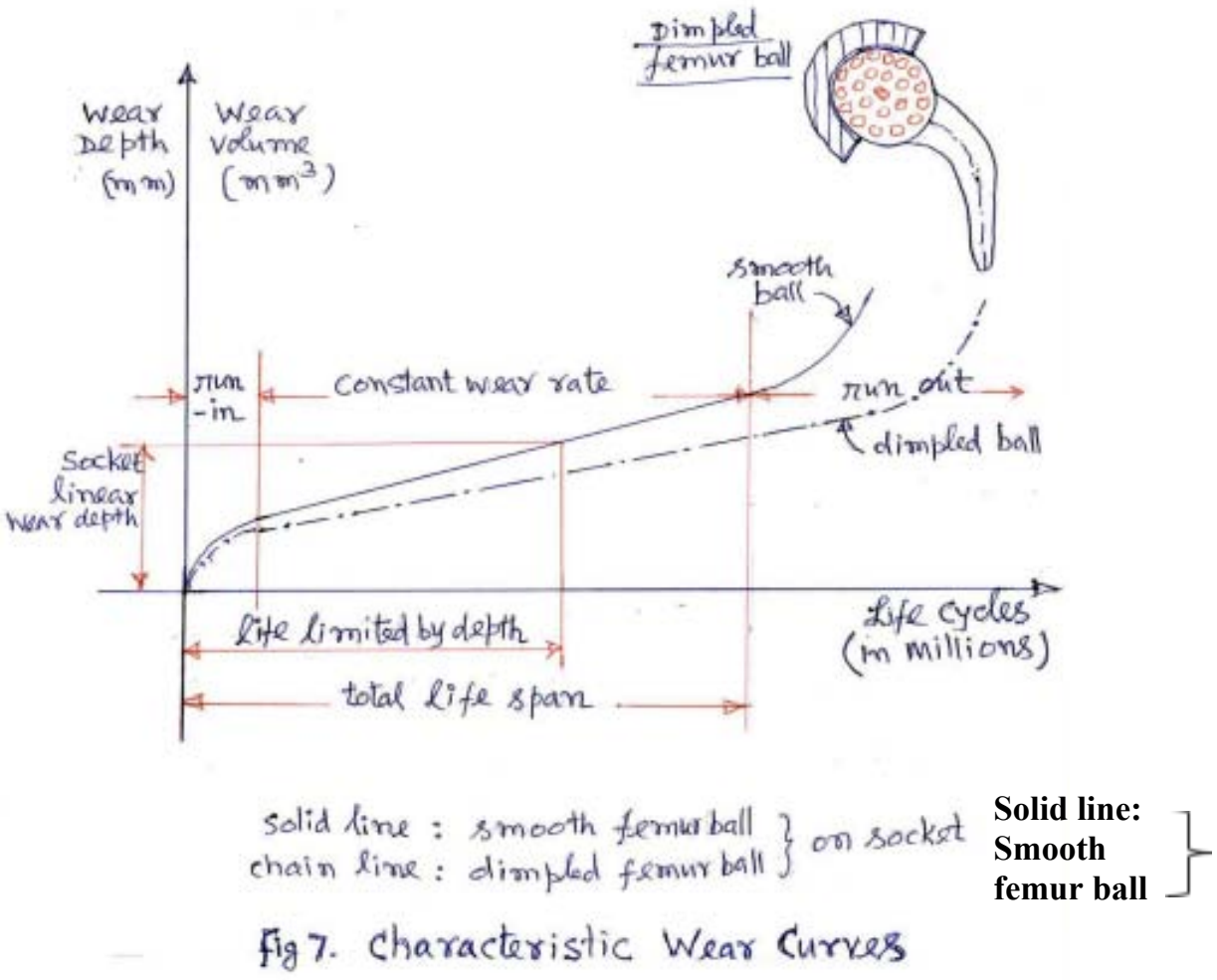
Fig. 6a. Trifoliate specimen discs with circular wear scars, at a wear station, after washing.
Fig. 6b. Transferred Teflon film on to a steal ball, as conjugate elliptical patches from the wearing discs.



(Note: Fig 1 and Fig 2 are taken from the Doctoral Thesis [1]

Fig. 6a: Circular wear scars: Fig. 6b. Elliptical Transferred film Worn ABS discs after washing ABS plastic

Fig. 7 Characteristic wear curve / Dimpled femur ball.



Chain line: dimpled femur ball on socket

Fig. 7: Characteristic Wear Curves

II. Conclusion

Comparative grading of prosthetic implants on the basis of constant wear-rate and resulting wear debris types, for over decades equivalent of gait cycles, (touching up to the tertiary wear region) forms an impressive catalogue, like the Periodic Table for the physical elements. A Standard Comparator and unaccelerated testing makes the wear assessment more realistic, and hence the grading process of implants / biomaterials / and coating becomes a practically useful catalogue, with details of wear life span.

The dimpled ball type bettering in lubrication might be the prosthetic best design with functional ease due to least friction & wear; which is already confirmed by the recent study [4]. Unaccelerated testing will further perfect the art and science of wear testing of hip joint prosthetic implants.

Like Charpy and Izod tests for fracture mechanics, Trifemur uses the pendulum actuator for wear testing, essentially a harmonically driven, linearly damped, mechanical oscillator. Biased merits of products, obtained on varied tests, mostly in the accelerated conditions, can be remedied only by a common comparator, unaccelerated test standardized for that purpose only. Pursuit of such a goal is in the domain of Accademia and other professional Testing Authorities.

Note on Author's Name

Githaguru and Geethaguru both refer to the same author; phonetic identity triggers the variant spelling.

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2. Indo-Japan conference proceedings on: Damage Tolerant Design and Materials, held at 1.1.T Madras, India (2004) – pp294. Dimpling of prosthetic ball is first referred in this proceeding, then in the Doctoral Thesis of the author.
3. "Trifemur" – Invention by the author, a new hip-joint simulator for wear study. Indian Patent No: 198349 (2003). Now, it is free for all; some have already pursued it academically. Details of the device Trifemur is available as the Thesis in the public domain.
4. Arkansas university USA report Jan.(2022) and the Journal of Func. Mater (2021)12(2)38 refers to the "the effect of dimples on the femoral head on wear…." and its benefit of the wear reduction.

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Eco-friendly Road Cleaning Machine

By Shivam Deokar, Arpit Gaikwad, Gaurav Bhoge & Om Dange

Abstract- This paper is related to design and development of most effective machine that is manually operated mechanical pollution free road cleaner. The Road cleaner is used to keep our mother earth clean. So that we feel fresh while walking on streets. Generally, in era of modern technology, different devices such as electric motors, diesel engines and robots are being used to clean floor, road. These methods make much pollution, maintenance and very tough to carry out. The main objective of this paper is to spread this idea of our prototype road cleaner to each one which aims to. Hence, the present work is aimed to design and develop a manually operated road cleaning machine which is eco-friendly, cost effective, portable and less maintenance. Cleaning has become a basic need for all human beings and it is unavoidable in our daily routine process. The conventional floor/road cleaning machine is most widely used in railway stations, airports, hospitals, Bus stands, colleges etc. also this machine needs electrical energy for its operation. It is not user friendly as well as ecofriendly. In summer time there is power crisis and most of the floor/roads cleaning machines are not used effectively due to this problem particularly. In our project we are using easily available materials with low cost. It is the better alternative for conventional machine. Hence this project is very useful in our day to day life.

