Online ISSN : 2249-4596
Print ISSN : 0975-5861

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Global Journal of Researches in Engineering: A
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Mechanical and Mechanics Engineering
Volume 13 Issue 8 (Ver. 1.0)

Open Association of Research Society

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Offset Typesetting

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Packaging & Continental Dispatching

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Contents of the Volume

Global Journal of Researches in Engineering
Mechanical and Mechanics Engineering
Volume 13 Issue 8 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Optimum Design of Autofrettaged Thick-Walled Cylinders

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Keywords: autofrettage, residual stress, von mises stress, working pressure, pressure vessel, elasto-plastic junction.

GJRE-A Classification : FOR Code: 290501p

OPTIMUMDESIGNOFAUTOFRETTAGEDTHICKWALLEDCYLINDERS

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Optimum Design of Autofrettaged Thick-Walled Cylinders

Md. Tanjin Amin [α], Dr. Abu Rayhan Md. Ali [σ], Tousif Ahmed [ρ] & Faisal Ahmed [ω]

Abstract- The effect of autofrettage process on thick-walled cylinders has been investigated here. It is observed that flow stress distribution along the cylinders remains same for same k values. Comparison with Zhu & Yang's model has been also done in determination of optimum elasto-plastic radius, r_{opt} and optimum autofrettage pressure, p_{opt}. Equivalent von Mises stress is used as yield criterion. It is observed that percentage of reduction of maximum von Mises stress increases as value of k and working pressure increases. Maximum von Mises stress is minimum for lower working pressure at same value of k and autofrettage pressure. Autofrettage process never starts if autofrettage pressure does not exceed working pressure. It is also observed that two limits of autofrettage pressure Py1 & Py2 are not appropriate. Effect of loading stages on autofrettage process is also investigated. As long as the pressures in first and last stage remains constant, there is no effect of loading stages on autofrettage process; no matters how many stages prevails between these two pressures.

Keywords: autofrettage, residual stress, von mises stress, working pressure, pressure vessel, elasto-plastic junction.

I. Introduction

In recent years, the researchers have been investigating for a long time to find out the optimum design of high pressure vessels to save materials and reduce higher cost of construction. Autofrettage is an elasto-plastic technique that increases the capacity of high pressure vessels. In autofrettage process, the cylinder is subjected to an internal pressure which is capable of causing yielding within the wall and then removed. Upon the release of this pressure, a compressive residual hoop stress is developed at certain radial depth at the bore. This compressive stresses reduce the tensile stresses developed as a result of application of working pressure, thus increasing the load bearing capacity [1]-[2]. The magnitude of applied pressure must be below the yield strength of the material. The analysis of residual stresses and deformation in an autofrettaged thick-walled cylinder has been given by Chen [3] and Franklin & Morrison [4]. Determination of optimum autofrettage pressure, p_{opt} and radius of elasto-plastic junction is the major challenge in the analysis of autofrettage process. Harvey [6] tried to give a concept of autofrettage, but the details were missing. A repeated trial calculation approach to determine optimum radius of elasto-plastic junction was proposed by Brownell & Young [7] and Yu [8]. This method was complicated and inaccurate. This method is based on first strength theory which suits brittle materials; but most of the pressure vessels are made of ductile materials which are in excellent agreement with third or fourth strength theory. The graphical method presented by Kong [9] was also inaccurate. Zhu & Yang [10] developed analytic equations for determining optimum autofrettage pressure, p_{opt} and radius of elasto-plastic junction. Ghomi & Majzoobi [11] proposed a set of equations to determine optimum radius of elasto-plastic junction. In this work, optimum radius of elasto-plastic junction is determined using Ghomi & Majzoobi's proposed set of equations and optimum autofrettage pressure is determined using commercially available software ANSYS 11 Classic. Then total work is compared with Zhu & Yang's model.

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II. Analytical Approach

Engineering metals exhibit a linear stress-strain response within the elastic regime, up to their initial yield stress σ_y, their post-yield stress-strain behavior is described by one of the following models: non-linear, bi-linear and multi- linear.

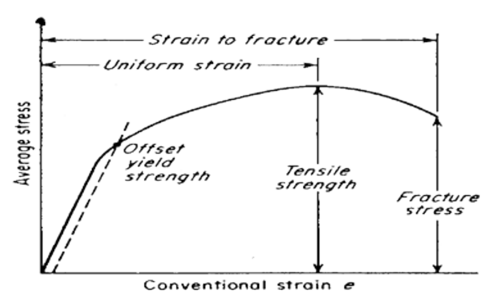

Figure 1 : Non linear Stress Strain Curve

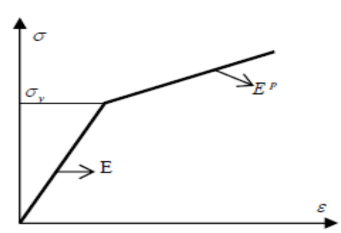

Figure 2 : Bi-linear Stress Strain Curve

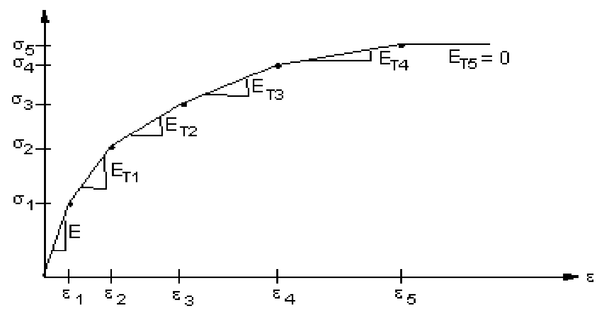

Figure 3 : Multi linear Stress Strain Curve

In this paper, bi-linear elasto-plastic behaviour of materials has been considered. According to fig. 2,

$$\sigma = \sigma_y + E^p\varepsilon \qquad (1)$$

In which, σ is the effective stress, σ_y is the initial yield stress, E^p is the slope of the strain hardening segment of stress strain curve, and ε is the effective strain.

When a metal is strained beyond the yield point, an increasing stress is required to produce additional plastic deformation and the metal apparently becomes stronger and more difficult to deform. This effect is known as strain hardening. Strain hardening of thick-walled cylinders has been also considered in this work.

a) Residual Stress Pattern

Stresses that remain after the original cause of the stresses (external forces, heat gradient) has been removed are residual stresses. They remain along a cross section of the component, even without the external cause. An aluminium cylinder of internal radius, a= 0.02 m, and external radius, b= 0.04 m has been taken into consideration to find out the residual stress pattern in an autofrettaged cylinder. The material properties of aluminium are summarized below in table I.

Table 1 : Material Properties

Mat.	σ_y(MPa)	E(GPa)	E^p(GPa)	ν
Al.	90	72	1.75	0.33

When an internal pressure is applied to the cylinder, the wall becomes plastic up to a certain portion of the cylinder. The internal pressure is called the autofrettage pressure. When autofrettage pressure is released, there is some compressive stress left in the cylinder due to the elasto-plasticity. This compressive stress reduces maximum von Mises stress when another pressure known as working pressure is applied and hence increases the capacity of the cylinder. Ghomi & Majzoobi [11] proposed a set of equations for different regions of autofrettaged cylinder to calculate residual radial and hoop stresses. From these equations, the obtained residual stress pattern is shown in fig. 4:

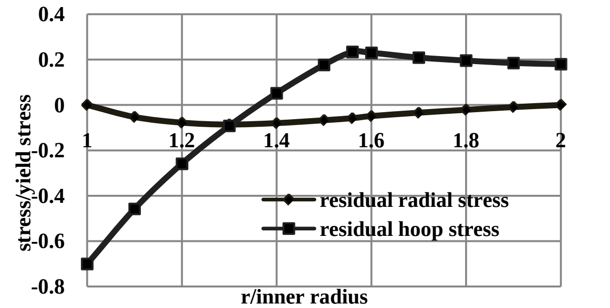

Figure 4 : Residual Stress Pattern in Autofrettaged Cylinder

From fig. 4, it is observed that residual compressive hoop stress occurs near the bore and residual tensile radial stress occurs in outer bore region. The radius up to which walls become plastic, is 0.0312 m. Rayhan, Nidul & Tanvir [5] obtained a similar figure as fig 4. with same values of stress/yield stress and r/inner radius while they examined the distribution of residual stresses with an aluminium cylinder of internal radius, a= 0.01 m, and external radius, b= 0.02 m. This proves that developed residual stresses in autofrettage process is dependent on value of k (b/a).

b) Optimum Radius of Elasto-Plastic Junction

Variation of maximum von Mises stresses along the cylinder is calculated using Ghomi & Majzoobi's [11] proposed a set of equations to determine the optimum radius of elasto-plastic junction. The results are plotted in fig. 5.

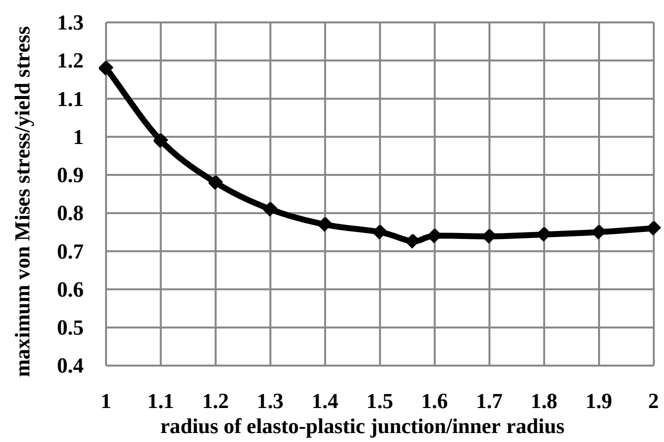

Figure 5 : Variation of Maximum von Mises Stresses at Different Elasto-plastic Radius

From fig. 5, it is observed that when working pressure is applied to the cylinder, maximum von Mises stress decreases as the radius of elasto-plastic junction increases. It decreases to a certain value and then again starts to increase. The point where maximum von Mises stress is minimum, is the optimum radius of elasto-plastic junction [5].

Zhu & Yang [10] developed an equation to determine the optimum radius of elasto-plastic junction.

a) Based on third strength theory (Tresca-yield)

$$r_{opt} = a \exp (p_w / \sigma_y) \quad (2)$$

b) Based on fourth strength theory (von Mises)

$$r_{opt} = a \exp (\sqrt{3} p_w / 2\sigma_y) \quad (3)$$

For the aluminium cylinder mentioned previously, r_{opt} is 0.03114 m when working pressure, p_w= 46 MPa. Fourth strength theory has been used to calculate r_{opt}. From fig. 5, r_{opt} is between 0.031 m to 0.032 m.

Ghomi & Majzoobi [11] determined r_{opt} using MATLAB. There is always 3-11% deviation between Zhu & Yang and Ghomi & Majzoobi's model.

c) Effect of k on Optimum Radius of Elasto-Plastic Junction

To observe the effect of k on optimum radius of elasto-plastic junction fig. 6 is considered.

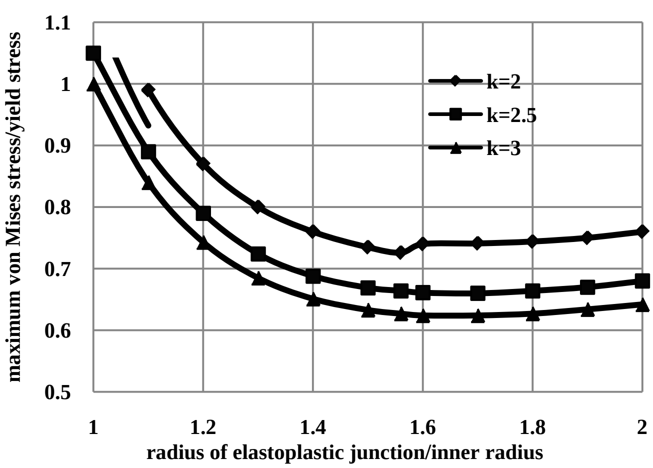

Figure 6 : Variation of Maximum von Mises Stresses at Different Elasto-plastic Radius for Different k values

According to Zhu & Yang, r_{opt} is dependent on inner radius, a for constant value of p_w and σ_y. No matter what is the value of k, r_{opt} will be constant as long as a, p_w and σ_y are constant. But from fig. 6, it is observed that the values of r_{opt} are not same for different values of k though a, p_w and σ_y are constant. As the value of k increases, r_{opt} tends to be increased from Zhu & Yang's calculated r_{opt}. Value of k has significance on optimum elasto-plastic radius.

d) Effect of k on MVS

To observe the effect of k on variation of maximum von Mises stress, maximum von Mises stresses correspond to optimum elasto-plastic radius for different k values at working pressure of 46 MPa & 55 MPa have been potted in fig. 7.

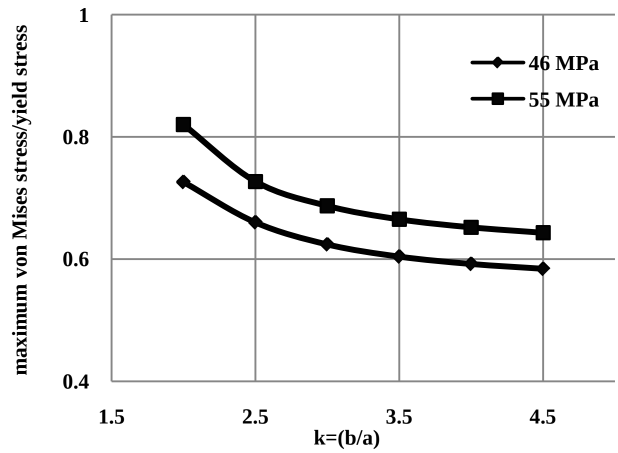

Figure 7 : Variation of Maximum von Mises Stresses Correspond to Optimum Elasto-plastic Radius for Different k values

It has been observed that MVS is lower for a specific value of k for lower working pressure and MVS decreases as k increases. This means the thicker will be the pressure vessel, the more will be the capacity due to autofrettage.

III. Numerical Results

For numerical simulations and modeling, ANSYS 11Classic has been used. The element is Quad 4 Node PLANE 42. It has the capacity of elastic and plastic material modeling. A single steel cylinder of internal radius, a= 0.1 m & outer radius, b= 0.2 m has been considered. The material properties of steel are summarized below in table II.

Table 2 : Material Properties

Mat.	σ_y(MPa)	E(GPa)	E^p(GPa)	ν
Steel	800	207	4.5	0.29

The two pressure limits [1-11] of autofrettage process are:

$$P_y1 = \sigma_y (1-1/k^2)/\sqrt{3} \quad (4)$$

$$P_y2 = \sigma_y \ln (k) \quad (5)$$

Where, P_y1 is the pressure at which yielding starts at inner surface and P_y2 is the pressure at which plasticity spreads throughout the cylinder.

For the considered cylinder, P_y1 is 347 MPa and P_y2 is 555 MPa. That means autofrettage effect will start at 347 MPa and continue affecting up to 555 MPa. Before 347 MPa, there will be no autofrettage effect as any portion of the cylinder does not go to plastic regime hence flow stress distribution throughout the cylinder remains unchanged. After 555 MPa, there will be adverse effect and capacity of cylinder will decrease.

The cylinder is subjected autofrettage pressure ranging from 250 MPa to 650 MPa for the working pressure of 100 MPa. Variation of MVS with autofrettage pressure is shown in fig. 8.