Keywords: *eco-friendly, floor clean, sweeper roller, effortless, manually operated, eco-friendly, human powered etc.*

GJRE-A Classification: *FOR Code: 0905*

Strictly as per the compliance and regulations of:

Eco-friendly Road Cleaning Machine

Shivam Deokar [α], Arpit Gaikwad [σ], Gaurav Bhoge [ρ] & Om Dange [ω]

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Keywords: eco-friendly, floor clean, sweeper roller, effortless, manually operated, eco-friendly, human powered etc.

I. Introduction

Cleaning machine is very much useful in cleaning around us like road, ground our colleges campus, outside ground and public place etc. In modern days interior as well as outside cleaning are becoming an important role in our life.

Cleaning of waste is a very important one for our health and reduces the man power requirement. Many of road cleaning machines are available but we had developed a machine which is very simple in construction and easy to operate. Anybody can operate this machine easily. Hence it is very useful in cleaning the cricket ground, any large area space.

II. Literature Survey

1. Manual cleaning is time consuming so, by using manually operated road cleaning machine we can save time.
2. It was seen from literature survey that cleaning is less effective where the road seems to be very rough and damage.
3. Maintenance of machine is less and it is easy to control and clean.
4. Vacuum, Brushes, Vipers, Mobs, Scrubbers, etc. from these can be use to make the design economical and conventional.
5. Further modification in the vehicle can be made automated using sensors and electrical circuits.
6. This can be modified according to the Indian road conditions and where it needs to be used.

a) *Working Principle*

Eco friendly road cleaning machine is an advanced type of machine used for the roads or streets. Eco friendly road cleaning machine we are making without using any power supply, fuels and engines. The machine is run by a human effort or a man power. The system is fixed with pair of wheels which are connected with the help of shaft. The shaft makes the wheels connected to one and other.

The wheels are moved for a desired position with a help of manual force which can handle is provided to move. The handle can be adjusted for a required height. A chain drive is connected to the wheels. The chain is moved according to the wheel. The brush moving opposite direction of the wheels move and the brush brooms the waste present on the road also it dumps the waste into the waste collecting box. The waste collecting box is removed to dump the waste into desired places.

b) *Specifications*

Specification of Chassis

Length	780 mm
Breadth	370 mm
Height	
Thickness	
Mass	

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Author ω: Sanjivani K. B. P. Polytechnic.
e-mail: krushnadange735@gmail.com

Specification of wheel

Diameter of the Rear wheel	380 mm
Diameter of the Front wheel	200 mm
Number of the wheel	4

c) Problem Identification

During the manual cleaning operation some dust and dirt particle may remain on the floor and due to the action of air. The dirt and dust particle transfer from one surface to another surface which create the problems during cleaning which tends to increase manual effort. Due to which desire cleaning of the surface is not gain and because of that it takes more time.

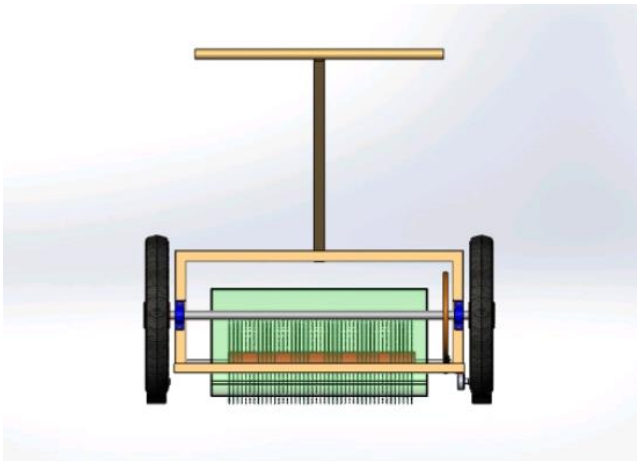
d) Objectives

1. To develop a machine that helps in easy and quick cleaning.
2. To provide the alternative method for road cleaning.
3. To reduce human efforts.
4. To save the time.
5. To reduce the cost anyone can use and easy to operate.

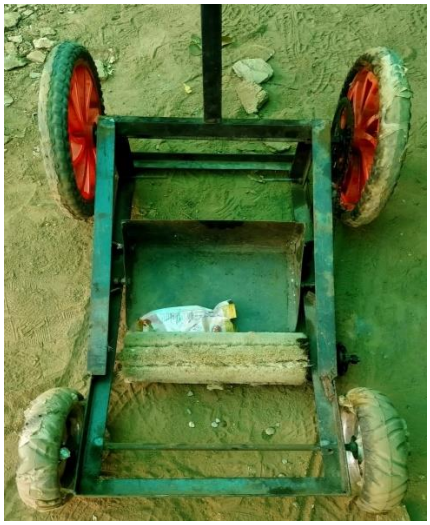
e) Design

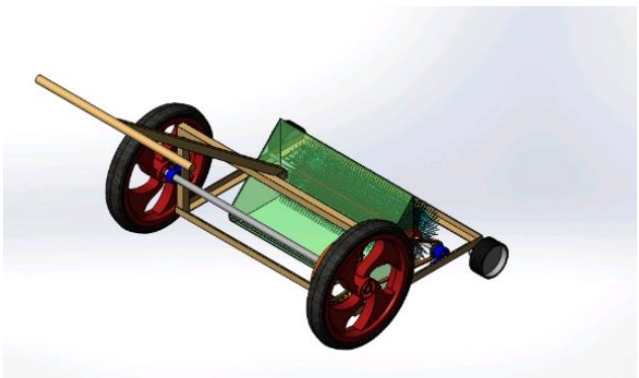
In the design of the road cleaning machine is very compact as compare to other cleaning machine are available in the market but has the attractive design and high durability and cheap cost as compare to other road cleaning machine.

3D VIEWS

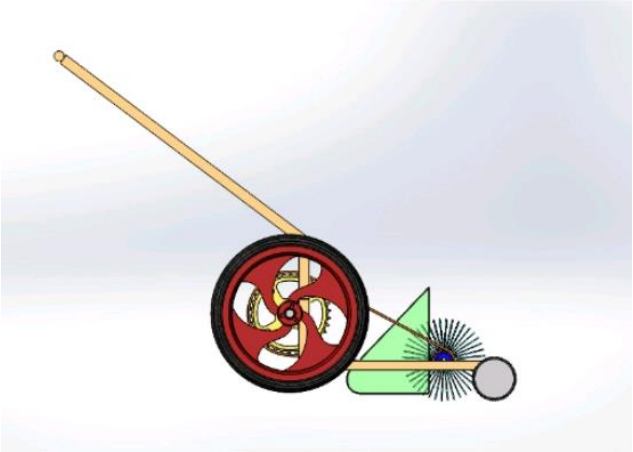


1. FRONT VIEW





2. TOP VIWE



3. SIDE VIWE

f) Components used in Road Cleaner

1. Wheels
2. Shaft
3. Bearings
4. Brush
5. Chain
6. Chain Sprocket
7. Frame

g) Applications

Around Hospitals- Cleaning machines are used in hospitals for cleaning in order to obtain hygienic surface.
Roads- To maintain the desired cleaning surface finish.
Colleges- It is mainly used to clean the dust which is collected on the surface in campus.

h) Future Modification

1. *Plastic Brush can be changed to coir brush*

The plastic brush which is not long lasting can be avoided by using a coir brush which is more efficient for the machine.

III. Conclusion

The manually operated eco-friendly road cleaner is successfully designed, analyzed and fabricated. This project works and implements the manually operated ecofriendly road cleaner for road cleaning that reduces the cost, human efforts as well as time. It is the best alternative for automated road cleaning machine during power crisis. It is found that the existing road cleaning machines uses petrol and diesel. It can cause pollution and also the vibration produced in the machine causes noise pollution. While manual cleaning may cause healthy problem as the person directly comes in contact with dust. Also, the shoulder problem due to continuously sweeping occurs.

A manually operated eco-friendly road cleaner is an alternative concept for avoiding such problems. The manually operated eco-friendly road cleaner can work very efficiently with respect to covering area, time and cost of road cleaning process compared with the existing machineries. Also it is economical. It was seen while testing of machine, that the cleaning is less effective where the road seems to be very rough and damaged. It can provide job to the uneducated person who is in need for such jobs as human energy is needed to drive the machine.

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Tilt & Swivel Vertical Axis Wind Turbine for High Speed Regions on or Off Shore. Model Rotor(s) Experiments Lead as Instructive Scaffold to the Prototype

By V. Githaguru

Abstract- To harness high velocity and fluctuating wind, this new tilt & swivel type vertical axis rotor, as an original idea is investigated. If the conventional anchoring of its top end with guy wires to the ground is simply done away with, the rotor axle becomes a cantilever; requires it to be more rigid, strong and hence heavy. Instead, the lower end of the axle is modified with fulcrum and the rotor is kept upright with the counterweights. Hence the whole balanced assembly of rotor and generator located on opposite ends, can easily tilt about the turnnion, in tune with the wind speed. Counter weight to the rotor can include additional dead weights, along with the generator and gear train. By automatic tilting, the rotor can work through and up to higher cut-out wind speed. Change of wind direction causes the axle to swivel and align for the continued smooth rotor operation. Hence both the tilt and swivel freedom of the vertical axle/axis, renders a complete new design of the wind turbine for high speed regions up to 50 m/s.

Keywords: tilt rotor on or off shore/nonlinear dynamical system/kovalvaskaya top-alike.

GJRE-A Classification: LCC: TJ 828.T55

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Tilt & Swivel Vertical Axis Wind Turbine for High Speed Regions on or Off Shore. Model Rotor(s) Experiments Lead as Instructive Scaffold to the Prototype

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Heralding of this new design and the realization of its prototype is the outcome of this experimental study presented herewith. In the offshore installation, if the generator and counter weight assembly is to operate under water, then the buoyancy and fluid damping effects merit consideration. In essence, let the tons of steel, wood and all that, harness the high wind in such ease and grace; appearing as if the daffodils toss and turn in the breeze!

Keywords: tilt rotor on or off shore/nonlinear dynamical system/kovalvaskaya top-alike.

I. Introduction

Horizontal Axis wind Turbines (HAWT) have been popular for large scale power generation right from the beginning. Favourable turbulence intensity and higher wind velocities over the sea, encourages offshore wind farms as well [1], [4]. However, several practical issues such as wing production of airfoil blade type, logistic and assembling difficulties should also be addressed along with the impact on environment and economy [1]. Since the stiffness is not increased proportionately, as the wind turbines grow in size, the big structures become severely dynamical sensitive. Nonlinear systems may experience almost periodic and even chaotic response[1]. The cantilevered blades with its considerable tip displacements, sometimes fouling against the tower and the nearly solid disc-like high speed rotors taking head on the high wind as thrust load on tower, are the major vulnerabilities of the HAWT. Particularly the blade hitting the tower is the notorious self destruction. And due to the heavy wake rotation issues, the spacing between the turbines has to be more, resulting in larger farm area for the same power capacity[1].

In the aforesaid (HAWT) uncomfortable background, the vertical Axis Wind Turbine (VAWT) is considered as an alternate candidate especially in the highwind conditions, of course with crucial design changes. It will not certainly be as fast and fiercely efficient as the HAWT; it need not! But with its moderate speed, medium efficiency and rigidly closed shell-like rotor geometry, it can maneuver through the torrential wind currents, safely and easily!. Also the present design strategy can lend the rotor to rock and roll in the turbulent wind and find its own stable rhythm, to sustain and operate continuously[2]. With minimal effort of installation and maintenance, also by working in the high wind for a long duration, Tilt & Swivel type turbine can become a winner in its own right. As for its safety beyond the cut-out wind speed, the rotor may degenerate into either an idle spinner saving the blades by centrifugal stiffening, or can get stopped by brake and become just a drag chute in the wind current. Cantilever blades accidently dashing against the tower just does not exist here at all! Also the blades of the present turbine is of symmetric airfoil; hence economical in the case of any replacement, if it arises.

a) *Physical Experiments, An Overview: Exp (1) Mini Rotor(s) Spin, Tilt and Oscillate*

Mini model rotors of Savonius, Darrieus and Gyromill types, of average 0.23m^2 size and about 3 kg mass are chosen for the trials. They are cantilever axle supported, with pivot and collar bearing rotors, freely

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Ṙ *Publishing of this research (a decade old) due to its growing relevance globally and hence terming it as "Rubric report 2023" is explained as an attachment.*

spinning and orbitally oscillating "top-alikes" in the horizontal air flow. The vertical axis of the rotor (12mm dia steel rod of 1.5m length) with its free top-end, is able to rock over the horizontal fulcrum-bar, located at the lower end. The tilt angle of the rotor is proportional to the wind velocity; apart from the tilt, it also oscillates orbitally with a cone angle. Model rotor is kept upright with suitable counter weight at the opposite end of the axle, it also governs the tilt angle along with the wind velocity. The counter weight is about 5 kg dead weight. The turnnion rolls in two simple caller bearings mounted on the high pedestal structure. An electric fan blower is the source of wind flow, locating the models at desired wind flow potential depends directly proportional to its distance from the fan. For each rotor, after it has been self-started or kick-started and reached a steady state, the following data are noted down. The tilt angle of the axle from the vertical, rotors spin rate in r.p.m and the concomitant orbital oscillation rate in c.p.m. The oscillation is just an artifact of projecting the three dimensional trajectory onto the two dimensional visual plane. This experiment was repeated for different orientation of the fulcrum-bar. That is 0, 90 and 45 degrees w.r.t. the horizontal wind direction. As expected, the 90 degree position allows the rotors to gain maximum tilt angle and settle in there, for smooth operations with minimum vibration. The twin needs of the axle's tilt as well as swivel freedom became evident.

b) Exp(2) Tilting Vertical Axis Rotors on Load Test

Next, two bigger rotors of cantilevered–sleeve types: one Gyromill type and the other modified Darrius type were fabricated and tested in the open air flow field. Electric fan blower is the source of flow, small dynamo meant for bicycle was the token load on the rotor. Both the rotors demonstrated satisfactorily; they are fully tiltable vertical axis types, sans swivel freedom.

c) Exp(3) Swivel Plus Tilting Rotor on Load Test

Finally, the turbine-to-be was provided with the swivel bearing as well. The fulcrum-bar swivels with support-wheels which were directly mounted and guided on a circular rail, integral with the pedestal structure. Modified Durries type of medium size rotor was preferred of all the three rotor types. This specially fabricated rotor had its vertical axle changed into a rotating shaft, to check the rotor's behavior. During performance, the tilt rotor aligning automatically to the changing wind direction was witnessed; hence the need for swiveling stands vindicated. In this experiment also, the electric fan blower is the flow source and the bicycle dynamo acted as the token load on the rotor.