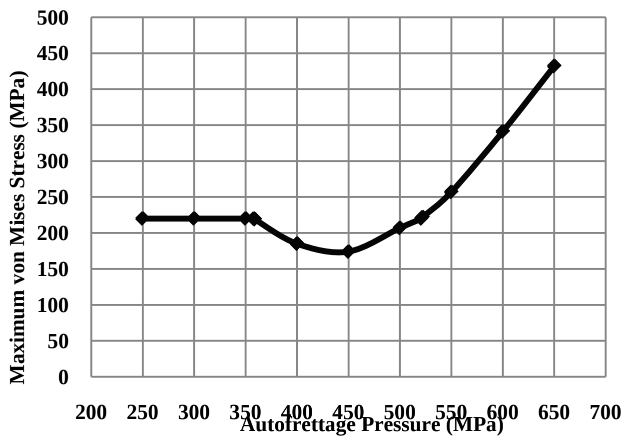

Figure 8 : Variation of Maximum von Mises Stresses at Different Autofrettage Pressure

From fig. 8, it is observed that at first maximum von Mises stress decreases as autofrettage pressure increases. MVS decreases up to a certain minimum value. After that MVS starts to increase again. This minimum value gives the optimum point. That means the autofrettage pressure corresponds to which maximum von Mises stress is minimum, is the optimum autofrettage pressure, p_{opt}. From fig. 8, it is observed that this optimum autofrettage pressure is around 460 MPa. But one interesting observation is that autofrettage starts at 359 MPa and converse effect starts after 521 MPa. The limiting values should be 347 & 555 MPa. To make sure that there is some deviations in simulated value from the value obtained using equation (4) & (5), three single steel cylinders of different k value are internally pressurized at 100 & 200 MPa working pressure. The results are summarized in table III.

Table 3 : P_y1 & P_y2 Values From Equation & Simulation For Different K Values And Working Pressure

k	Working pressure (MPa)	Py1according to equation (MPa)	Py1according to simulation (MPa)	Py2according to equation (MPa)	Py1according to simulation (MPa)
2.0	100	347	359	555	521
2.0	200	347	365	555	615
2.5	100	388	407	733	582
2.5	200	388	407	733	749
3.0	100	411	450	878	625
3.0	200	411	450	878	778

It is observed from the table III that Py1& Py2 obtained from simulation are never equal to that obtained from the equations. There is always significant deviation. For Py1, it does not vary much with the variation of working pressure for same k value. But for Py2, as working pressure increases, it varies enormously for same k value. The variation may go up to 5-30% based on working pressure and k value.

In this paper, the effort is made to find out the effect of working pressure, value of k (b/a) and autofrettage stages on autofrettage process.

a) Effect of Working Pressure

A number of autofrettage pressures have been applied to the steel ranging from 250 MPa to 650 MPa for the working pressures of 100, 200, 300 and 400 MPa. Variation of maximum von Mises stresses has been plotted against different autofrettage pressure for different working pressure in fig. 9.

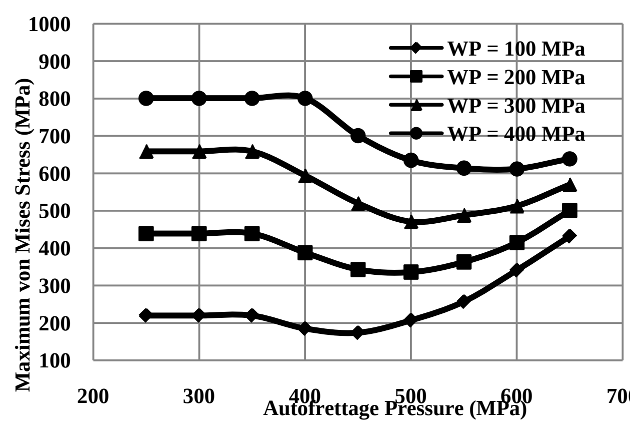

Figure 9 : Variation of Maximum von Mises Stresses at Different Autofrettage Pressure for Different Working Pressure

It has been observed from fig. 9 that MVS remains unaffected nearly P_y1, then it starts to decrease to a certain value. After obtaining this lowest value i.e. p_{opt}, MVS starts to increase. Increasing to a value nearly P_y2 depending on working pressure and k value, MVS experiences converse effect and plasticity spreads throughout the cylinder. For working pressure 100, 200 and 300 MPa, autofrettage starts nearly P_y1. But for working pressure 400 MPa, autofrettage never starts nearly P_y1 rather starts when autofrettage pressure exceeds 400 MPa. It means that autofrettage pressure will have to be always higher than working pressure for the beginning of yielding. The autofrettage pressure must be greater than the working pressure. If the autofrettage pressure is lower than working pressure there is no effect of autofrettage process. From graph analysis it is observed that for working pressure less than 300MPa the auto frett age effect starts when the auto frett age pressure attain a value of 350 MPa. For working pressure 400MPa it is also observed that auto frett age pressure should be more than 400MPa to initiate the auto frett age effect. The optimum point is not same for all the working pressures. As working pressure increases, p_{opt} tends to shift to higher auto frett age pressures. Zhu & Yang [10] developed equation to determine p_{opt}.

- Based on third strength theory (Tresca-yield)

$$P_{opt} = \sigma_y/2[1-(1-2p/\sigma_y) \exp(2p/\sigma_y)] + p \quad (6)$$

- Based on fourth strength theory (von mises)

$$P_{opt} = \sigma_y/\sqrt{3}\,[1-(1-\sqrt{3}p/\sigma_y) \exp(\sqrt{3}p/\sigma_y)] + p \quad (7)$$

P is working pressure in above equations. The comparison with Zhu & Yang's P_{opt} based on fourth strength theory and simulated P_{opt} is given below in tableIV.

Table 4 : Comparison Between Zhu & Yang's Calculated Optimum Autofrettage Pressure And Simulated Optimum Autofrettage Pressure

Working Pressure (MPa)	Zhu & Yang's P_{opt} (MPa)	Approximate Simulated P_{opt} (MPa)
100	112.52	461
200	258.00	485
300	451.94	512
400	714.76	600

It is observed from table IV that Zhu & Yang's calculated P_{opt} is far away from simulated P_{opt} for lower working pressure. But as working pressure increases, both values tend to be closer. Further increase in pressure creates significant deviations again.

b) Effect of value of k

The cylinder is subjected to different autofrettage pressures ranging from 250 MPa to 650 MPa for different values of k at 100 MPa working pressure. Inner radius, a is kept constant for all values of k. The results are shown in fig. 10.

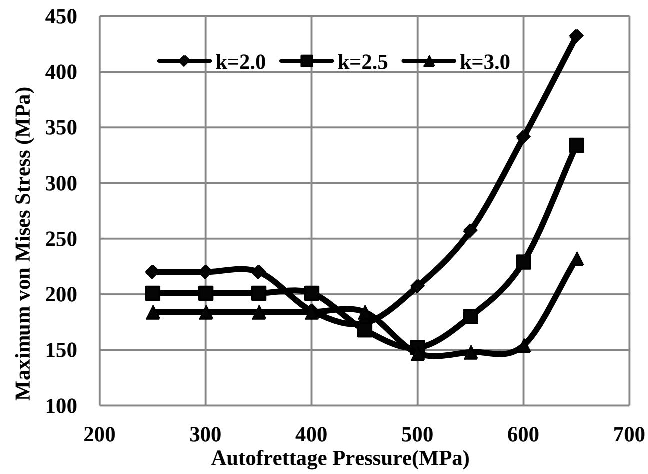

Figure 10 : Variation of Maximum von Mises Stresses at Different Autofrettage Pressure for Different Values of k at 100 MPa Working Pressure keeping inner radius constant

It is observed from fig. 10 that optimum autofrettage pressure increases with the increase of value of k.

Again different autofrettage pressures are applied to the cylinder ranging from 250 MPa to 650 MPa for different values of k at 100 MPa working pressure. This time outer radius, b is kept constant for all values of k. The results are shown below in fig. 11.

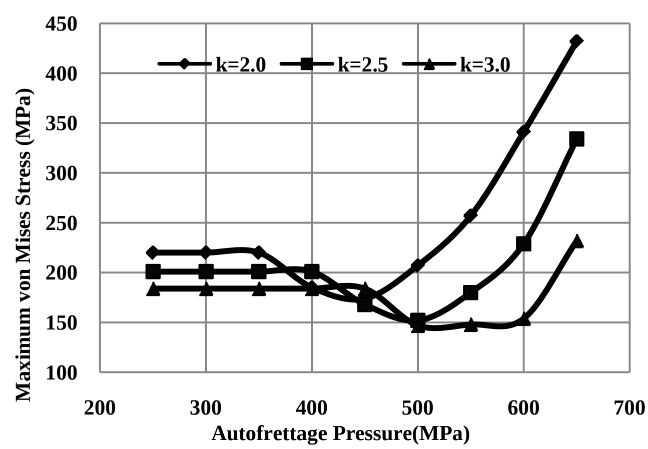

Figure 11 : Variation of Maximum von Mises Stresses at Different Autofrettage Pressure for Different Values of k at 100 MPa Working Pressure keeping outer radius constant

From fig. 11, it is observed that the flow stress pattern remains same though inner radius and outer radius are changed from the previous case. Fig. 10 & fig. 11 suggest that p_{opt} is only dependent on k value. For same k values, p_{opt} is always same.

The percentage of reduction of MVS due to different k values for autofrettage pressure of 500 MPa and working pressure of 100 MPa is summarized in table V.

Table 5 : Effect of K Value on Mvs Reduction

K (b/a)	Without autofrettage (MPa)	With Autofrettage (MPa)	% of reduction of von Mises stress
2.0	220	207	5.91
2.5	201	152	24.38
3.0	184	147	20.11

From the table V, it is observed that percentage of reduction of MVS is higher at higher values of k. Though it is found that for k=3.0 percentage of reduction of MVS is lower than that of k=2.5, actually k=3.0 gives more reduction on higher autofrettage pressure and for k=3.0, autofrettage process starts later than k=2.5. For comparison among these three k values, we needed to consider lower autofrettage pressure as when k=2.0, converse effect starts after autofrettage pressure of 521 MPa. That's why we find lower reduction for k=3.0. But actually higher k values will give better reduction. That means the autofrettage effect is more beneficial with the increase of the thickness of the cylinder wall.

c) Effect of Autofrettage Stages

To observe the effect of stage loading, the cylinder was subjected to autofrettage pressure of 450 MPa and working pressure of 200 MPa in two steps. At first step, it is done in three stages and in second step; it is done in eleven stages.

3 Stage Autofrettage

Stage 1 (MPa)	Stage 2 (MPa)	Stage 3 (MPa)
450	0	250

11 Stage Autofrettage

Stage 1 (MPa)	Stage 2 (MPa)	Stage 3 (MPa)	Stage 4 (MPa)	Stage 5 (MPa)	Stage 6 (MPa)
450	0	400	0	350	0
Stage 7 (MPa)	Stage 8 (MPa)	Stage 9 (MPa)	Stage 10 (MPa)	Stage 11 (MPa)	
300	0	250	0	250	

It is observed that the MVS in final stage in both cases is 343 MPa. So, it can be concluded if the values of pressure at first and last stage remains same, there is no effect of loading stages on autofrettage process.

IV. Conclusion

The following decisions can be taken from the investigations mentioned in this paper:

1. In autofrettaged cylinder, maximum stress occurs in near bore region.
2. The maximum applicable pressure is limited by the yield strength of the materials.
3. Flow stress distribution remains same for same k values.
4. Optimum elasto-plastic radius is not constant for different k value.
5. Higher the working pressure; more will be the benefit from autofrettage process.
6. The limiting values of autofrettage pressure Py1 & Py2 do not follow the calculated value strictly.
7. The thicker will be the material; more will be the capacity.
8. Autofrettage pressure must have to be higher than working pressure to start yielding.
9. Loading stages has no effect on autofrettage process as long as the pressures at first & last stages remain constant.
10. Zhu & Yang's calculated optimum autofrettage pressure is always far away from the simulated result.

Appendix

Table : Nomen Clature

Symbol	Meaning	Unit
a	Internal radius	(m)
b	External radius	(m)
$\sigma_{\theta r}$	Residual hoop stress	(MPa)
σ_{rr}	Residual radial stress	(MPa)
P_w	Working pressure	(MPa)

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Global Journal of Researches in Engineering
Mechanical and Mechanics Engineering
Volume 13 Issue 8 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Optimization of Public Seat Functions to Assure a Comfortable Sitting Posture in Diverse Conditions

By Takeshi Kitamura, Takeo Kato, Koichiro Sato & Yoshiyuki Matsuoka
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GJRE-A Classification : FOR Code: 091399

OPTIMIZATIONOFPUBLICSEATFUNCTIONSTOASSUREACOMFORTABLESITTINGPOSTUREINDIVERSECONDITIONS

Optimization of Public Seat Functions to Assure a Comfortable Sitting Posture in Diverse Conditions

Takeshi Kitamura [α], Takeo Kato [σ], Koichiro Sato [ρ] & Yoshiyuki Matsuoka [ω]

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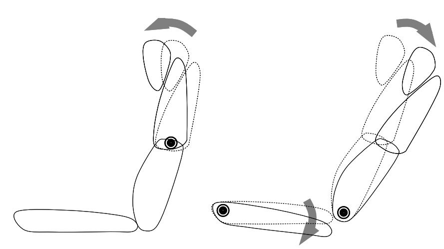
I. Introduction

To assure a comfortable sitting posture, some seat functions, such as the forward tilt of the seatback or seat swing function (Fig. 1), are included in public seats in railway vehicles and passenger airplanes [1] to [3]. However, it is unclear how these functions contribute to a comfortable sitting posture. Currently designers select seat functions based on their experience or sensory evaluation experiments [4]. Moreover, the conventional design assumes standard conditions in which all passengers have average physiques and standard sitting positions. Consequently, conventional design solutions are often poorly evaluated for non-standard conditions, including those with non-average physiques and varied postures (diverse conditions) [5] and [6].

The objectives of this study are to determine which seat functions assure a comfortable sitting posture and then optimize these seat functions for diverse conditions. To determine the relative importance of the seat functions, we conducted a sensory experiment using evaluation factors to elucidate factors for a comfortable sitting posture. We then analyzed the results of the sensory evaluation experiment via an analytic hierarchy process (AHP) and a fuzzy analytic hierarchy process (Fuzzy AHP) [7] and [8]. Second, we constructed a human-seat model for selected seats and performed simulations to optimize seat functions using the model. In this study, the signal-to-noise (SN) ratio from the Taguchi method [9] and [10] was used to consider variations in user physiques and the diversity of sitting postures. Finally, we conducted a sensory experiment to evaluate the optimized design solution.



1)forward tilt function 2)Seat swing function

Figure 1 : Structure of forward tilt function and seat-swing function

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Table 1 : Physique of examinees

Height (mm) / Weight (kg)	1637 ($\mu_h - \sqrt{1.5}\sigma_h$)	1714 (μ_h : Average)	1796 ($\mu_h + \sqrt{1.5}\sigma_h$)
53.2 ($\mu_w - \sqrt{1.5}\sigma_w$)	Physique 1 (Short physique)	Physique 6 (Corpulent physique)	
63.3 (μ_w : Average)	Physique 4 (Corpulent physique)	Physique 2 (Average physique)	Physique 5 (Slim physique)
73.4 ($\mu_w + \sqrt{1.5}\sigma_w$)		Physique 7 (Slim physique)	Physique 3 (Tall physique)

II. Seat Functions that Assure a Comfortable Sitting Posture

a) *Sensory Experiment*

i. *Experimental Conditions*

- Examinees: To incorporate passengers with various physiques, we evaluated passengers using combinations of three different heights and weights. Of the nine possible combinations, two are statistically rare, and consequently eliminated (Table 1). The height and weight levels are defined using their mean values μ_h and μ_w and standard deviations σ_h and σ_w.
- Sitting posture: Each examinee adjusted the seat to assume the most comfortable sitting posture.
- Evaluated seat functions: A sample seat was prepared with five different seat functions: adjustable head rest height, forward tilt, seat swing, seat cushion slide, and footrest. Figure 2 shows the seat functions of the experimental seat. The specifications of the sample seat are identical to an actual public transportation seat found in the Hatsukari express train in Japan.

ii. *Evaluation method*

Based on the results of a previous study [11], we chose two factors to evaluate seat functions: the fitness of the sitting posture and the amount of freedom for various sitting postures with a relative weighting of 7 to 3. The examinees evaluated each factor by answering the following questions using the semantic differential (SD) method on a five-point scale. “Is it possible to achieve a comfortable sitting posture?” and “Is it possible to achieve a variety of sitting postures?”

b) *Analysis of important seat functions for a comfortable sitting posture*

i. *Application of AHP and Fuzzy AHP*

To analyze the importance of seat functions in assuring a comfortable sitting posture, the results of the evaluation were analyzed using AHP and Fuzzy AHP.