II. Results and Analysis

a) Tilting Mini Rotors on Spinning Spree!

Figures 2.5/pp12, 2.7/pp14 and 2.9/pp16 of the guided project [3] are the photos of the tilt type vertical axis mini rotors. These three model rotors were tested one at a time, positioned at 200 cms from the fan blower, in an open air flow of 10 m/s velocity. Figures 2.10/pp 17, and 2.27 & 2.28/pp 32, of the project [3] show the experimental set-up and the tilting angle of rotor axle (ψ) for various fulcrum positions (θ) in degrees. Figures 4.2 and 4.3/pp 40 give (ψ Vs θ) and (ψ Vs λ) T.SR –Tip speed ratio relations graphically, for all the rotors [3]. Due to no load, the rotors were on the spinning spree.

Taking as an example for Darrieus rotor: as the fulcrum orientation 'θ' changes from 0 to 90 degrees, the tilt angle of the axis from the vertical increases from 10 to 39 degrees. Spin rate of rotor drops from 265 rpm to 218 rpm – down by 20% but the axle orbital oscillation goes up from 50 cpm to 99 cpm – up by 200%. Spin rate and orbital oscillation rate are universally related. This trend continued for all the three rotors. Rotational and orbital kinetic energy share is such that the whirling axle trajectory is comfortable with least action.

A point to note is that, the (ψ) minimum of 10 degree is actually not the tilt of the axle; rather it is the cone angle of its whirling nutation. All the rotors prefer to gain maximum tilt possible, hence yearn for swiveling also. Orbital oscillation seemed either forward whirl or backward whirl, and also either periodic or chaotic. The Savonius rotor showed the least tip-speed ratio, of all the types of rotors tested.

b) Tilt only type Regular Rotor(s) on Load

Bigger Rotors: Darrieus (170cm x 100cm) with wooden core with FRP skin symmetric airfoil blades and Giromill (170 cm x 86cm) with symmetric airfoil blades of mild sheet, were fabricated. Both are cantilever supported, with pivot bearing and sleeve type rotors. The sleeve acts as the torque-tube and the blades are attached directly to it. Bicycle dynamo was to be the token load on the rotor. Photos in page 55 and page 56 of the guided project [5] show both the rotors, the square shaped pedestal structure of steel, dynamo, the gear wheel, and the fan blower in the far behind. Fulcrum round bar is positioned snugly and diagonally on to the square top of the pedestal structure. When the spinning rotor tended to tilt due to the wind thrust, as a gyroscopic reaction, the fulcrum-bar was thumping down one end and lifting up the other end alternatively. Flip-flopping the heavy rotor as if tossing a doll, was a wonderful phenomenon to watch and consolidate the learning of gyroscope in practical application. It reminded rotors for high wind up to 50 m/s [4] and their complex dynamics.

Graphs in page 44 and page 45 of the guided project [5] indicate the rotor(s) spin rate for three flow potentials with and without load. Darrieus rotor being bigger, both by size and inertia, its no-load steady state spin rate shows greater values of 100 to 80 rpm, whereas the Giromill shows values of 90 to 40 rpm.

Upon applying the load, spin rates of both rotors precipitously decline to nearly one fourth of their no-load values. During operation, both the rotors maintained upright position; with the axle oscillating cone angle was about 15 degrees. Graphs in page 47 and page 49 of the report [5] show the output voltage as the quality marker of the rotor performance; (that of the future turbine-to-be) which was satisfactory with about 12 to 16 volt.

c) Tilt & Swivel Darruious Rotor's Performance

Figure 5/pp 10 of the guided project [6] shows the tilt plus swivel type vertical axis rotor set-up as a precursor to the new wind turbine. The fan blower, positioned in the far behind is visible. This medium sized, modified, Darrieus type is (67cm x 40cm) of two-bladed wooden rotor and with its steel vertical shaft weighing about 8 kg. It is kept up right by the counterbalanced dead weights of 20 kg, positioned below the fulcrum shaft. Figure 7/pp13 shows the details of swivel-base with circular-rail, and the guided support wheels of the fulcrum shaft. The rotor's token loading using the bicycle dynamo is also indicated. A brightly glowing 16 volt DC bulb is the indicator of performance. One crucial change is, the vertical axle has been changed to rotating shaft and fitted with two ball bearings to improve the spin rate of rotor. The top-end of the rotor continues with the pivot bearing, but the lower end in integrally fixed to the shalt by a base clamp plate.

The rotor is experimented for three flow potentials. Maximum r.p.m of 250 was reached on no-load. The data are presented as: (i) performance with load (ii) automatic tilt of axis in degrees (iii) swivel duration taken by the rotor for aligning with the changing wind direction. These have been shown respectively in graphs: (i) Figure 19/pp 32, (ii) Fig.21/pp 34 and (iii) Fig. 23/pp 36 of the guided project [6]. Despite the two-bladed, modified Darrieus rotor being used here for the simplification purpose, full scale design analysis for the prototype may favor a three-bladed rotor, also the one with troposkein shape. Upon pursuing, the geometrical solution of this dissipative nonlinear dynamical system would be a fascinating fractal composition in the phase-space with strange attractors amidst chaotic motions/ trajectories.

i. *Instructive Scaffold to the Prototype*

This rudimentary experimental study, consisting of six primitive rotors, lasting for about sixty hours render certain qualitative insights about the tilt and swivel type vertical axis wind turbine, to harness high velocity winds, say up to 50 m/s [4].

Next is to go in for the prototype of the first generation: a virtual one leading to the optimally physical one, with the required design-life. Beyond the cut-out wind speed, the rotor's tilt angle may be large enough/say 40^0 causing the blade's stall condition, leading to zero power output. Then the rotor either spins idly or by applying brakes, it just becomes a drag chute with zero spin. These options being configuration specific, have to be assessed using the virtual prototype with numerical modeling [7]. Probably, the results may favor a three-bladed Darrieus type rotor with its troposkein geometry, both from the structural and aerodynamic considerations. Avoidance of self-oscillation might be a crucial criterion for the overall stability aspects and control system for safe operation!