AHP is a decision-making method that considers subjective human criteria. In AHP, a hierarchal model is initially created. The model consists of three components: the design object, evaluation factors, and alternatives. The factors in the decision-making problems are divided based on the hierarchy model. Then the degree of importance for each evaluation factor is determined using an evaluation matrix based on paired comparisons. Finally, the degree of importance of the alternatives based on the hierarchy model is numerically simulated using the degree of importance of the evaluation factors and the results of SD method.

The degree of importance for AHP is an additive measure because the sum is equal to one. However, an additive measure cannot evaluate substitutability and complementarity of a sensory evaluation. Substitutability states that even if there is only one excellent evaluation among a number of evaluations, the overall evaluation is higher. In other words, substitutability emphasizes a

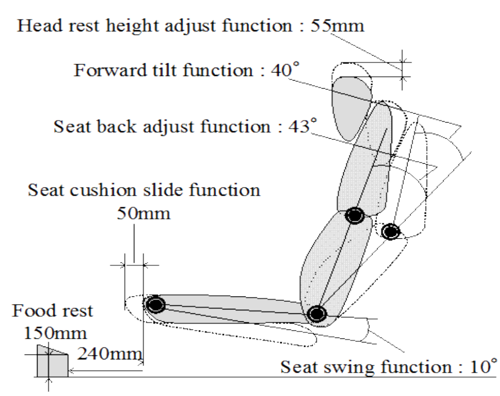

Figure 2 : Specification of the sample seat

good evaluation. In contrast, complementarity means that one inferior evaluation lowers the overall evaluation. Because AHP emphasizes overall balance, herein we employ Fuzzy AHP uses non-additive measures (possibility and necessity measures), which are described below.

First, we expressed the additive measure generally used in AHP, the degree of importance y of the alternatives as a weighted sum of the degrees of importance w_i ($0 \le w_i \le 1$) of the evaluation factors x_i, and the evaluation value $f_j(x_i)$ of j^{th} alternative of x_i. Then y can be expressed as where n is the number of

$$y = \max_{j} \sum_{i=1}^{n} w_i f_j(x_i) \quad (w_1 + \ldots + w_n = 1) \tag{1}$$

evaluation factors. Fuzzy AHP normalizes the degrees of importance w_i ($0 \leq w_i \leq 1$) for cases where $w_i = 1$ for more than one i. For example, wi can be normalized by their maximum value. The classes A_l of the number of n is established using w_i' ($r_1 < r_2 < \ldots < r_n = 1$), which is the modified degree of importance, X is the class of

$$A_l = \{x_i \mid w_i' \geq r_l\} \ , \quad l = 1, \ldots, n \quad , \quad x \in X \tag{2}$$

evaluation factors. The probability m of each class A_l is allocated as

$$m(A_l) = r_l - r_{l-1} \quad , \quad l = 1, \ldots, n \quad , \quad r_0 = 0 \tag{3}$$

The possibility measure expectation E* (upper limited expectation), which adopts the maximum evaluation value f(x) for evaluation factors x included in each class A_l, while the necessity measure expectation E* (lower limited expectation), which adopts the minimum evaluation value, using probabilities m_l from

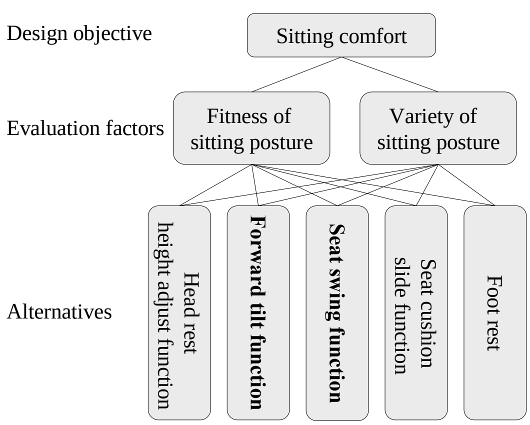

Figure 3 : Constructed hierarchy model

equation (3), are respectively expressed as

$$\begin{aligned} E^*(f) &= \sum_{l=1}^{n} m(A_l) \max_{x \in A_l} f(x) \\ &= \sum_{l=1}^{n} (r_l - r_{l-1}) \max_{x \in A_l} f(x) \end{aligned} \tag{4}$$

$$\begin{aligned} E_*(f) &= \sum_{l=1}^{n} m(A_l) \min_{x \in A_l} f(x) \\ &= \sum_{l=1}^{n} (r_l - r_{l-1}) \min_{x \in A_l} f(x) \end{aligned} \tag{5}$$

Thus, the most favorable degrees of importance of alternatives (y*, y*) in the possibility and necessity measures are expressed as

$$y^* = \max_{j} E^*(f_j) \tag{6}$$

$$y_* = \max_{j} E_*(f_j) \tag{7}$$

The seat functions were selected by applying these degrees of importance of the alternatives.

1.2.2. Data analysis and the selection of alternatives

Figure 3 shows the hierarchy model employed in this study. To determine the compound degree of importance of each measure and alternative, we applied three types of values: the degree of importance of the evaluation factors, the evaluation value assigned by each examinee, and the results of equations (1), (6), and (7).

Figure 4 shows the average of the compound degree of importance, as well as the measures for possibility, additivity, and necessity. The forward tilt and the seat swing functions are the most highly rated

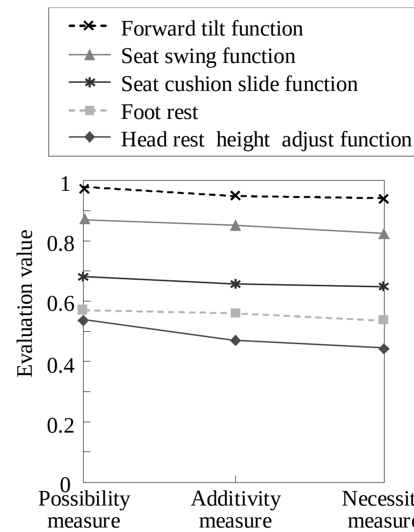

Figure 4 : Evaluations of the Alternatives

measures followed by the seat cushion slide, footrest, and headrest height adjustment functions, in that order. These findings can be explained by the body pressure distribution. In general, the lower the pressure on the body from the seat is thought to be more desirable [12].

It is possible that the forward tilt and the seat swing functions distribute the pressure to large regions of the body by increasing the pressure on the back. Thus, we expect these functions to be highly rated. In summary, we selected the forward tilt and the seat swing functions, which were highly rated in the three measures — possibility, additivity, and necessity — as the necessary seat functions to assure a comfortable sitting posture for varied conditions.

III. Optimization of Seat Functions for a Comfortable Sitting Posture

Here we focus on the forward tilt and seat swing functions as the functions necessary to realize a comfortable sitting posture. Because we optimized the forward tilt function in a previous study [13], we briefly summarize the optimization. Then we clarified the optimization of a seat swing function with and without a forward tilt function in diverse conditions. Finally, a sensory experiment confirmed the effectiveness of the seat swing function with a forward tilt function.

a) Optimization of the forward tilt function

The forward tilt function is the function that bends the seatback between the thorax and the lumbar regions. This function contributes to fitness of the

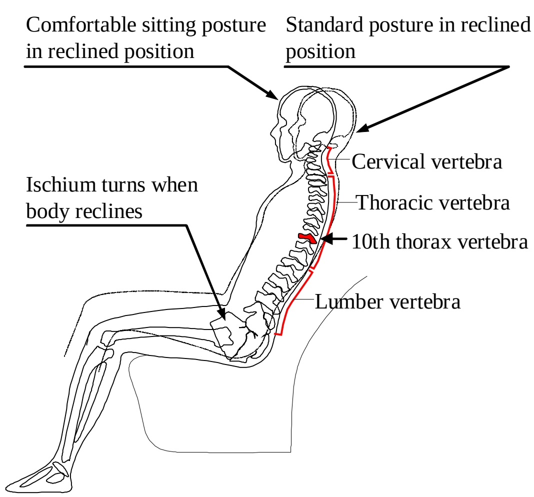

Figure 5 : Forward tilt pivot position

seatback for assuming a comfortable sitting posture. We have determined the optimal pivot point of the forward tilt and the movement range of the forward tilt angle (FA) based on a sensory experiment with diverse users in a previous study. These results are summarized below.

i. *Optimization of the forward tilt position*

Previously a sensory experiment involving 16 Japanese participants (8 male and 8 female) with varying physiques (height percentile from 10% to 99%) determined the optimal forward tilt position for diverse users. The pivot point of forward tilt function is behind the 10th vertebra (Fig. 5) because the point of largest movement in the spine (except the thorax) is between the 10th and 11th vertebrae.

ii. *Optimization of the movement range of the forward title angle*

A sensory experiment evaluated the comfort of a sitting posture and determined the optimum movement range of FA using the same conditions as above. Figure 6 shows the acceptable comfort range of FA for each examinee. Based on the results, we selected an FA movement range between 0 and 30 degrees.

iii. *Relationship between the forward tilt function and the seat swing function*

The previous section demonstrates that the forward tilt function can assure a comfortable sitting posture by tilting the seatback at a pivot point behind the 10th thorax vertebra and a 0 to 30 degree movement range. Moreover, the design solution of the seat swing

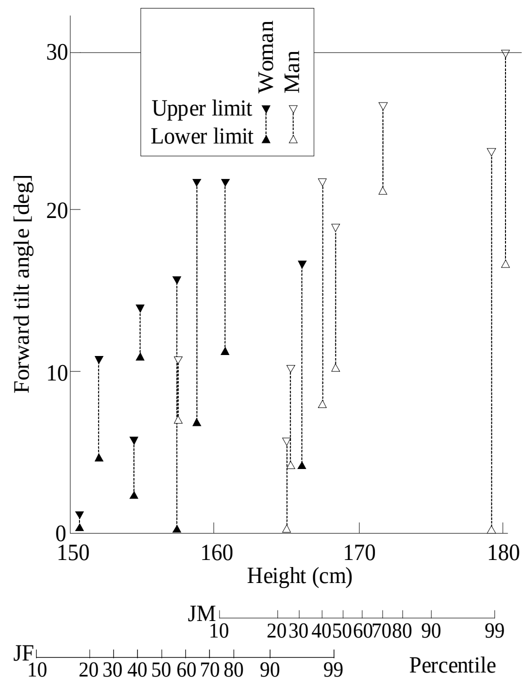

Figure 6 : Suitable forward tilt angle range for different builds

function is related to FA because the seat swing function sinks the back end of the seat cushion on the axis of the front edge of the seat cushion in tandem when adjusting the seatback to prevent the hip sliding force. The force is usually generated on the buttocks in an anterior direction from the human body dynamics varied from the seat angles. The hip sliding force is one cause of uncomfortable sitting [14], and varies as a function of the back angle (BA), which is the angle between the seatback and the vertical direction, and the cushion angle (CA), which is the angle between the seat cushion and the horizontal. BA and CA are adjusted by the seat swing function. In addition, the hip sliding force varies with FA as adjusted by the forward tilt function.

b) Optimization of the seat swing function

The optimal combination between BA and CA minimizes the hip sliding force and optimizes the seat swing function. In this study, the seat swing functions with and without the forward tilt function were optimized. Here users adjusted FA to a certain value.

i. *Design method*

The seat swing function was optimized using the SN ratio, which is the measure from the Taguchi method to evaluate the stability of the functional value of a design objective with respect to the variance of a variety of factors. When data is divided into a functional characteristic value S (signal) and variance N (noise), the ratio of these values is the SN ratio [15], and indicates the stability of a functional value. Maximizing the SN ratio improves the performance of the design objective; thus, selecting a design solution that

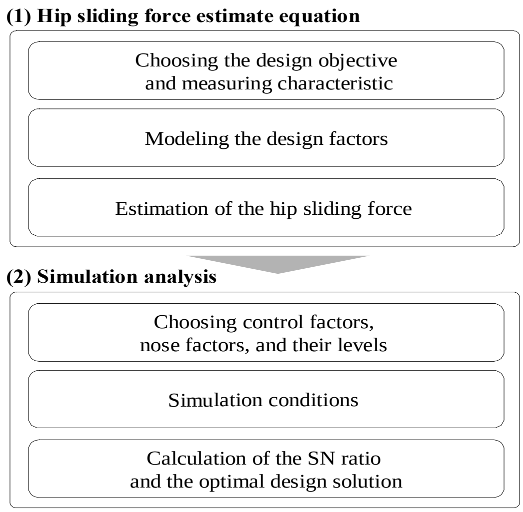

Figure 7 : Flow of seat swing function optimization

maximizes the SN ratio minimizes the influence of noise factors, which can destabilize a function.

ii. *Optimization Steps*

Figure 7 shows the procedure to optimize the seat swing function. First the hip sliding force is estimated, and then simulations analyze the results. There are three steps to construct the hip sliding force estimation equation: (1) select the design objective and measure its characteristics, (2) model the design factor, and (3) estimate the hip sliding force.

- *Select the design objective and measure its characteristics*

The seat swing function reduces the hip sliding force. Therefore, the design objective is for the hip sliding force to be 0 N.

- *Model the design factors*

To model the factors that influence the hip sliding force, initially a human model and seat model must be separately constructed. Then a human-seat model, which depicts their relationship, is constructed.

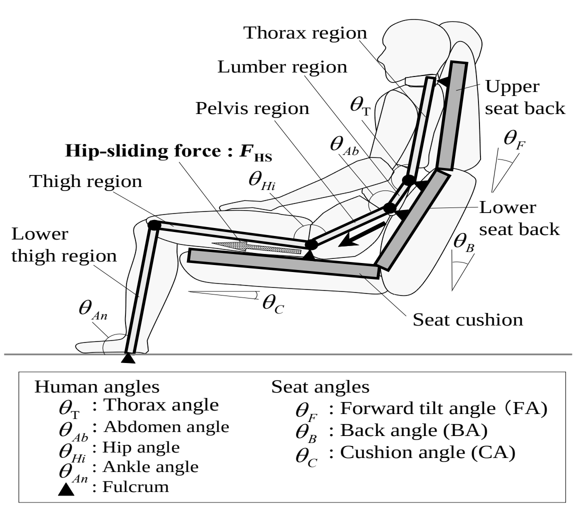

Figure 8 : Human-seat model

Because the human model needs to be split into parts, we selected division points based on both human anatomy and sitting posture [16]. Our two-dimensional model includes the thoracic, lumbar, and pelvic regions as well as the thigh and lower thigh regions. For each body region measurement, we used the statistical average of the human body measurements [17].

For each body region weight, we renormalized the weights from an earlier study to match the models used in this study [18]. We considered three types of sitting postures: the standard one and two types of hip sliding postures (stretched waist and bent waist) [19]. In the standard sitting posture, a passenger sits such that the buttocks are positioned deep on the seat cushion and the waist is in contact with the seatback. In the hip sliding posture, the passenger sits with the buttocks slid forward and the pelvis rotated such that waist does not come into contact with the seatback. The stretched waist sitting posture stretches both the pelvis and the waist, while the bent waist posture bends both the pelvis and the waist. The greater trochanter point of the hip sliding sitting posture is set 100 mm forward from the standard sitting posture, based on an earlier study [19].

The two-dimensional seat model consists of three parts: upper seatback, lower seatback, and seat cushion, which are rigid-body link structure. As shown in Section 2.1.1, the forward tilt function rotates around a pivot point behind the 10th thorax vertebrae. The size and adjustability of the sample seat are based on a real-life Hatsukari public seat (Section 1.1.1).

We constructed the human-seat model using the above human and seat models (Fig. 8). Because the hip sliding force estimate and the features of the sitting position can be viewed from the sagittal plane of the human body, the human-seat model in this study is constructed in the sagittal plane. Forces include friction between the human body and the seat, where the vertical component of force from each seat part (the upper seatback, the lower seatback, and the seat cushion) is multiplied by the friction coefficient, which is assumed to be 0.3 [20].

- *Estimate the hip sliding force*

Then we constructed human-seat models with respect to varied sitting postures to estimate the hip sliding equation for all postures (Figs. 9–11, equations 8–10). Table 2 explains the variables in these equations [21].

Similar to the estimation of the hip sliding force, the simulation analysis consists of three parts: (1) select the control and noise factors as well as their levels, (2) determine the simulation conditions, and (3) calculate the SN ratio and optimal design solution.

- *Select the control and noise factors as well as their levels*

  First, we defined the factors influencing the design objective. Then these factors are

Table 2 : Sign on formulation of hip sliding force estimation

Sign	Meaning	Sign	Meaning	Sign	Meaning
F_{HS}	Hip sliding force	H	Height of seat cushion	i=1	Thorax region
F_h	Horizontal force on trochanter major	M	Body weight	i=2	Lumber region
F_v	Vertical force on trochanter major	M_i	Weight of i th body section	i=3	Pelvis region
F_i	Force on i th human body section	l_{ia}	Ratio of L_i and the length from i th body section upper-edge to gravity-center	i=4	Thigh region
L	Body height	l_{ib}	1 - l_{ia}	i=5	Lower thigh region
L_i	Length of i th body section	l_{ma}	Composite ratio of 3rd and 4th body section in stretched waist sitting posture	k	Coefficient of frictional resistance
L_h	Buttock-trochanterion length	$l_{m'a}$	l_{ma} in bent waist sitting posture.		

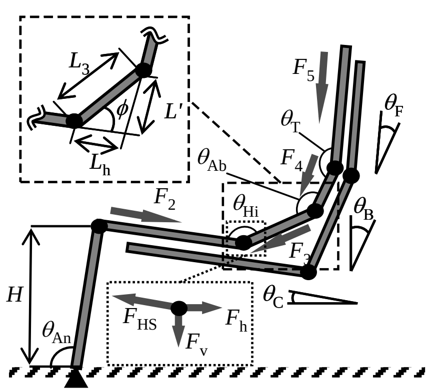

Figure 9 : Standard sitting posture

$$F_{HS1}=-F_h\cos\theta_C-F_v\sin\theta_C-\kappa(-F_h\sin\theta_C+F_v\cos\theta_C)$$

$$\left(\begin{aligned}
&F_h=F_2\cos\theta_C-F_3\sin(\theta_{Hi}+\theta_C)\\
&F_v=F_2\sin\theta_C+F_3\sin(\theta_{Hi}-\theta_C)+M_2l_{2b}g+M_3l_{3a}g\\
&F_2=\frac{M_1l_{1b}g+M_2l_{2a}g}{\sin\theta_C-\cos\theta_C\tan\theta_{An}}\\
&F_3=\frac{F_{4-5}+(M_4l_{4a}g+M_3l_{3b}g)(\cos\theta_B-\kappa\sin\theta_B)}{-\cos\theta_{Ab}-\kappa\sin\theta_{Ab}}\\
&F_4=(M_5l_{5a}g+M_4l_{4b}g)(\cos\theta_B-\kappa\sin\theta_B)+F_5(\cos\theta_F-\kappa\sin\theta_F),\\
&F_5=M_5l_{5b}g\{\cos(\theta_B-\theta_F)-\kappa\sin(\theta_B-\theta_F)\}\\
&\theta_{An}=\sin^{-1}(H/L_1),\ \theta_{Hi}=180°-\phi,\ \ \theta_{Ab}=\phi+90°-\theta_C+\theta_B-\theta_F,\\
&\phi=\sin^{-1}\{(L'/L_3)\sin(90°+\theta_B-\theta_C)\}\\
&L'=L_h\cos(90°+\theta_B-\theta_C)+\sqrt{L_3{}^2-L_h{}^2\sin^2(90°+\theta_B-\theta_C)}
\end{aligned}\right)$$

(8)

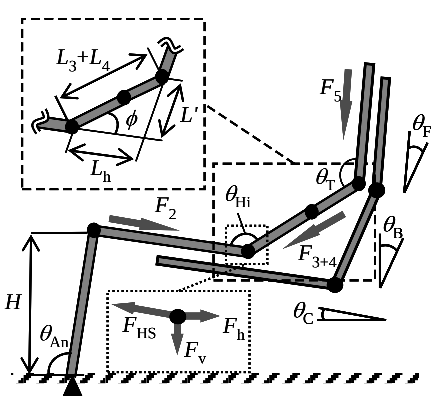

Figure 10 : Hip-sliding sitting posture(Stretched waist)

$$F_{HS2}=-F_h cos\theta_C-F_v\sin\theta_C-\kappa(-F_h\sin\theta_C+F_v\cos\theta_C)$$

$$\left(\begin{aligned}
&F_h=F_2\cos\theta_C+F_{3+4}\cos(\theta_{Hi}+\theta_C),\\
&F_v=F_2\sin\theta_C+F_{3+4}\sin(\theta_{Hi}+\theta_C)+M_2l_{2b}g+(M_3+M_4)l_{ma}g\\
&F_2=\frac{M_1l_{1b}g+M_2l_{2a}g}{\sin\theta_C-\cos\theta_C\tan\theta_{An}}\\
&F_{3+4}=\frac{F_5+(M_5l_{5a}g+(M_3+M_4)l_{mb}g)(\cos(\theta_B-\theta_F)-\kappa\sin(\theta_B-\theta_F))}{-\cos\theta_T+\kappa\sin\theta_T}\\
&F_5=M_5l_{5b}g(\cos(\theta_B-\theta_F)-\kappa\sin(\theta_B-\theta_F)),\\
&\theta_{An}=\sin^{-1}(H/L_1),\ \ \theta_{Hi}=180°-\phi,\ \ \theta_T=\phi+90°-\theta_C+\theta_B-\theta_F,\\
&\phi=\sin^{-1}[\{L'/(L_3+L_4)\}\sin(90°+\theta_B-\theta_C)]\\
&L'=L_h\cos(90°+\theta_B-\theta_C)+\sqrt{(L_3+L_4)^2-L_h{}^2\sin^2(90°+\theta_B-\theta_C)}
\end{aligned}\right)$$

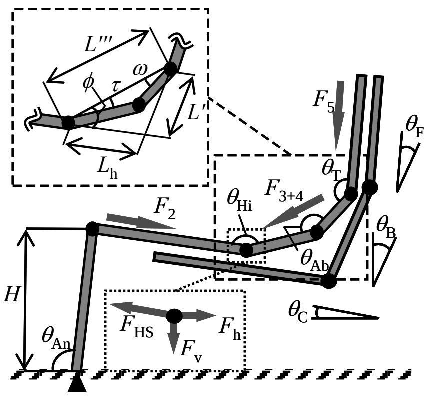

Figure 11 : Hip-sliding sitting posture (Bent waist)

$$F_{HS3} = -F_h \cos\theta_C - F_v \sin\theta_C - \kappa\left(-F_h \sin\theta_C + F_v \cos\theta_C\right)$$

$$\left\{\begin{array}{l}
F_h = F_2 \cos\theta_C + F_{3+4}\cos(\theta_{Hi} + \theta_C - \tau), \\
F_v = F_2 \sin\theta_C + F_{3+4}\sin(\theta_{Hi} + \theta_C - \tau) + M_2 l_{2b} g + (M_3 + M_4) l_{m'a} g \\
F_2 = \dfrac{M_1 l_{1b} g + M_2 l_{2a} g}{\sin\theta_C - \cos\theta_C \tan\theta_{An}} \\
F_{3+4} = \dfrac{F_5 + (M_5 l_{5a} g + (M_3 + M_4) l_{m'b} g)(\cos(\theta_B - \theta_F) - \kappa \sin(\theta_B - \theta_F))}{-\cos(\theta_T - \omega) + \kappa \sin(\theta_T - \omega)} \\
F_5 = M_5 l_{5b} g(\cos(\theta_B - \theta_F) - \kappa \sin(\theta_B - \theta_F)), \\
\theta_{An} = \sin^{-1}(H/L_1),\ \theta_{Hi} = 180° - \phi + \tau,\quad \theta_T = \phi + 90° - \theta_C + \theta_B - \theta_F + \omega, \\
\phi = \sin^{-1}\{(L'/L''')\sin(90° + \theta_B - \theta_C)\} \\
L' = L_h \cos(90° + \theta_B - \theta_C) + \sqrt{(L''')^2 - L_h^{\,2}\sin^2(90° + \theta_B - \theta_C)}, \\
L''' = \sqrt{L_3^2 + L_4^2 - 2L_3L_4\cos(180° - 24°)}
\end{array}\right. \quad (10)$$

Table 3 : Conditions of Each Simulation

Simulation No.	Control factor	Noise factor		
		Physique	Sitting Posture	FA
Simulation 1 : Optimization of seat swing function considering standard condition	BA, CA	1 level (standard)	1 level (standard)	1 level (0 deg)
Simulation 2 : Optimization of seat swing function considering diverse condition	BA, CA	7 levels	3 levels	1 level (0 deg)
Simulation 3 : Optimization of seat swing function with forward tilt function considering standard condition	BA, CA	7 levels	3 levels	3 levels

divided into control and noise factors. A designer can determine the level of influence of a control factor, but not that of a noise factor. We identified the following factors:

a. CA (control factor)
b. BA (control factor)
c. FA (noise factor)
d. Physiques (noise factor)
e. Sitting postures (noise factor)

The level of each factor was determined, as described below. CA has 51 different values from 0 to 50 degrees in one-degree increments. In this study, physique, sitting posture, and FA, are noise factors with seven, three, and three levels, respectively. FA is set to 0, 15, or 30 degrees.

iii. *Determine the simulation conditions*

We used three different conditions in the simulation analysis (Table 3).

- Simulation 1: The seat swing function is optimized for the standard condition. In particular, CA minimizes the hip sliding force Y (equation 8) for each BA value.
- Simulation 2: The single seat swing function is optimized by determining the levels of physique and sitting posture.
- Simulation 3: The seat swing function with the forward tilt function is optimized by determining the levels of physique, sitting posture, and FA.

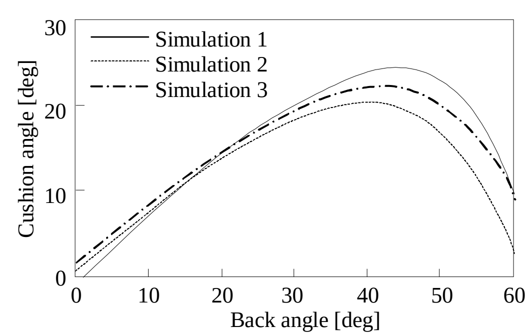

Figure 12 : Specification of the sample seat

In the simulations, the SN ratios of the hip sliding force are estimated for each combination of BA and CA. The SN ratio is the ratio of the signal factor to the noise factor. Then the optimal design solution is selected by the combination of BA and CA that maximized the SN ratio against each BA.

iv. *Calculate the SN ratio and Optimal Design Solution*

The equation for the SN ratio differs according to the type of measurement characteristic. In this study, the target value of hip sliding force is 0 N. When the SN ratio is minimized, it is defined as where FHSi is the hip sliding force and n is the number of the measurement

$$\eta = -10\log\frac{1}{n}\sum_{i=1}^{n} F_{HSi}^{2} \tag{11}$$

characteristics (Yi). If the mean of the hip sliding force is *μ*, and its variance is *σ2*, then the expected value of the SN ratio (*η*) is

$$E(\eta) = -10\log\left[\mu^{2} + \sigma^{2}\right] \tag{12}$$

Therefore, the true value of the SN ratio includes both the mean value of the hip sliding force and variance due to the noise factor.

This simulation yields the optimal CA with the maximum SN ratio for each BA, which prevents the hip sliding force (the hip sliding prevention curve).

- *Simulation results and analyses*

Figure 12 shows the results of simulations 1, 2, and 3 (the hip sliding prevention curves). The curve of simulation 3 lies between those of simulation 1 and simulation 2. This observation can be explained by the interplay of two forces: a decrease in the hip sliding force with the hip sliding posture (calculated from eq. 9), and an increase in the hip sliding force with the forward tilt (calculated from eq. 8).

IV. Sensory Experiment

To confirm the effectiveness of the optimized design solution for the seat swing function with a forward tilt (simulation 3), we performed a sensory experiment to compare the optimal design solution (simulation 3) and the standard solution (simulation 1).

a) Sensory experiment

i. *Conditions*

The sensory experiment included seven different physiques, two types of sitting postures, and the seat described in Section 1.1.1. BA and CA were selected such that CA clearly affected the hip sliding force prevention curves; that is, the experiment included simulations 1 and 3. For each BA (30, 35, and 40 degrees), simulation 1 used CA = 20, 23, and 25 degrees, while simulation 3 used CA = 19, 21, and 23 degrees respectively.

ii. *Method*

Examinees sat in two different sitting postures (standard and hip sliding sitting posture) on the seat using the previously mentioned combinations of CA and BA, and then evaluated the extent to which they "did not feel the hip sliding force" using the SD method on a five-point scale.

b) Analysis of the effectiveness of the optimal design solution

i. *Estimate of the SN ratio*

The SN ratios of the design solutions from simulations 1 and 3 were estimated using the ratings from the sensory experiment on a five-

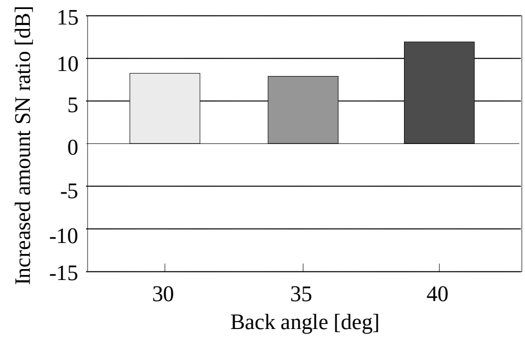

Figure 13 : Increment in SN ratio from conventional solutions (simulation 1) to the proposed solution (simulation 3)

point scale. The SN ratio η is then calculated as

$$\eta = -10\log\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^{2}} \tag{13}$$

where yi is the rating from a given experiment, and n is the number of combinations of CA and BA. The total number of ratings is 14 because examinees evaluated two different sitting postures.

ii. *Analysis of the Sensory Experiment*

Figure 13 indicates that simulation 3 has a larger SN ratio than simulation 1 for all BAs. The solution for simulation 3 prevents the hip sliding force for diverse physiques, sitting postures, and FAs. Thus, the sensory experiment confirms the effectiveness of our optimized solution using diverse conditions (simulation 3).

V. Conclusion

Two seat functions, forward tilt function and seat swing function, are necessary to assure a comfortable sitting posture. Thus, we optimized these functions using the SN ratio, which was obtained by the Taguchi method by considering users' diverse physiques and sitting postures. Moreover, we conducted a sensory experiment to confirm the effectiveness of the optimal design solution. The key findings are summarized below.

1. AHP and Fuzzy AHP analyses reveal that the forward tilt and seat swing functions are most highly rated to assure a comfortable sitting position for diverse conditions, physiques, and sitting postures. Thus, these are the key functions to assure a comfortable sitting posture.
2. A comparison of the design solutions for standard conditions (standard physique, sitting posture, and

FA = 0 degrees) and the seat swing function with a forward tilt (varied physiques, sitting postures, and FAs) reveals that the CA for each BA is lower for the seat swing function with a forward tilt than the standard condition. Although the hip sliding force increases as FA increases, the hip sliding posture decreases the overall force.