The cantilevered-sleeve type rotor, with the sleeve acting as a torque tube seems highly worthy of incorporating. Torque tube could be roomy enough to accommodate large bending deflection of the cantilever axle. The tilt plus swivel axle-turnnion-frame shall have the stability to maneuver the spin & whirl of the rotor and endure the fatigue load due to the turbulent wind. If needed, maximum tilt angle shall be constrained by tying the axle's lower tip, with a leash chain of fixed length anchored to the ground / zero point. The counter weight's bulk and leverage manipulation is one crucial aspect of the overall control system with feedback; its full potential may pave the way for the smoother and safe continuous turbine operation, as a dynamical navigation.

Mass and rotational inertia of the rotor, counter weight, fulcrum point of the vertical axis, maximum allowable tilt angle, elbow room for counter weight movement, within the pedestal structure, swivel bearing base circle diameter, its height from the ground level, and all such parameters are to be delicately balanced in the wind flow, to produce this turbine as a dynamic entity. Frustum of the cone-like shell frame is suitable for the pedestal support structure. The present swivel base may require a top retainer rail additionally and make a cage-type bearing. This helps to tackle gyroscopic reaction couples and extreme severe lift up the rotor, in the stormy and gusty winds up to 50 m/s; as if to pluck away the rotor!

As for safety, at the worst blades may buckle or break but never a towering inferno is waiting in the wing, as in the case of HAWT. Any newly designed turbine has to undergo meticulous laboratory and extensive field trials & fine tunings for its assessment. Taming this seemingly chaotic "spinning-top-alike" to deliver a regulated performance is both challenging and beautiful! Hence, these strategic observables, gleaned from the rudimentary experiments seem to render an instructive scaffold for realizing the successful prototype.

The artistic impression of this new version of turbine shown in the last page, kinematically resembles to fit in between the Lagrange-top and Kovalveskaya-top. This is just a coincidence and even if it is a pareidolia, to be in their rank is truly the windfall. May this device be blessed to identify its singularities and steer clear toward success.

III. Conclusion

Harnessing through high winds up to large cut-out wind speed, with major safety and minimal maintenance, is the hallmark of the new Tilt & Swivel type vertical axis wind turbine T&S (VAWT). It is expected that loss of efficiency due to its tilting can be more than compensated by its prolonged working duration in high winds up to 50 m/s. Beyond the cut out speed for safety, the rotor can degenerate into a drag chute in the flow field, either with spin or no spin. At the worst, the blades may break or buckle, but can never cause self-destruction of the whole power plant, which is a strong plus point of this design.

Also, the Darrieus type three-bladed rotor with its troposkein geometry results in a light and strong shell structure, to freely spin, toss, and harness the high speed turbulent wind. For the offshore installation as mentioned earlier, the buoyancy and fluid damping effects have to be considered appropriately, with floating base option. This report is about qualitatively suggesting a pertinent design evolved experimentally, for a new turbine meant for high energy wind field. As touched upon in the introduction, there is no qualm in repeating that, this new device is visualized to perform more as a tossing and turning daffodil in the breeze, yet a flexible and tenacious prime mover generating power!

Note on Author's Name

Githaguru and Geethaguru both refer to the same author; phonetic identity triggers the variant spelling.

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2.3 TYPS OF ROTORS USED :

2.3.1 GIROMILL :

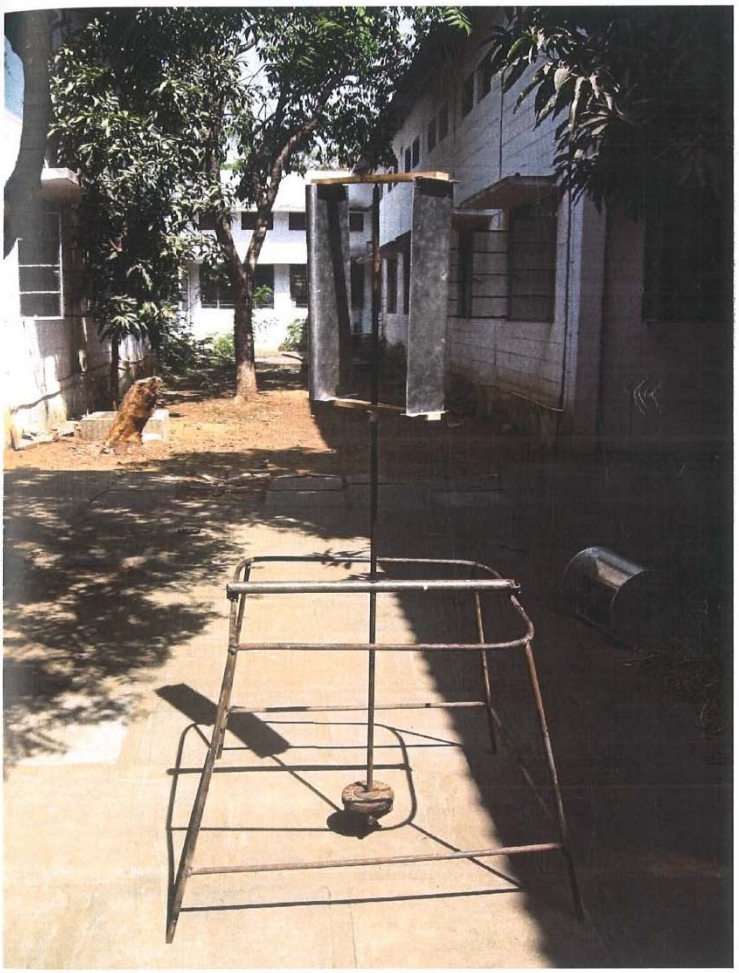


Figure 2.5: Experimental Setup With Giromill Rotor

3.2 SAVONIUS ROTOR:

Figure 2.7: Experimental Setup With Savonius Rotor

.3 SIMPLIFIED DARRIEUS ROTOR:

Figure 2.9: Experimental Setup With Simplified Darrieus Rotor

2.3.3.1 SIMPLIFIED DARRIEUS ROTOR'S DIMENSIONS:

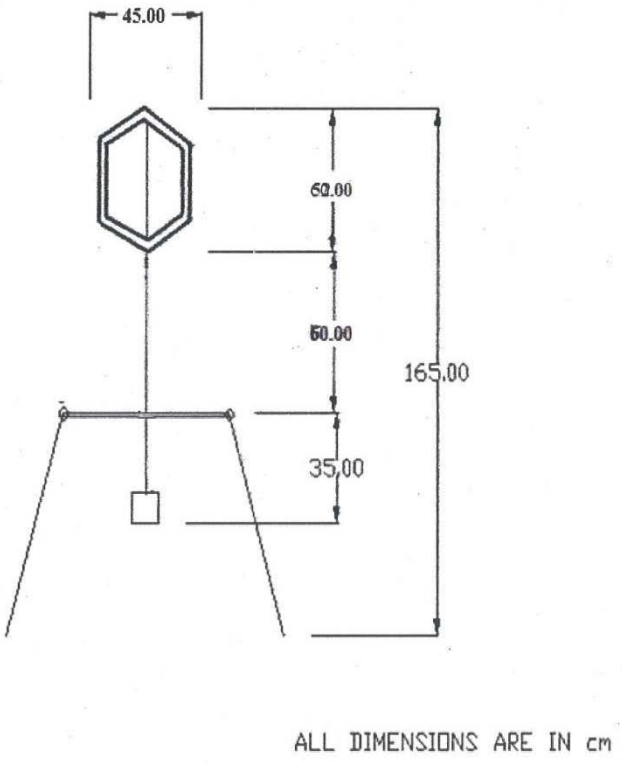


Figure 2.10: Rotor Dimensions (Simplified Darrieus)