3. To compare the optimal design solution of the seat swing function with the forward tilt function to standard solution, we conducted a sensory experiment for varied physiques and sitting postures. The SN ratio of the optimal design solution is higher than that of the standard one, confirming the effectiveness of the design solution in assuring a comfortable sitting posture under diverse conditions.

Herein we have designed a public seat that combines the seat swing function with a forward tilt to assure a comfortable sitting posture. In the future, we plan to optimize public seats based not only on pressure minimization, but also on other aspects of human physiology, such as muscle activity and blood flow.

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Global Journal of Researches in Engineering
Mechanical and Mechanics Engineering
Volume 13 Issue 8 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Improving the Flow Rate of Sonic Pump by Means of Parabolic Deflector

By Ivan A. Loukanov, Motaedi M. & Keaitse M.
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Abstract- This paper investigates the effect of a parabolic deflector on the flow rate of a sonic (resonance) pump. A specially shaped parabolic deflector is designed and manufactured to fit to a1.5" spring-loaded poppet valve and tested on a solar powered sonic pump at resonance frequency of 5.33 Hz. It was found that the flow rates increased by as much as 51% at 22 Watt and by 5.1% at 38 Watt as compared to the case without a deflector and no air in the pipe system. Whenever air is present in the pipes the deflector enhanced the flow rate by as much as 216% at 22 Watt and by 63% at 38 Watt forcing to remove quickly the air from the system. These results are dependent upon the position of the deflector with respect to the valve body, the power input to the oscillating system and the existence of air in the pipe system. It is concluded that the deflector is a simple and suitable means for increasing the pump flow rate.

Keywords: spring-loaded poppet valve, valve head losses, parabolic deflector, valve parameters.

GJRE-A Classification : FOR Code: 290399, 290501p

IMPROVINGTHEFLOWRATEOFSONICPUMPBYMEANSOFPARABOLICDEFLECTOR

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Keywords: spring-loaded poppet valve, valve head losses, parabolic deflector, valve parameters.

I. Introduction

The sonic pumps were used for many decades in the oil industry all over the world. They have the capacity to pump crude oil from as deep as 2000 m (Usakovskii 1973) and are energy efficient since they operate in resonance. Some investigators employ successfully these pumps for pumping ground water from medium to deep boreholes (Loukanov 2007,) and a pumping depth of 100 m is achieved by Usakovskii, 1973. It is also found that the pump performance depends mainly upon the valve design and the number of valves employed (Usakovskii 1973). If poppet valves are to be used the pump performance depends upon valve spring stiffness, valve spring preload, valve stroke and valve diameter (Loukanov, 2010). Since the valves are the only pumping elements involved in the pump design they have to be submersed at suitable depth under the water level in the well (Loukanov, Uziak 2011).

Therefore to design sonic pumps with desirable flow rate one should be familiar with the operating cycle of the pumps, the mechanical parameters of the valves to be used, as well as of how to enhance the valve discharge to satisfy the flow rate requirements. In the study conducted by Loukanov (2013) three valve designs with low friction losses were designed, manufactured and tested: Mainly cluster poppet valve and valves with lateral suction ports. It was found that these valves improve the sonic pump performance. As a result of the above research a parabolic deflector is invented to further minimize valve's head losses and hence the objective of this study is to investigate the effect of the parabolic deflector connected to a spring-loaded poppet valve and find out its contribution to the flow rate of the sonic pump.

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II. Material and Methods

To meet the above objective a special parabolic deflector is designed using the Solid Work software and the shape and overall schematic is shown in Figure 1. The inner and outer design configuration of the proposed deflector is a parabola of rotation to create 3D shaped solid body.

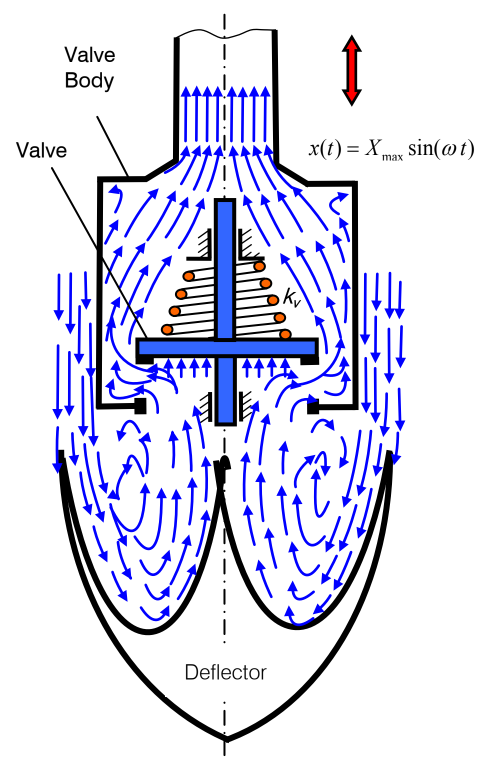

Figure 1 : Diagram of the water flow around and in the valve body as well as within the parabolic deflector

The design is based on the fact that the valve body-parabolic deflector assembly is fixed to the oscillating pipes and hence moving vertically up and

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down consequently the still water in the well appears to move relatively to the assembly.

As seen in the Fig. 1 the inner parabolic shape of the deflector is intended to change the direction of the outer water flow moving relatively to the assembly and redirect it towards the valve input port during the upward stroke of the system. Conversely the outer shape of the deflector is designed to provide the necessary streamlines of the valve body-deflector assembly when the latter moves during the downward stroke and helps minimizing the drug forces. The inverted water flow generates upward pressure on the bottom face of the valve pushing it to stay opened after the point of separation of the water column (WC) from the valve seat (Loukanov 2007) until the top dead position of the oscillating system is attained. When WC separates from the valve a vacuum is generated above the valve itself, which forces it to open allowing the water from the well to enter in the valve body. In this case the WC acts as a piston and the valve body and the pipes as a cylinder. It is the authors that the presence of the parabolic deflector will help reducing the head losses in the valve body by keeping it fully opened as well as aiding the water flow to fill in quickly the vacated volume by the suction effect of the WC.

Next the proposed parabolic deflector is machined from a solid aluminum bar and polished to perfection for minimizing the fluid friction. The complete deflector is shown in Fig. 2, where the parabola shape of rotation of the internal and external shape is seen. It can be observed that the deflector is furnished with three taped holes M4 spaced at 120 degrees to each other to provide the necessary ports of attachment to the body of 1.5”spring-loaded poppet valve.

Figure 2 : An interior-exterior view of the parabolic deflector

The internal shape of the deflector is obtained by rotating a quadratic parabola about the longitudinal axis of symmetry and the shape obtained is called a paraboloid of rotation. After that the parabolic deflector is fixed to a 1.5” poppet valve by means of three aluminum bars and M4 screws. Each bar is furnished with holes to allow three positions of the deflector relative to the valve body. The holes are to be used to determine the correct relative position of the deflector in order to obtain maximum discharge from the valve.

Figure 3 : Assembly view of the parabolic deflector as connected to the 1.5”spring-loaded poppet valve, No. 3

The final assembly of the parabolic deflector as attached to 1.5”, No. 3 spring-loaded poppet valve is shown in Fig. 3. The mounting holes on the bars designated as No. 1, 2, and 3 as well as the attached parabolic deflector are seen in the figure. After preparing the valve assembly it is connected to the oscillating pipe system of the pump and a large numbers of tests are conducted at resonance frequency of 5.33 Hz. This frequency is obtained by a careful selection of the resultant stiffness of spring suspension system as related to the total oscillating mass of the system.

The experimental setup of the sonic pump and the valve assembly is shown in Fig. 4, where the solar panel, mechanical shaker, oscillating pipe and the valve assembly is submersed in the water source, the flow meter and the power equipment are noted.

The DC and AC supply equipment of the sonic pump consisted of one 230 Watt solar panel, two 12 Volt silver calcium batteries connected in parallel, a control charger and a DC to AC inverter. The use of DC-AC inverter is necessitated since the driving motors of the mechanical shaker are two single phase AC motors.

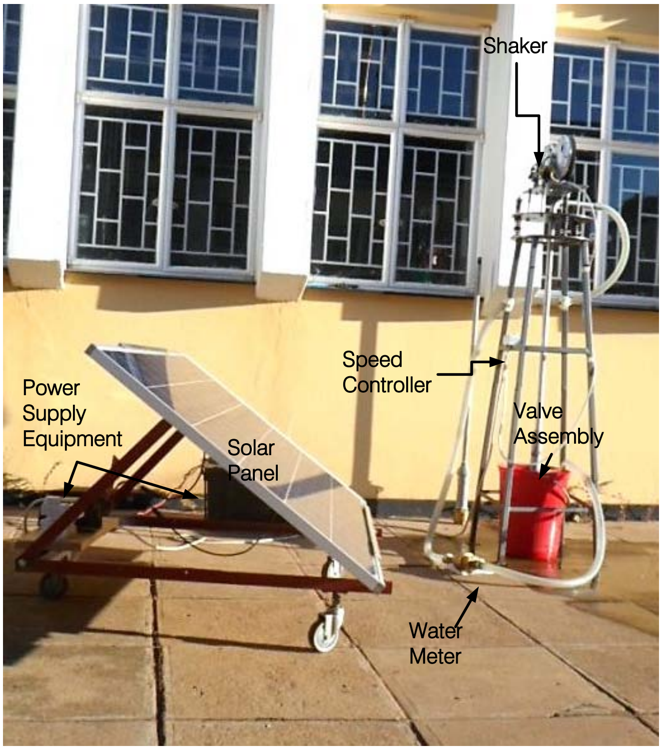

Figure 4 : Test arrangement for the 1.5” spring-loaded poppet valve with and without a parabolic deflector with a model sonic (resonance) pump.

The power supply equipment is shown in figure 5, where the control charger, DC-AC inverter, AC outlet, power meter and the battery pack are noted.

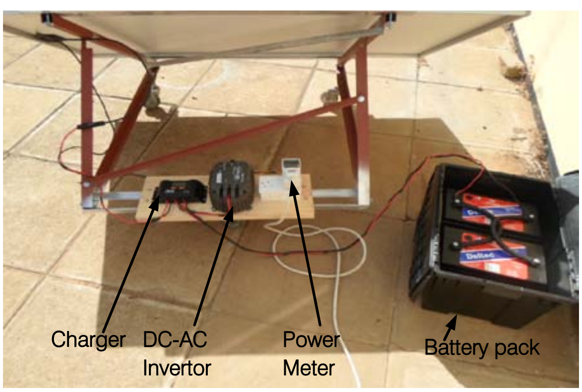

Figure 5 : Back view of the solar panel showing the installation of charger controller, DC-AC inverter, AC socket, power meter plugged in and the battery pack.

III. Results and Discussion

Experiments are conducted on a model sonic pump operated at resonance frequency of 5.33 Hz employing a 1.5”, No.3 spring-loaded poppet valve furnished with and without a parabolic deflector and operated with and without air in the pipe system. The depth of pumping is 1.75 m limited by the height of the pump stand and is measured from the valve inlet port submersed in a container with water to the top end of the oscillating pipes. Water is forced to circulate through a water meter (HP 35, ¾-inch) and return back to the container.

Each trial is repeated four times and the input power is varied from 22 to 38 Watt. The data obtained with no air in the pipes and the deflector being positioned at three relative locations to the valve body is listed in Table 1.

Table 1 : Average flow rates obtained with no air in the pipes by using 1.5”, No.3 valve with and without deflector vs. the power input to the oscillating system

FLOW RATE [liter/minute]				
Power input [Watt]	Without Deflector [no hole]	With deflector [hole 1]	With deflector [hole 2]	With deflector [hole 3]
38	9.38	9.86	10.1	9.24
36	8.81	9.4	10.06	9.39
34	7.65	9.23	9.81	9.44
30	6.97	8.38	9.01	8.88
26	6.03	7.64	7.58	8.01
22	4.02	6.07	5.64	5.94

Figure 6 shows the variation of the average flow rates with no air in the pipe system showing the effect of the parabolic deflector on the valve discharge.

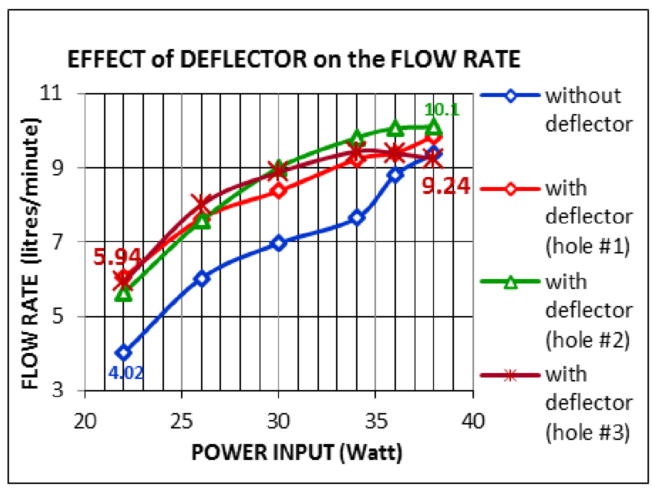

Figure 6 : Comparison of flow rates for 1.5” No. 3 spring-loaded poppet valve with and without a parabolic deflector and with no air in the pipes vs. power input.

A direct observation of the graphs shows that any of the three positions of the deflector give better flow rate than the case without a parabolic deflector.

A comparison made for the effectiveness of parabolic deflector indicates an increase of all flow rates depending upon the input power and the position of the deflector with respect to the valve body. The results show that for power varying from 22 Watt to 38 Watt and deflector positioned in holes No. 1, 2, 3 the percentage increase of the flow rates are found to be: from +5.12% to +51% for the deflector positioned at hole No.1, from +7.7% to +40.2% at hole No.2, and from -1.49% to +47.8% at hole No.3 respectively.

Apparently the presence of the parabolic deflector contributed significantly to the increase of the flow rate and that influence is more noticeable at lower power inputs (22-34 Watt) than at maximum power (36-38 Watt). The reason being is that at maximum power the flow rate values for each setup reached almost their maximums, so the contribution of the deflector is minimal. Obviously the position of the parabolic deflector corresponding to hole No. 2 is the best in terms of the flow rate attained, 10.1 l/min at 38 Watt. It should be noted that in this experimental setup the power input is limited to a maximum of 38 Watt since there were no more spare offset masses to be placed on the shaker. On the other hand the power input may be increased by increasing the speed of rotation but this would require changing the spring suspension system and therefore changing the resonance frequency of the system. To increase the power input for the same resonance frequency more offset masses should be manufactured and installed on the shaker to achieve larger excitation force. So we decided to carry on the experiments at maximum power input of 38 Watt.

The next step in our study was to investigate the effect of the air into the pipe system on the flow rate with and without a parabolic deflector. The experiments were conducted on the same pump setup under the same operating conditions. It is found that when the valve (pump) operates without a deflector it is unable to push the air out of the pipes and only a maximum flow rate of 6.6 l/min at 36 Watt is attained. Surprisingly a further increase in the input power to 38 Watt gave a reduced flow rate of 6.04 l/min. Perhaps it is due to the fact that the valve reached its maximum discharge capacity at 36 Watt. After the experiments it is noted that the air still remained trapped in the pipe system and this is why the flow rate was so little.

A phenomenon similar to this but not exactly the same is detected when the 1.5" No.3 valve is furnished with the parabolic deflector positioned at hole No. 1. The above hole appears to be the most remote with respect to the valve body. It is observed that the valve managed for a short while to gradually push the air out of the pipe system and start increasing the flow rate until a maximum value of about 9.86 l/min is attained corresponding to 38 Watt power input. Obviously this is due to the presence of the parabolic deflector and this fact indicated its strong influence on the flow rate.