POSITION 2:

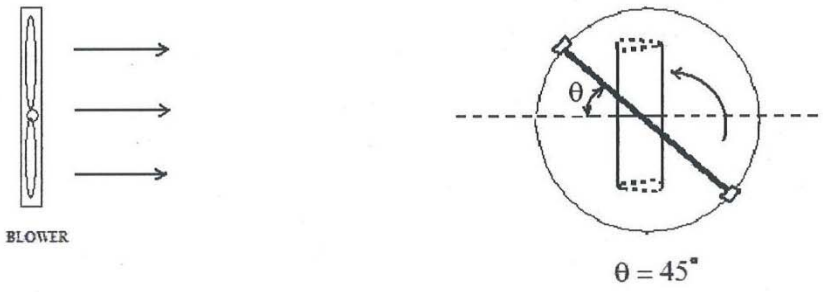


Figure 2.27: Position 2 Setup (Simplified Darrieus Rotor)

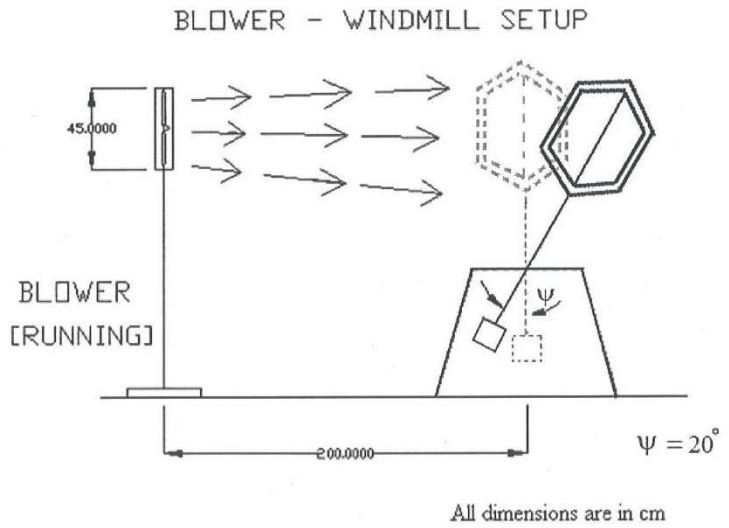


Figure 2.28: Angle Of Tilt For Position 2 Setup (Simplified Darrieus Rotor)

4.2 Ψ Vs θ :

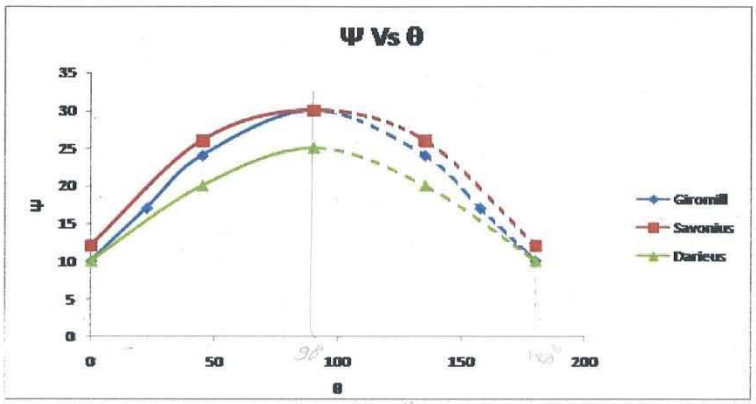


Figure 4.2: ψ Vs θ

4.3 Ψ Vs TSR (λ) :

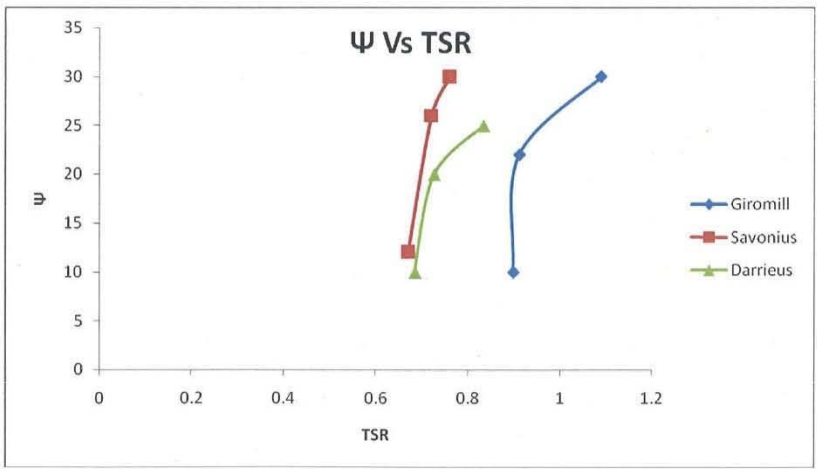
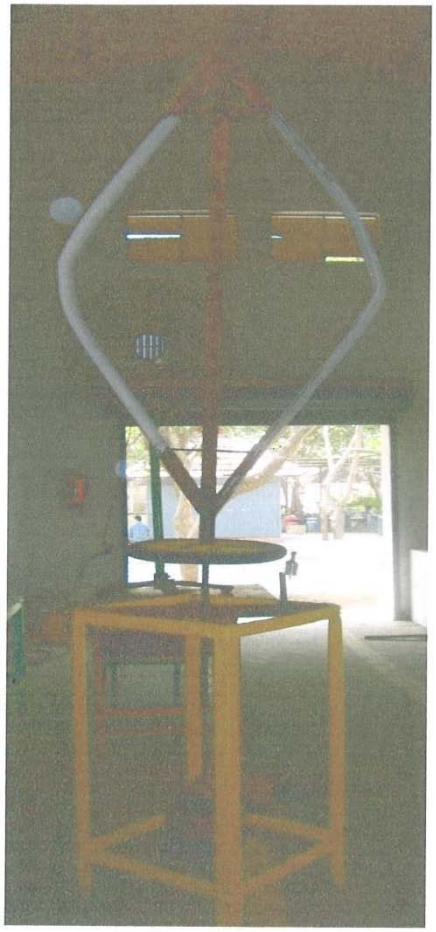


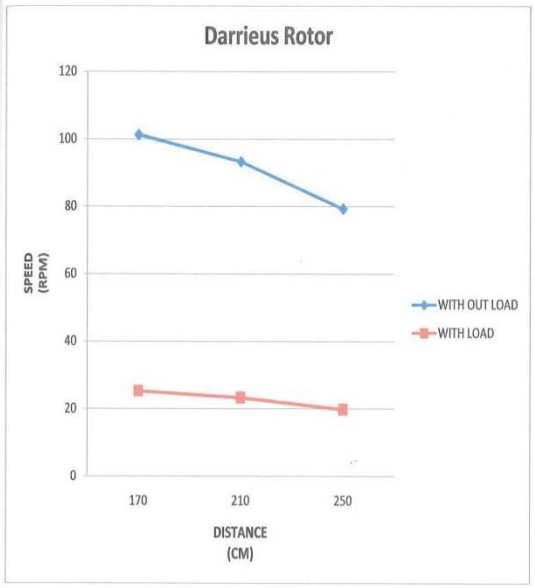
Figure 4.3: ψ Vs TSR (λ)