Subsequently new experiments were conducted with no air in the pipe system with the same location of the parabolic deflector and the same valve. The results revealed that the pump flow rate varied considerably as compared to that when air is available in the system. To illustrate these, two graphs are constructed showing the effect of the parabolic deflector on the flow rate with air and without air in the pipe system. The graphs are shown in Fig. 7, where some of the values of the experimental points are revealed for an easy comparison of the data analysis.

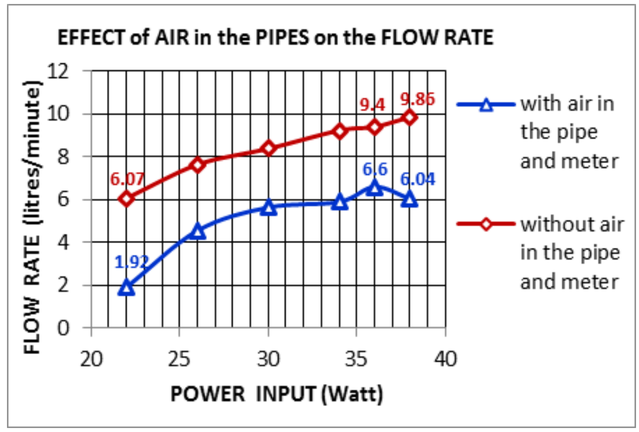

Figure 7 : Comparison of flow rates discharged by a 1.5" spring-loaded poppet valve, hole No.1 with and without air, and with and without a deflector vs power input

From the above graphs one can appreciate the boosting effect on the flow rate caused by the parabolic deflector, where the percentage increase ranges from 216% at 22 Watt to 63% at 38 Watt power input. Once again the higher value is obtained at the lowest power input as found in the case of no air in the system (Fig. 6).

The above results indicate that the effect of the parabolic deflector on the flow rate is significant as compared to the setup without a deflector. The new fact is that the valve with a deflector is capable of pushing the air out of the pipe system and quickly reach the maximum flow rate, which appear to be impossible for the same valve alone. Therefore the presence of the deflector helped the pump to quickly achieve the designed flow rate when air is available in the pipes.

IV. Conclusion

In this paper the results of a unique experimental study comprising a special valve arrangement designed for improving the flow rate of sonic pumps is presented. This included a parabolic deflector connected to a spring-loaded poppet valve which redirects the water flow from around the valve body in the well during the upward stroke of the oscillating system, pushing it towards the valve interior and the pipe system.

As a result the valve is kept fully opened due to the pressure build up on the bottom face of the valve which helped minimizing the head loses in the valve body and thus increasing the flow rate of the sonic pump. It is found that the improving effect of the deflector complimented with the existing suction effect caused by WC in the pipes since it acts as a piston and the pipes as a cylinder likewise as the reciprocating pumps. Both effects work simultaneously towards an

Global Journal of Researches in Engineering (A) Volume XIII Issue VIII Version I Year 2013

increased flow rate of the pump nearly for the same power input delivered by the oscillating system.

Considering the water flow within the parabolic deflector as shown in Fig. 1, it is evident that there are some inevitable energy losses due to fluid friction and changed direction of motion of the fluid. Fortunately these losses are compensated by the energy accumulated in the redirected water flow being taken from the resonance vibrations of the oscillating system. The experimental results revealed that the parabolic deflector contributed appreciably to the increase of the flow rate when there is no air in the pipes by as much as 51% and a flow rate of 10.1 *l*/min was attained at 38 Watt power input.

It is also found that the deflector is capable of removing the air from the pipe system resulting in substantial increase of the flow rate by an average of 216% at of 22 Watt and about 63% at 38 Watt power input respectively.

Therefore it may be concluded that the parabolic deflector changes radically the performance of the pump when operated with the 1.5" spring-loaded poppet valve.

Considering the substantial increase of the valve discharge when coupled to a parabolic deflector we suggest that more experiments to be conducted with larger sizes of similar valves mainly the 2" and 3" spring-loaded poppet valves connected to a suitable size of parabolic deflectors. Perhaps it may be found a higher increase in the discharge of these valves depending upon the effect of the parabolic deflector combined together with the increased valve diameters and the corresponding valve stroke limiting areas of the valves.

It is also important to investigate the effect of the parabolic deflector in relation to the valve parameters such as valve stroke, valve spring stiffness and valve spring preload and investigate the valve performance.

In conclusion to the above recommendations it is suggested to design deflectors using different parabola equations for the interior and study which one is the most effective in obtaining the largest flow rate. In this regard the best parabolic deflector could be employed for practical applications in pumping ground water from deep boreholes.

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Global Journal of Researches in Engineering
Mechanical and Mechanics Engineering
Volume 13 Issue 8 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Computer Assisted System for Manufacturability Evaluation of Prismatic Component During Design Phase

By Devusudhakar S.P, S.S.Hebbal & K Hemachandra Reddy
P.D.A. College of Engineering, India

Abstract- The current work focus on the issues related to the consideration and application of manufacturing knowledge and manufacturing data during product design through integrated product and process design. The work in this direction is expected to enhance productivity and quality and reduce total cost and the time to market. The paper presents a long term research work that involves development of a computer assisted system for the manufacturability evaluation of a given prismatic part. Feature technology and computer assisted tools for automation have been employed for the utilization of manufacturing knowledge and information about the available manufacturing recourses during the design of the product. The features of the system developed for this purpose is described in this paper.

Keywords: design for manufacturing, manufacturing feature, feature based.

GJRE-A Classification : FOR Code: 410499p, 091399

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I. Introduction

The major characteristics of present day manufacturing systems are low quantity, high variety, small batch production, automation of various activities, and application of information technology for integrating different activities. Major business challenges for today's manufacturing enterprises are: Time-to-market, global competition and continuous improvement to satisfy higher expectations of customers. The major goals of manufacturing industries are: high quality, low cost and short delivery time. For achieving these conflicting but essential goals and to be in competition, the manufacturing enterprise must constantly evaluate its business strategy and fine-tune its processes as and when needed. They must be able to implement new production strategies rapidly. The strategy which is currently getting much attention of manufacturing industries is the consideration and determination manufacturability of a product during the preliminary stages of its design.

Manufacturability of a product can be defined as an indication of the effort required for manufacturing that product. Evaluating the manufacturability of a product design involves determining whether or not it is manufacturable with a given set of machining operations and recourses and if it is, determining the corresponding manufacturing efficiency. Since there can be alternative ways of manufacturing a proposed product design, the production plans related to all the possible ways to manufacture it should be considered, in order to determines which one meets the design and manufacturing objectives and is optimal. Given a set of manufacturing resources and product information, the problem of manufacturability evaluation simple becomes to determine whether or not the design is manufacturable and if manufacturable, determine the manufacturability of the given product in terms of manufacturing time, costs, quality and necessary resources.

II. Literature Survey

The basic concepts of Manufacturing features and feature-based representation of given part have been considered as a key area of research on manufacturing systems and engineering, owing to their ability to provide necessary link between design information and manufacturing operations. However, there are several critical research issues which should be must be taken into consideration while fitting the concepts of feature technologies into a systematic framework for manufacturing organizations. A good number of research works are being carried out in this direction. A sample of reported works is presented below.Belay [04] has presented a paper whose aim is to consider the different product development methods in particular on Design for Manufacturability and Concurrent Engineering. Companies can realize and be benefit by minimizing product life cycle, cost and meeting delivery schedule. In this paper work shows the simplified models that can be used by different companies based on the companies' objective and requirements. The Methodologies that are used in this research work are taken in case studies. For the product development process two companies were taken for analysis. From this research, it has been found that the two companies fail to achieve delivery time to the customer. It is found that 50% to 80% of their products

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not delivered in time to the customers, have analyzed the most frequent coming products. The companies which are following the conventional way of product development that is sequentially design and production method, which highly influence time to market. In the case study it is observed that by using these new methods and by forming multi disciplinary team in designing and quality inspection; the work flow steps have reduced from 40 to 30.

Hoque and Szecsi [2 ,3] have explored the application of feature-based representation and design in the area of Design-for-manufacture. The idea is to incorporate parameterized geometry of features; the feature is produced by description of the manufacturing process. (including cutting tool, machine tool, possible fixtures, cutting conditions, and production volume), design limitations, relative cost information, functionality rules, and links to Design-for-manufacture rules at the early stages of design. The designers use the feature library to select the manufacturing features. Upon insertion, the system ensures that Design functionality and Design-for-manufacture rules are applied in real time during the actual design process. The designers are warned if they attempt to include features that are difficult to manufacture or violate functionality rules.

Hendry et al [07] have also proposed a feature library that is able to manage the knowledge of process planners. By enabling the management of the knowledge of process planners, the proposed feature library may be helpful to carry the generation of process plans. Bramall et al [05] have introduced an aggregate planning method, which translates early product characteristics into manufacturing necessities, forms the basis of a new intelligent support system for which the manufacturing evaluation, optimization and reporting functions are described. For the early evaluation of manufacturing scenarios, it allows integrated product and process design teams to evaluate rapidly the manufacturing requirements of a partially specified design based on these important criteria The system 'intelligently explores' the many alternative processing technologies and equipment choices available, seeking solutions that best satisfy a multi-criteria objective function encapsulating quality, cost, delivery and knowledge criteria. The designer is thus presented with the opportunity to redefine the design elements or process specifications, which would yield the greatest improvements in production

Xue and Dong [06] have taken two types of features called design feature and manufacturing features for considering the two product life cycles. The mechanical and mechanisms are represented to satisfy the design function for modeling of a design candidate. The analysis of a design function is based on Design feature coding system. A algorithm called fuzzy pattern clustering is used for design feature library into hierarchical feature group. A graph based search is used for required design feature. A geometric element is produced for manufacturing feature a coding system is developed for manufacturing feature based on product geometry and production operation. For the manufacturing code a group technology approach is used to recognize using fuzzy clustering algorithm. A special optimization module is used for production operations.

In a feature based integrated concurrent design system two coding systems for Generating the design candidates and planning Production process is implemented. Owodunni et al [09] have also presented an Extendible Classification of Design and Manufacturing Features. Salomons, et al [11] have reviewed pointed out In a feature based ,states that for the process planning point of view a feature based design is regarded as a key factor towards CAD/CAPP integration. For supporting design process a feature based design offer better than current CAD system do. In a design Process feature and their rule, design object and design object knowledge are discussed. In a feature based design the main research issues are listed out they are; feature validation, features and tolerances, feature representation, multiple view points of a features and feature standardization. The conclusion is that in the design process better integration with manufacturing is required. In this area more research is needed even though major advances have already been done.

T. Szecsi [12] has pointed out a new design system For development of a design from manufacturing features the system has many modules like manufacturing feature library, manufacturing rule system, manufacturing feature based design module, manufacturing feature recognition module, design advisory module and design analysis module.

Chen and Wei [14] have stated that to support the practice of concurrent engineering a feature based design for manufacturing frame work is used.To develop a design evaluation facilities,object oriented modeling technologies and knowledge based are used.For design evaluation an embedded.

With product design, process knowledge and object oriented product model to recognize area is consructed and used.For a overall shape geometric reasoning is performed on feature, feature interaction with a design principle.

III. System Developed for Manufacturabilty Evaluation

Your paper At present which is recognized as era of automation, it is usual practice to present a designed part through its CAD representation. From the CAD data of the product, it is possible to recognize the manufacturing features of the given part with help of automated procedures and reconstruct the part model in the form of feature based product model. Then it becomes feasible to conveniently associate the manufacturing knowledge and data to the recognized features in order to determine the manufacturability of the given part. The research work carried out for this purpose includes;

- Classification of the manufacturing features systematically and identification of a scheme of representation with help of a set of characteristics of features which play an important role in associating a given feature with necessary manufacturing information.
- A systematic plan to compile, organize and store the manufacturing knowledge and information in well defined databases and also presenting it in the required formats.
- Prepare a feature library which the design personnel can use for consideration during the process of product design.
- Development of a feature based operational library which readily provide the information about the feasible operations for both rough cut and finishing.
- Operations for a given feature. Along with the list of operation for a given feature the associated manufacturing resources are also specified.
- Representation of the manufacturing recourses such as machine tool, cutting tool and fixtures through a set of individual characteristics.
- Utilize the available automated features recognition methodologies to recognize the manufacturing features of a given part.
- Development of computer assisted procedures to relate the characteristics of features with the manufacturing knowledge and information stored in the manufacturing databases.
- Scanning of the database of available resources to search for recourses whose characteristics matches or close to the expected characteristics in order to select most suitable resources for machining the given feature.
- Finally the application of the data gathered from above mentioned databases for determining the manufacturing time, cost and quality aspects (in terms of meeting dimensional and geometrical accuracy and surface finish requirements) to make an Assessment about the manufacturability of the given product.
- Report about the manufacturability of a given part certifying the product design as acceptable and producible or recommend for redesign with suitable suggestions.

In the present work, a system for determining the manufacturability of prismatic parts, has been developed for which the main input required is the CAD file of the given part. It collects the technical data about the tolerances and surface finish from interaction with the user and data about the available resources and machinability data from the databases are generated to support activities of the system. For performing the different functions related to the determination of machinabilty of given prismatic parts, a series of programs are written in C++ and arranged in different modules. For executing the programs one after other without interruption, they are grouped into main programs in which the individual programs are made as program segments of the related to main program. The lists of the programs are developed below

a) The main program that must be executed first for the proposed System is named as MENU.CPP, which welcomes the user and introduces to the system by displaying the menu indicating the necessary order in which the other programs can be executed.

b) The next major program is for the Feature Recognition which is named as FEAT-REC.CPP which performs all the activities related to feature recognition. This program has program segments to perform various activities starting from reading a CAD file to recognize the manufacturing features of the given part. The following are the important program segments of this program:

- Interfacing program segment to read the CAD data, interpret the CAD data in terms of lines and circles and circles into edges.
- Program segment to determine the geometry of each face.
- Program segment to recognize through depression type features.
- Program segment to recognize blind depression type features.
- Program segment to recognize protrusion type features.
- Program segment to recognize complex features.
- Program segment to determine dimensions of each feature.

c) Interactive Technical Data collection program is named as TECH-DATA.CPP, which first receives the output of the FEAT-REC.CPP program and then interacts with the user by displaying the details of the faces of the given part and collects the technical data, i.e., tolerance and surface finish information. It has program segment to add the technical data so collected to each feature.

d) FEAT-OPERATION.DAT is the data base to stores the data about the available manufacturing operations in a given system. The data is complied and arranged with respect to various manufacturing features of prismatic parts.

e) FEAT-OP-SELECTION.CPP is the program which permits the user to edit the information on Feature Based Operations.

f) MACHINE-TOOL-DB.DAT is the database in which details of the available machine tools are arranges in a pre determined format. The program which helps in editing the information on available machine tools is named as MACHINE-TOOL.CPP

g) CUTTING-TOOL-DB.DAT is the data base in which details of the available cutting tools are recorded. The main program which helps in editing the information on available cutting tools and determination of suitable code for each cutting tool is named as CUTTING- TOOL.CPP

h) WORKPIECE-DB.DAT is the database used for storing the information on available work pieces and MACHINING-DATA-DB.DAT is the database used for recording the machinablility data The main program which program permits the user to edit the information on Mach inability Data and available work piece sizes is named as MACHINING-DATA.CPP.

i) The main program of the Machining Planning is named as MACHINING-PLANNING.CPP, which has program segments to carry out the activities related to machining planning and present the list of recommended operations along with the machine and cutting tool and machining parameters for each feature. The following are the important functions performed by its program segments:

- Selection of the work piece.
- Selection of list of operations for each feature.
- Machine tool selection for each specific feature.
- Cutting tool selection for each specific feature.
- Parameter selection for each specific feature.
- Another major segment is for the Setup Planning Subsystem which is concerned with the display of optimal set plan along with the sequence of operations in each setup and the order of execution is setup.
- Related to the Setup planning activities it has a program segment to perform the fallowing activities.
- to list the feasible set up plans.
- to develop all the setup plans and choose the optimal setup plan.
- to evaluate the order of execution of setups.
- to determine the sequence of operations in each setup.
- The last segment is featured to present the report about the machinability of a given component.All the activities performed by the different programs of the system to generate a report about the machinability of the given prismatic part, which are shown in the following Flowchart.