11.1. DARRIEUS ROTOR



11.2. GIROMILL ROTOR

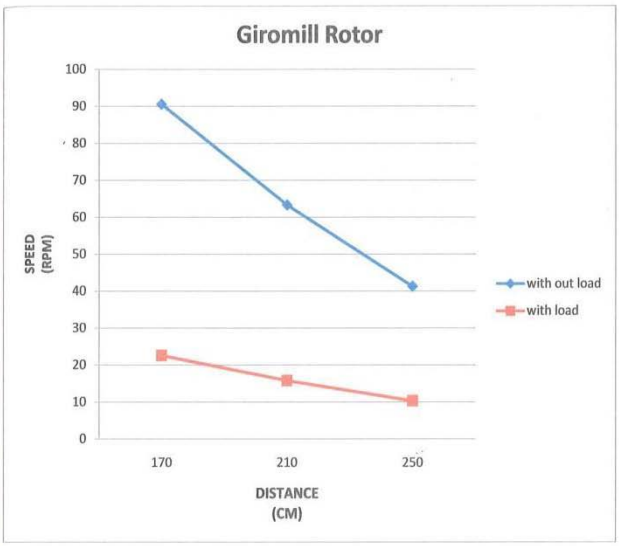
8.3.GRAPH : DARRIEUS ROTOR



X AXIS – DISTANCE (CM)

Y AXIS - SPEED (RPM)

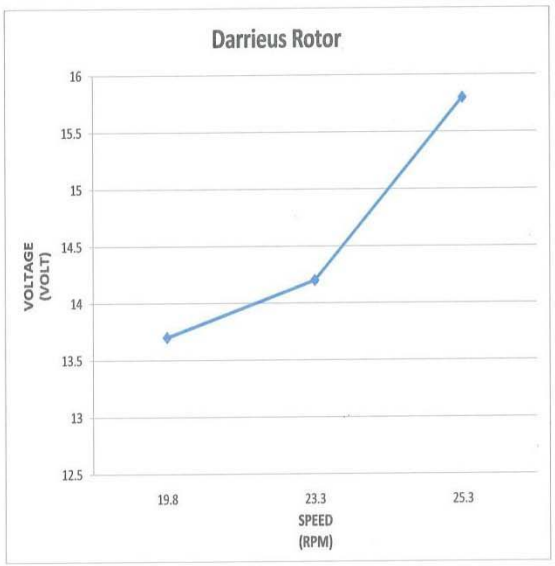
8.4.GRAPH : GIROMILL



X AXIS - DISTANCE (CM)

Y AXIS -SPEED (RPM)

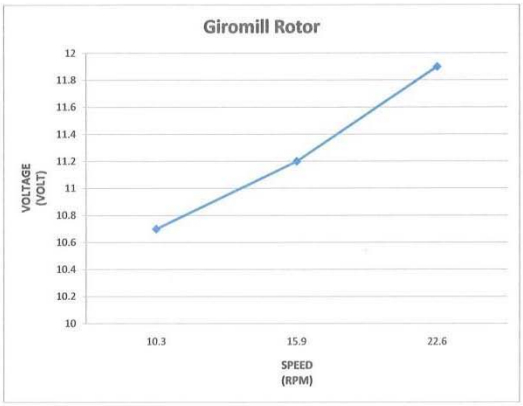
8.5.2. GRAPH : SPEED VS VOLTAGE



X AXIS – SPEED (RPM)

Y AXIS – VOLTAGE (VOLTS)

8.5.4.GRAPH : SPEEED VS VOLTGE



X AXIS – SPEED (RPM)

Y AXIS – VOLTAGE (VOLT)

Figure 5: Tilt rotor

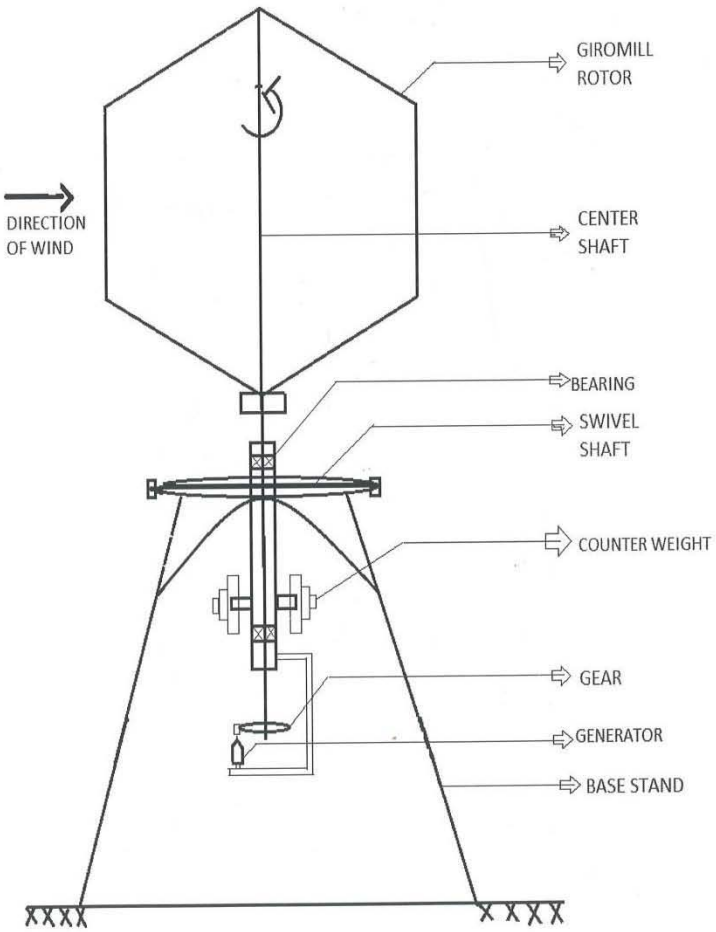


Figure 7: Parts of the tilt rotor

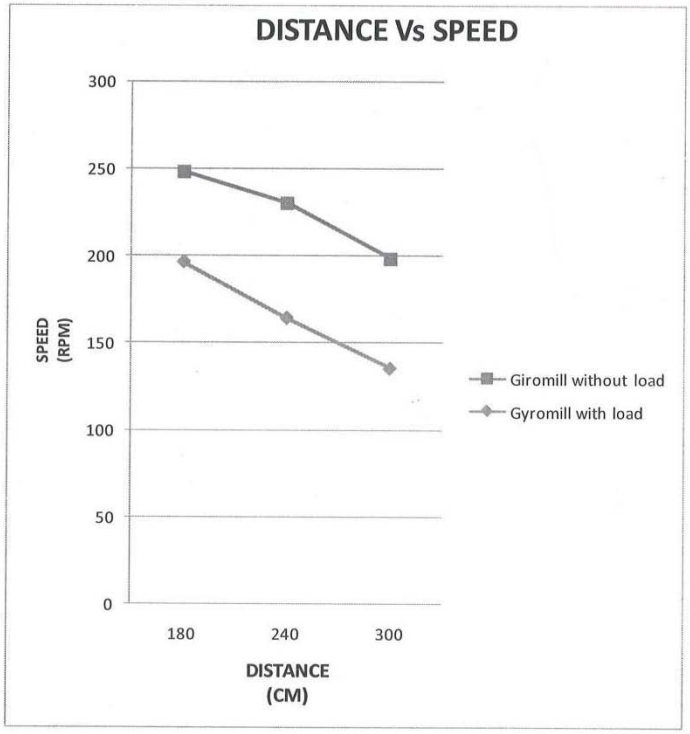


Figure 19: Graph of distance vs speed (with and without load)