Table 1 : Representation of Feature Through Slot

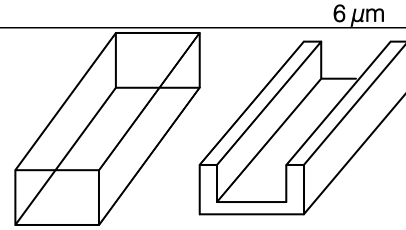
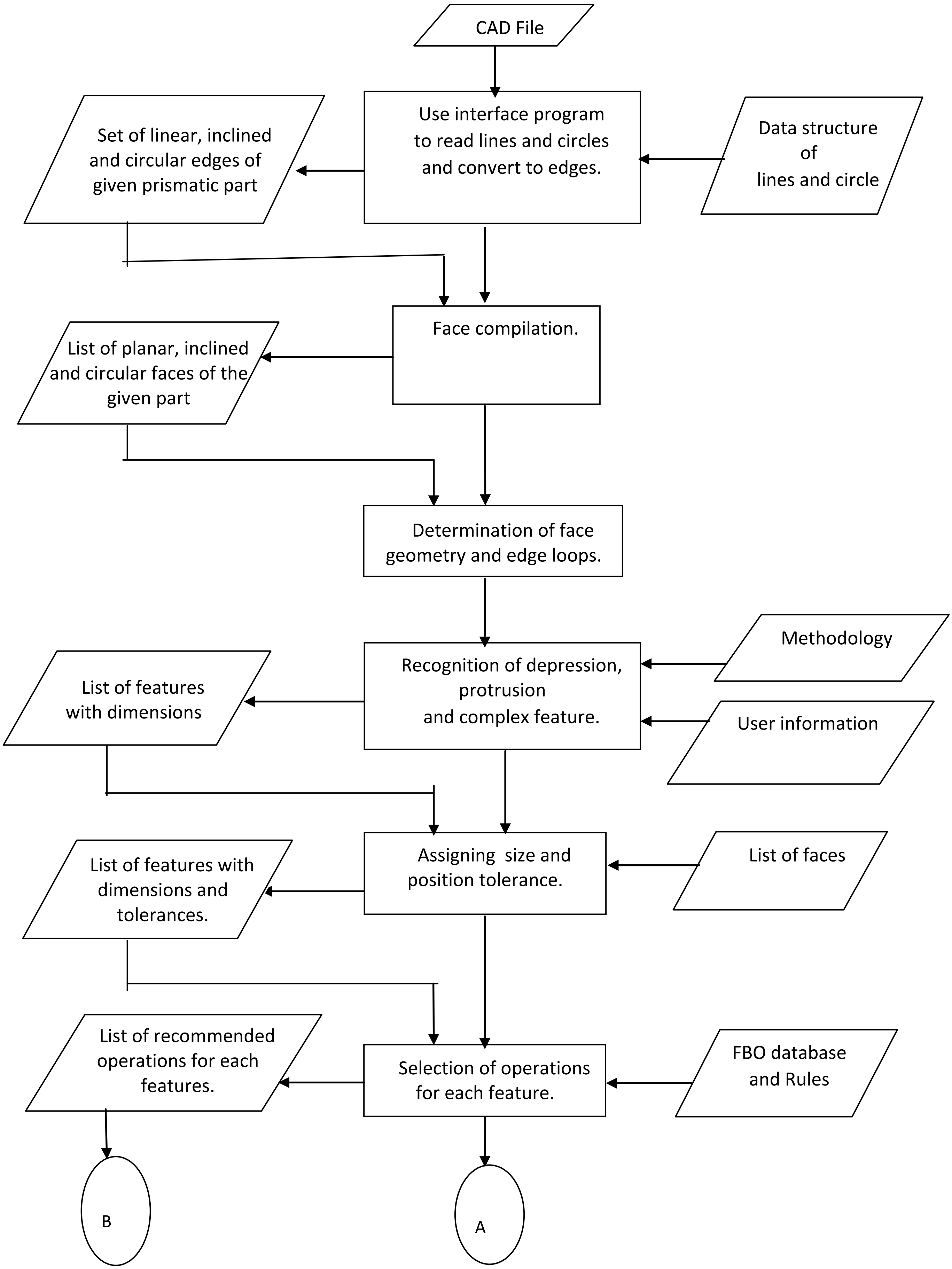
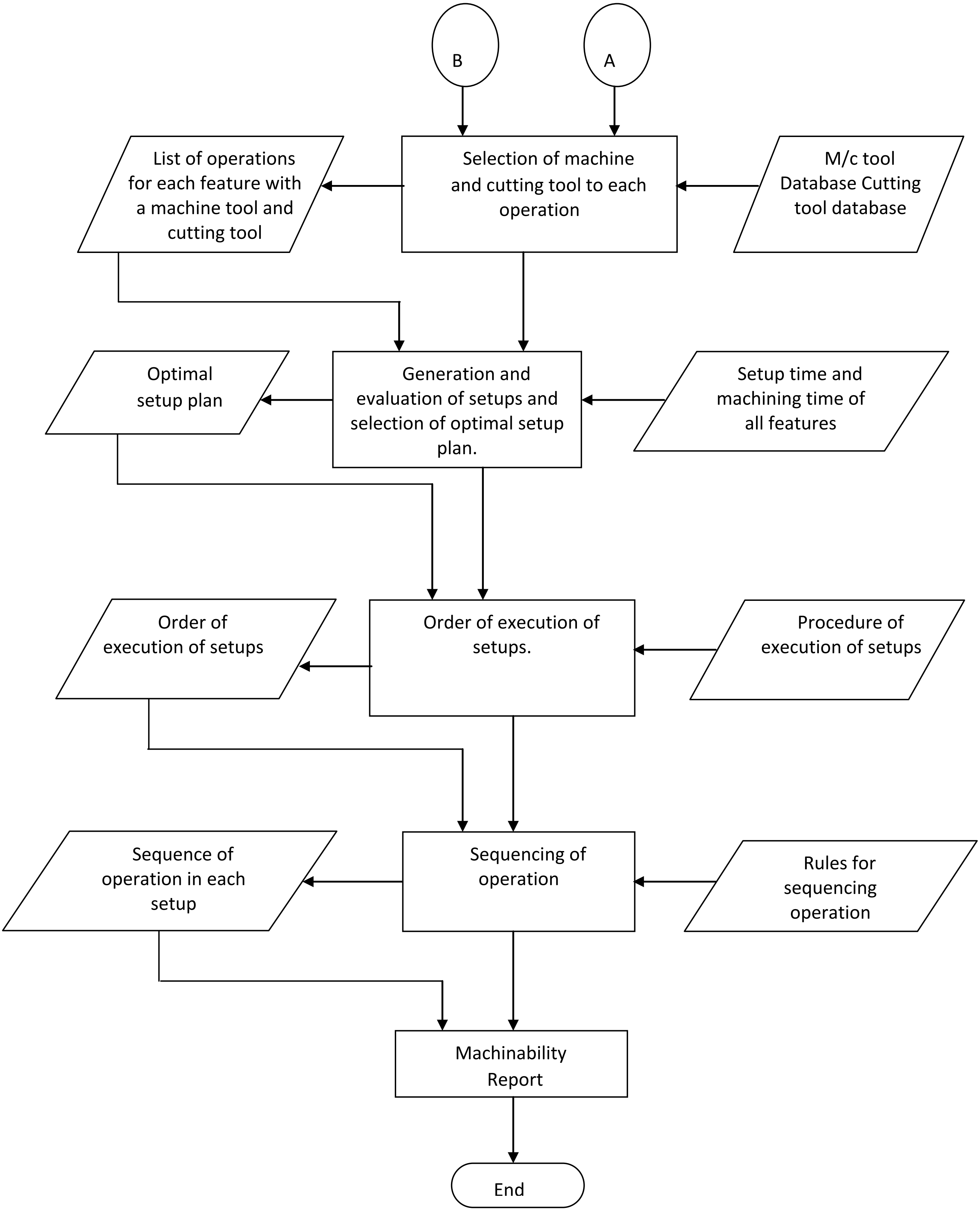
Representation of manufacturing feature-slot	
Feature Description : **Depression type -Through slot**	
Feature Characteristics	
Feature Dimensions	50 X 60 X 200
Faces providing access to feature	f_4 and f_5
Faces forming the feature	f_1 f_2 and f_3
Faces to be used as primary datum	f_6
Tool approach directions	X and Z
Feature designation	Primitive orthogonal
Feature Status	Independent
Surface finish	6 μm
Machinable Volumes for rough and finishing operations	
Dimensional and Geometrical tolerances	$\pm$ 0.01 , $\pm$ 0.01 for position of FFF
Operational References	f_7 for f_2 , f_1 for f_3, and f_8 for f_1
Manufacturing methods / operation	
1. **End Milling** 2. **Side Milling** 3. **Face Milling** 4. **Shaping**	

Table 2 : Sample Table Showing Feature Based Operational Data for Rough Cuts

Feature Name and its code	Operation	Machine tool	Cutting tool	Fixture
TSTPN (Normal)	Side milling	Horizontal. Milling M/C.	Side Milling Cutter	
	End milling	Vertical Milling M/c	End Mill	
TSTPD (Deep)	Side milling	Horizontal. Milling M/C.	Side Milling Cutter	
	End milling	Vertical Milling M/c	End Mill	
TSTPW (Wide)	Face Milling	Vertical Milling M/c	Face Milling Cutter	
	Shoulder Milling	Horizontal. Milling M/C.	Shoulder mill	


CAD File
Use interface program to read lines and circles and convert to edges.
Set of linear, inclined and circular edges of given prismatic part
Data structure of lines and circle
Face compilation.
List of planar, inclined and circular faces of the given part
Determination of face geometry and edge loops.
Recognition of depression, protrusion and complex feature.
Methodology
User information
List of features with dimensions
Assigning size and position tolerance.
List of faces
List of features with dimensions and tolerances.
List of recommended operations for each features.
Selection of operations for each feature.
FBO database and Rules
B
A


B
A
List of operations for each feature with a machine tool and cutting tool
Selection of machine and cutting tool to each operation
M/c tool Database Cutting tool database
Optimal setup plan
Generation and evaluation of setups and selection of optimal setup plan.
Setup time and machining time of all features
Order of execution of setups
Order of execution of setups.
Procedure of execution of setups
Sequence of operation in each setup
Sequencing of operation
Rules for sequencing operation
Machinability Report
End

IV. Conclusions

For customer needs The integration of product and process design will be in a more producible, A faster and smoother transition to manufacturing leading to less time to market better quality with a reduced total cost. For controlling the cost and product quality integration of product and process design with resources capabilities is an important during its design. For achieving the concurrent and process design to identify the necessary manufacturing resources and to quantify the manufacturing variable is an important part. The computer assisted automation tools are expected to play a critical and a significant role which lead towards aiming and sustaining in a competitive advantage through the development of high quality products which are manufactured by the synergy of integrated product and process design. Therefore the current work which aims at automation and optimization of integration of design and manufacturing is expected to satisfy the needs of current manufacturing industries to meet challenges of global competition.

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Global Journal of Researches in Engineering
Mechanical and Mechanics Engineering
Volume 13 Issue 8 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Quantum Aspects Evolutions Tribosystems

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Abstract- The present work deals with the changes which evolve in the tribosystem from the viewpoint of the quantum theory of measurement. It is shown that measurement both enables to determine some parameters of the friction unit and affects the tribosystem structure and properties. The theoretical argumentation in the article is based on the most fundamental concepts: the non-force quantum fields, nonlocal correlations, quantum entanglement, and model of H. Everett. The tribosystem evolution is viewed as the set of spatial transitions from non-local original state to tribosystem material state registrable by measurement. Some conclusions from the evolution quantum model are confirmed experimentally by studying triboplasma matter as a quantum object.

Keywords: tribosystem, measurement, decoherence, state vector, disturbance, triboplasma.
GJRE-A Classification : 010503, 091309

QUANTUMASPECTSEVOLUTIONSTRIBOSYSTEMS

Strictly as per the compliance and regulations of :

Quantum Aspects Evolutions Tribosystems

D.N. Lyubimov [α] & K.N. Dolgopolov [σ]

Abstract- The present work deals with the changes which evolve in the tribosystem from the viewpoint of the quantum theory of measurement. It is shown that measurement both enables to determine some parameters of the friction unit and affects the tribosystem structure and properties. The theoretical argumentation in the article is based on the most fundamental concepts: the non-force quantum fields, non-local correlations, quantum entanglement, and model of H. Everett. The tribosystem evolution is viewed as the set of spatial transitions from non-local original state to tribosystem material state registrable by measurement. Some conclusions from the evolution quantum model are confirmed experimentally by studying triboplasma matter as a quantum object.

Keywords: tribosystem, measurement, decoherence, state vector, disturbance, triboplasma.

I. Introduction

The existing at present the variety of antagonistic in many respects fiction models which absolutely mostly reflect adequately various regularities of friction processes may logically be mutually contradictory because they are based on correctly executed experiments. Proceeding from modern ideas of the theoretical physics, it can be assumed that the measurements proper affect the tribosystem, alter its original structure and turn it into a purely mechanistic system without any influence of molecular forces (the model of G. Epifanov). Meanwhile, following the ideas of D. Tomplinson, B. Derjagin, about the prevailing role of molecular interactions in the friction process confirmed by the experiments conducted by Bowden and Tabor [1], the tribosystem transforms into object subordinated to the microworld quantum laws. To eliminate this contradiction, let us assume that all validly confirmed friction models are separate reflections of one object which we call the "tribosystem proper".

The role of measurements we describe is unusual for three classic science, but in the quantum mechanics any measurement of physical parameters leads to exactly these changes in the physical system. The great Danish physicist N. Bohr was probably the first to realize it. He believed that physical measure-ements are not a simple routine of comparing the experimentally obtained results with the available standards; the measurement is a physical phenomenon of interaction of the object in question and the method of obtaining its information, or the instrument. The tribologists and other scientists lack principally the research methods which do not directly affect the object of study (the tribosystem) [2]. This object itself during measurements produces a certain influence on the instrument creating the inseparable system «object-instrument» [2, 3].

Recognition of the inseparability of the system «instrument-object» demanded from the quantum to introduce new stipulations: the principle of uncertainty and the issuing rejection of determinism of the classic physics and transition to the statistic description of physical processes and admission of existence of simultaneously immeasurable values (the non-commuting values in the quantum theory) et cetera. [2]. As regards the measurement result, then, following the works of P. Dirac, it is the only opportunity is to obtain the result coinciding with one of the eremitic operator value proper characterizing this physical value in the quantum mechanics as the function of coordinate, pulse and time [3]. To describe the act of measurement, the notion was introduced "the observed value" implying any practically measurable value. The inverse statement is true also: any at least theoretically observable value can be measured with a suitable instrument [3].

The physical essence of quantum measurements meets with the known contradiction according to which the quantum laws study the object and reproduce it in the classic instrument parameters. To describe this process, the notion of reduction (collapse) of the wave function was introduced at which the quantum parameters transform into the classic ones. The wave function reduction is invariably combined with the loss of a portion of information about the quantum system. This fact founded the assumption of A. Einstein that the quantum world description is incomplete [4]. N. Bohr carried out the detailed analysis of A. Einstein's viewpoint and proved that he was wrong and grounded the appearance of completely new ideas which led to the model of non-force interaction, the theory of quantum non-locality, the quantum entanglement of systems and the theory of non-local information state [4].