X axis - DISTANCE (CM)

Y axis – SPEED (RPM)

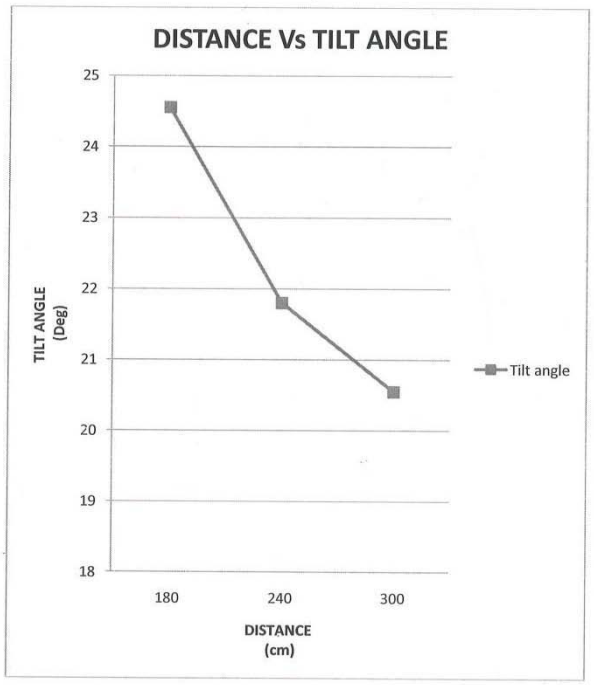


Figure 21: Graph of distance vs tilt angle

X axis - DISTANCE (CM)

Y axis – TILT ANGLE (Degree)

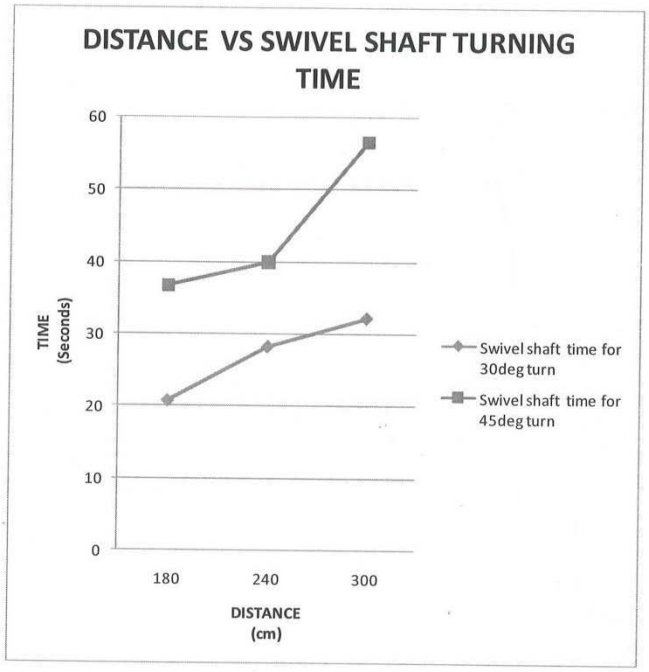
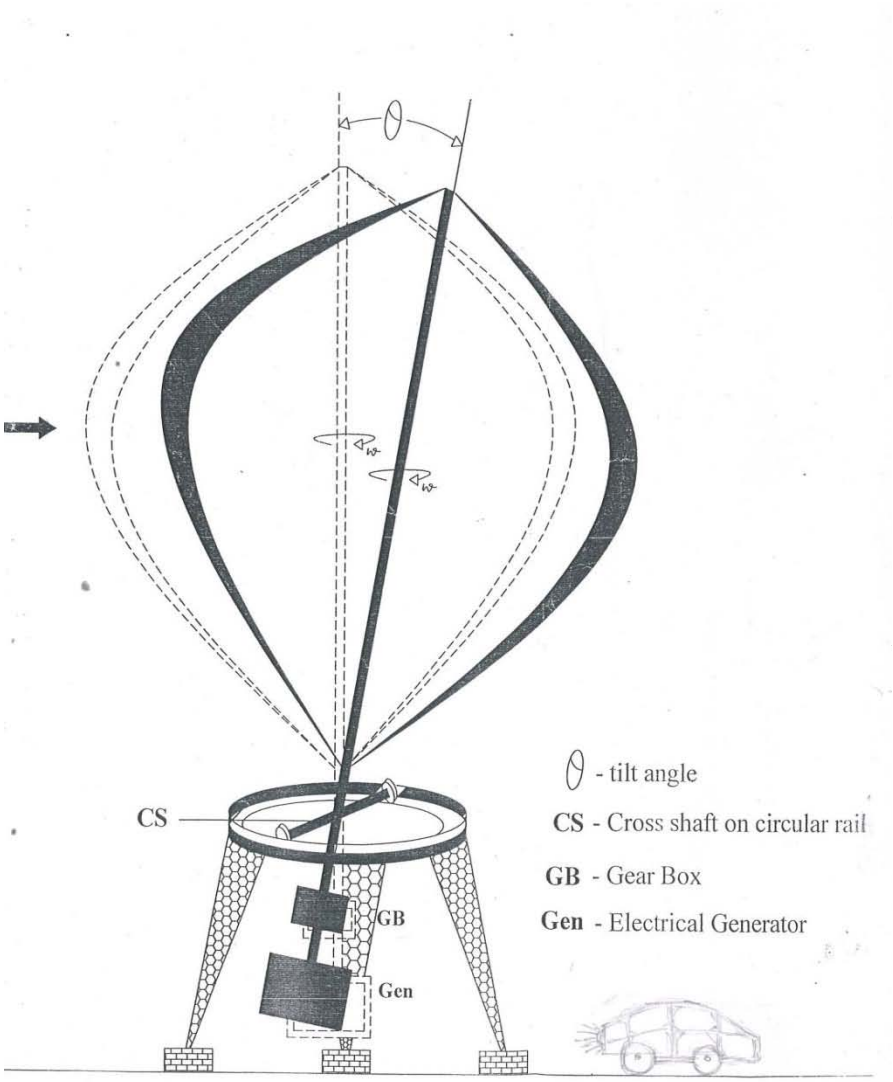


Figure 23: Graph of distance vs swivel shaft turning time

X axis - DISTANCE (CM)

Y axis - TIME (Seconds)



Tilt Rotor Wind Turbine

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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 though 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.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	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
Introduction	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
Methods and Procedures	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
Result	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
Discussion	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
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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