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The wave function reduction was explained in the concept of H. Everett [5]. In his view, the act of measurement reduces to transforming the instrument proper changing from one macroscopic state into another one; naturally, it cannot be described with the laws of quantum mechanics. Mr. Everett considered different classic instrument states as the division of the objective world into a number of subworlds which corresponds to the number of alternative variants (the own values) obtained when quantum equations are solved. Each subworld of Everett contains the same measuring instrument exploring an absolutely identical object as the corresponding observer's exact replica. The difference is that each subworld yields its own measurement result from the set of variants obtained by solving quantum equations. In the remaining part all the worlds of Everett are identical; therefore, they are physically unambiguous.

The Everett model acquired a particular significance after appearance of the theory quantum non-local states and the idea of quantum entanglement. The notions of quantum entanglement and non-locality relates strongly to the force interaction between quantum objects transforming them into a single entity so that it is impossible to split the physical system into separate independent parts. Under any conditions, these parts are considered integral [6].

The original quantum system prior to reduction is in the non-local state; Russian physicist theoretician S. Doronin terms it as "pure information" [6]. The material forms, such as secondary formations, appear due to some action (measurement) called decoherence. The wave function reduction in this context can be related to the 'materialization" of one of the possible subworlds of Everett which appears due to the decoherence of the original quantum system caused by measurement. It is particularly noteworthy that other "subworlds" (possible alternatives of quantum reality) do not vanish and can appear at any moment. The decoherence can be interpreted as the folding of the original space into a smaller space in which the current reality variant continues to exist also in other subsystems combined by the quantum entanglement. Hence, the decoherence measurement characterizes the transition of the studied object from one reality level to another one. Each of these quantum realities has a corresponding space of events possessing own metrics and temporal regularities [6].

II. Measurement of Quantum Tribosystem Structure

When the tribosystem is considered as the physical system evolving by the laws quantum mechanics can be determined as the earlier introduced notion of the "proper tribosystem" in the term of the "non-local" quantum theory. The tribosystem is a multidimensional quantum object which is in a strongly degenerated non-local state; its physical, mechanical and chemical properties are being formed and demonstrate in the process of measurement act. In other words, the technological characteristics result from the decoherence of the states of the "tribosystem proper" manifesting during specific measurements.

The decoherence and the relating transition from the original non-local state into material triboengineering forms can be considered as the projection of non-local information substance of the "tribosystem proper" from the multidimensional phase space into the tangible world of four-dimensional space and time continuum of G. Minkovskii [7]. This transformation of phase spaces from the viewpoint of linear algebra is the system of linear equations; their number equals the number of measurements of the phase space in which the "tribosystem proper" locates. The number of summands in each equation is determined by the space basis in which the decoherence product "materializes". Because this product is registered in the space of Minkovskii, these summands should number four.

Assume that A_1, A_2, A_n... act as some characteristics of the "tribosystem proper", q_1, q_2, q_3, q_4 act as the bases of its material state due to the decoherence. Let us use the symbols of P. Dirac and record the genera system of equations characterizing the tribosystem behavior:

$$
\begin{array}{l}
|A_1\rangle = a_{11}|q_1\rangle + a_{12}|q_2\rangle + a_{13}|q_3\rangle + a_{14}|q_4\rangle \\
|A_2\rangle = a_{21}|q_1\rangle + a_{22}|q_2\rangle + a_{23}|q_3\rangle + a_{24}|q_4\rangle \\
------------------------- \\
|A_n\rangle = a_{n1}|q_1\rangle + a_{n2}|q_2\rangle + a_{n3}|q_3\rangle + a_{n4}|q_4\rangle \\

\end{array}
\qquad (1)
$$

Where a_{ni} (i – the parameter characterizing the number of measurements of the space of Minkovskii) – the coefficients of vector decomposition of the wave function, $|q_i\rangle$ – the vectors of states.

The condition of a similar physical object, including the tribosystem, in accordance with the laws of quantum mechanics, should be orthonormal, respectively, the non-diagonal coefficients a_{ij} transform into the system of equations (1); the indices of which differ by more than a unity and are assumed equal to zero. In order that the system of vectors serves as the basis of liner space it is required and sufficient of the matrix a_{ij} be square and its determinant differs from zero. Then the matrix of coefficients a_{ij} turns plotted from sixteen components characterizing the sixteen dimension of the space of localization of the "tribosystem proper". By additionally assuming that the non-diagonal coefficients a_{ij} in the final matrix structure have zero equality, the following matrix is obtained:

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$$A_{ij} = \begin{Vmatrix} a_{11} & a_{12} & 0 & 0 \\ a_{21} & a_{22} & a_{23} & 0 \\ 0 & a_{32} & a_{33} & a_{34} \\ 0 & 0 & a_{43} & a_{44} \end{Vmatrix} \quad (2)$$

The appearance of the matrix A_{ij} (here three (2×2)-subsystems of diagonal elements are present, (Fig. 1) indicates that the tribosystem in the quantum state is a three times degenerated physical object.

The measurement act proper can be repre - sented in the following manner: assume the Hamiltonian H (energy operator) characterizing their original state of the "tribosystem proper", the Hamiltonian h of the tribosystem manifested due to it's decoherence when measured. Then, in accordance with the laws of quantum mechanics, the commutators of these values equal zero [3].

$$[Hh] = Hh - hH = 0 \,, \quad (3)$$

Both Hamiltonians H and h, due to different dimensionality of their space localization, are recorded in the matrix form as follows:

$$H = \begin{Vmatrix} H_{11} & H_{12} & H_{13} & H_{14} \\ H_{21} & H_{22} & H_{23} & H_{24} \\ H_{31} & H_{32} & H_{33} & H_{34} \\ H_{41} & H_{42} & H_{43} & H_{44} \end{Vmatrix}, \quad (4)$$

$$h = \begin{Vmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{Vmatrix}.$$

Correspondingly, the product (3) of matrices (4) is the following:

$$Hh = \begin{Vmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \\ C_{31} & C_{32} \\ C_{41} & C_{42} \end{Vmatrix}, \quad (5)$$

$$hH = \begin{Vmatrix} C'_{11} & C'_{12} & C'_{13} & C'_{14} \\ C'_{21} & C'_{22} & C'_{23} & C'_{24} \end{Vmatrix}.$$

Where C_{ij}, C'_{ij} – the coefficients found in the standard manner by multiplication of matrices.

If two independent measurements are performed of the "tribosystem proper" yielding the results h_1 and h_2 then it can be shown from relation (3) that: $Hh_1 + h_2H = Hh_2 + h_1H$, or in the matrix form it is recorded as follows:

$$\begin{Vmatrix} \Delta C_{11} & \Delta C_{12} \\ \Delta C_{21} & \Delta C_{22} \\ \Delta C_{31} & \Delta C_{32} \\ \Delta C_{41} & \Delta C_{42} \end{Vmatrix} = \begin{Vmatrix} \Delta C'_{11} & \Delta C'_{12} & \Delta C'_{13} & \Delta C'_{14} \\ \Delta C'_{21} & \Delta C'_{22} & \Delta C'_{23} & \Delta C'_{24} \end{Vmatrix}. \quad (6)$$

Expression (6) reflects the procedure of transponation of matrices proving that the state of quantum system described by matrices ΔC_{ij} and $\Delta C'_{ij}$ are conjugated. The latter in the geometrical interpretation can be considered as the turn by 90^0 of the basic linear spaces of localization of tribosystems [8] (Fig. 2). Fig. 2 is the presentation how the basic configurations change their orientation in the Minkovskii space during the decoherence of physical systems (tribosystems) as the traditional model "light cone" intensively applied in the special theory of relativity. The orthogonality of light cones ΔC_{ij} and $\Delta C'_{ij}$ indicates that there are not any "force" links between them, but it does not absolutely preclude the quantum correlations due to the non-local effects of the non-force origin. The existence of quantum correlation links between quantum subsystems of the type of electron paramagnetic resonance interaction[1] proves that there are non-diagonal coefficients a_{ij} in the matrix A_{ij} [9]. S.I. Doronin, Russian physicists and theoretician, remarked [7] that the symmetric matrix structure (Fig. 1) results from the properties of the quantum system which act always in pairs. The diagonal matrix elements determine the set of main states of the quantum system, while the non-diagonal elements characterize the correlation links between quantum subsystems.

III. Test of Tribosystem Quantum Model

The above arguments, at the first look, have the nature of abstract mathematical reasons. The quantum theory was constructed so as to intentionally exclude those values and notions which cannot be revealed by experimentation. While the tribology at present is mostly the experimental scientific discipline having a strictly application trend. Therefore, the experimental testing of the proposed tribosystem model based on the non-local elements of the quantum theory is the inseparable part of the developed theoretical tribological concept. As the staring point of this testing, let us use the idea abot the disturbing measurement effect on the degenerated information structure of the "tribosystem proper". Let us consider this effect from the viewpoint of the theory of disturbance [2]:

1. The position of disturbed levels depends on the extent of disturbance which increases the "spacing" between closest levels as a result the quantum system degeneration is removed.

[1] EPR is the abbreviation of the family names of A. Einstein and Austrian physicists B. Podolskii and N. Rozen who in 1935 emphasized the incompleteness of the quantum mechanical description of the physical system with the conceptual experiment implying measurement of parameters indirectly by affecting the system [4]. The EPR-interaction , for instance, appears when a particle is born having a zero own moment; a couple of particles (EPR twins) with oppositely directed spins and the behavior due to the principle of uncertainty of Heisenberg is interlinked (entanglement) irrespective of the spacing between them.

2. The degenerated quantum object with the main quantum number n, after the external field F is imposed, splits up into the ($2n$-1) component with the spacing between extreme demilevels after the splitting equal to [2]:

$$\Delta W = 3F \cdot n(n-1) \cdot \qquad (7)$$

In accordance with the general matrix view of decoherent tribosystems with the Hamiltonian terms, the quantum number n is equal to eight (n=8). In order to appreciate the relevance of this result, the tribosystem should be experimentally studied in the state in which the quantum effects are most evident. This state is the triboplasma or the super excited matter state on the friction surface [10, 11].

To study the quantum structure at this state, the tribometer type *Falex* was devised with the contact geometry "shaft – partial insert"; it is described in detail in works [11-16]. This tribometer used the non-destructive radio spectroscopy method to investigate the electromagnetic processes initiated by friction in the "fluorine plastic-steel" tribounit. The friction apparatus design permits to create electric and magnetic fields in the friction unit and to test it also in the vacuum [11, 17]. The friction parameters of the tribosystem are registered electrically by the power (P, W) of the friction apparatus motor expended directly to overcome the friction force.

The finding in the experiments published in works [13-14, 16] have revealed the following:

1. The friction power depends qualitatively on the frequency of external magnetic field imposed in the friction unit via the value range of maxima and minima.
2. The friction power for the selected testing conditions and friction unit materials corresponds to three broadest regions limited by frequency bands 80, 300 and 600 MHz (Fig. 3).

The obtained signal decomposition into separate harmonics reveals that the frequency range from the first minimum at 80 MHz belongs to two harmonics of the electromagnetic spectrum emitted by the triboplasma or 30 and 40 MHz, the second portion with the limited power P at 300 MHz belongs to five harmonics 80, 120, 160, 200, 250 MHz, the third portion belongs already to seven harmonics from 320 to 600 MHz. the dependencies in Fig. 3 in work [16] were analyzed and it was assumed that it is the case of distinct triboplasma shell structure like the quantum structure of atoms. The total number of harmonics is noteworthy or separate states N: N = 2+5+7 = 14 unities. Because the frequency range was above 600 MHz, we have not studied this range in detail and presume that the harmonics should number more. The spectral regularities permit to assume highly accurately that the total number of harmonics should be not less than N = 15…16. Earlier it has been remarked that the number of components N equal to the number of quantum states relates to the quantum number n through the relation N = $2n$-1. Thus, n is integer; assuming N = 15 find that n = 8, it corresponds to the matrix structure (6).

IV. Conclusions

This coincidence is little likely to be accidental, it is rather that the triboplasma quantum structure relates to the phenomenon of decoherence and the tribosystem we obtained formally mathematically with minimal tolerances reflects sufficiently the true internal processes evolving at micro levels of friction contact where the quantum correlations "reign". If it is actually so, it is particularly worthwhile to look for the non-power interactions determining the relation between vaqriious manifestation of the "tribosystem proper". This conclusion is validly confirmed by the fact that the matrix structure (2) presumes the existence of three subsystems "emerging" due to the decoherence of the original tribosystem as the quantum object and appearing to researchers as the objective reality resulting from the triboanalysis.

V. Acknowledgements

The authors would like to thank the LIK Co, Ltd for providing the funds for this work and invaluable help in manuscript preparing.

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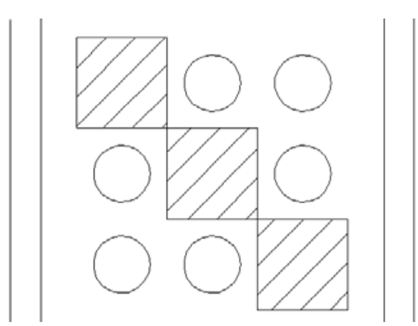

Figure 1 : Structure of matrix A_{ij} (4×4): shaded square areas correspond to three (2×2)-subsystems

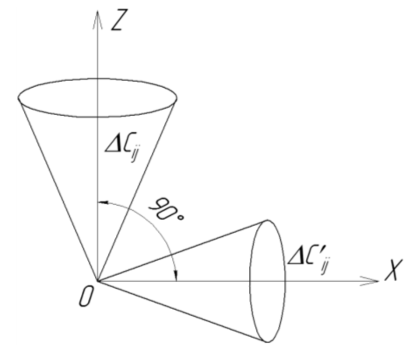

Figure 2 : Turn of light cone of space of Minkovskii of "tribosystem proper" when it undergoes decoherence during measurement

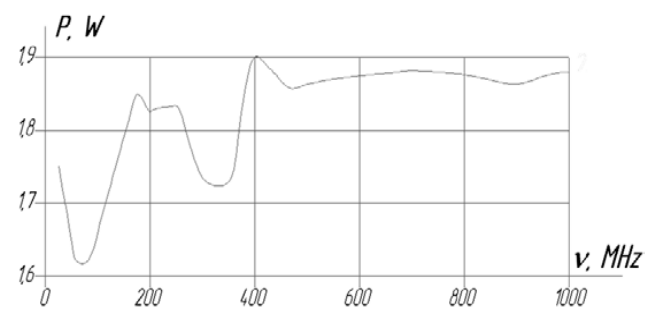

Figure 3 : Variations of power P (W) expended by friction apparatus electric motor to overcome friction forces in steady wear of friction couple "fluorine plastic-steel" in response to frequency ν (MHz) of electromagnetic field imposed on friction unit.

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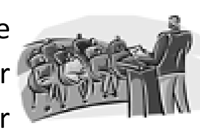

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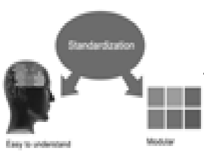

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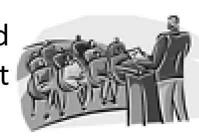

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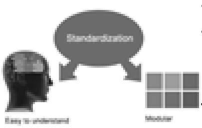

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Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

5.STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(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, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

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

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

Format

Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

Structure

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive 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) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

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

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin 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 research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, 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. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. 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.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

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The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. 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.

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

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

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

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

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. 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 to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

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

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

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

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After 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 to 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 in 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 criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of 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 the 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 evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

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

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing 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 approach 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. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than 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 maintain the initial two items to no more than one ruling each.

- Reason of the study - 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 quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

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

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

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

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

Methods:

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

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

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

Results:

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

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

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

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to 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 part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a 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 implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly 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 with prospect, and let it drop at that.

- Make a decision if each premise is supported, 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 the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One 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 available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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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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ISSN 9755861