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Enhancement in Tolerance design of Mechanical Engineering using Intelligent Techniques

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Abstract – Tolerance configuration has turned into a delicate and significant issue in item and procedure development in light of expanding interest for a key element in industry for improving item quality and the growing requirements for automation in manufacturing. Tolerance decisions can significantly affect the quality and cost of product. It is an intelligent procedure among structure and assembling decision making. Planners need tight tolerance to guarantee product execution; makers incline toward free resistances to lessen cost. There is a basic requirement for a quantitative plan tool for indicating tolerance. The examination and comparative analysis of recent studies related to the design requirements in mechanical engineering furthermore, producing capacities together in a typical model, where the impacts of resistance determinations on both plan and assembling prerequisites can be assessed quantitatively. In this paper, we presented the systematic review of tolerance configuration includes rehashed calculation following two interchange steps: (a) tolerance analysis and (b) tolerance synthesis. Critical measure of literature is identified with resistance methods. Outlines of best in class, the latest developments, and the outcome of this paper claims the various research gaps identified from literature review.

Keywords-: Tolerance Design, Mechanical Engineering, Intelligent Techniques

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1. INTRODUCTION

Routing Tolerance plays a vital role in any industrial product. Designer has to be very careful while dealing with tolerance. It is highly demanded to sell a product at low cost with higher accuracy. So it can perform efficiently. To fulfil such requirements it is advised to know about tolerance.

The wise specification of dimensional tolerances for manufactured parts is becoming recognized by industry as a key element in their efforts to increase productivity. Modest efforts in this area can yield significant cost savings with little capital investment. It is a prime example of the success that results from including manufacturing considerations early in the design process. Both engineering design and manufacturing personnel are concerned with the magnitude of tolerances specified on engineering drawings, as shown in **figure 1**.

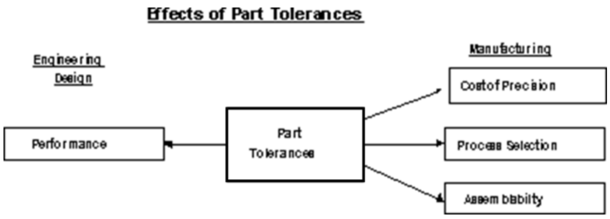

Fig. 1. Assignment of tolerances concerns both

2. ENGINEERING & MANUFACTURING

Engineers know that tolerance stacking or accumulation in assemblies controls the critical clearances and interferences in a design, such as lubrication paths or bearing mounts, and thus affects performance. Production people know that tight tolerances increase the cost of production. Tolerances also greatly influence the selection of production processes by process planners and determine the assimilability of the final product.

Tolerance specification, then, is an important link between engineering and manufacturing. It can become a common ground on which to build an interface between the two, to open a dialog based on common interests and competing requirements.

However, designers often assign tolerances arbitrarily or base their decisions on insufficient data or deficient models. Any resulting problems must be corrected as they arise during manufacturing planning, tooling and production. Clearly, today's high tech products and growing international competition require knowledgeable design decisions based on realistic models which include producibility requirements. Hence, several issues relative to tolerance specification methods are raised:

1. How can we get Engineering and Manufacturing to communicate their needs effectively?

2. Which tolerance analysis models are both realistic and applicable as design tools?

3. What role should advance statistical and optimization methods play?

4. How can we get sufficient data on process distributions and costs to characterize manufacturing processes for advanced tolerance analysis models?

In the following discussion, several useful tolerance design tools are described with examples, some of which have not appeared in print before. Some of the limitations of the common engineering models for tolerance analysis are pointed out. In response to these limitations, a simple new model suitable for designers is presented, which has greatly increased flexibility and permits a more realistic representation of actual manufactured parts. Finally, advanced tolerance analysis methods are reviewed, with an evaluation of their potential for use in design.

3. LITERATURE SURVEY

In [1] first formulated a technique for optimal tolerance allocation choosing one of possible many process alternatives. They used linear 0–1 integer programming, with cost as the objective function and design requirements as constraints. This technique is suitable where sequences and tolerances of operations are fixed. A similar model is that of Lee and Woo (1989), in that tolerances are treated as process-specific, but this model uses a simplified stack-up condition and a more efficient branch and bound algorithm. As a result, its applicability was improved. Chase et al. (1990) presented three methods— exhaustive search, univariate search, and sequential quadratic programming—to solve the models originally proposed by Ostwald and Huang. The advantages and disadvantages of each approach are discussed.

In [2] proposed a new slope-based method that took into account process selection. This method eliminates component-wise process selection, hence eliminating the generation of process combinations and improving efficiency.

All these models assume each component dimension is produced by only one process. The tolerance obtained from the process has a single fixed value. A cost is associated with each tolerance value. This assumption limits the model, however, because it rarely holds in practice.

In [3] reported an analytical model for simultaneously allocating design and machining tolerances based on a criterion of least manufacturing cost. In their model, tolerance allocation is formulated as a nonlinear optimization problem based on cost-tolerance relationships. A simulated annealing algorithm is used to solve the optimization problem. In [4] solved the same model using genetic algorithms; they found that genetic algorithms performed better than simulated annealing algorithms for solving nonlinear programming problem

In [5] are more practical than those previously mentioned because they allows single dimensions to be produced by multiple processes, and because the cost-tolerance function is treated as continuous rather than discrete. Also the models allow tolerances to be loosened—compared to the other models—they have been considered quite successful. However, they fail to consider product quality, which degrades when tolerances are loosened.

In [6] presented a general optimization model in terms of costs associated with variances of the components and losses associated with the variability from the quality characteristic target. They also derived formulae to calculate quality loss as a deviation from a norm. Cook and DeVor (1991) proposed a means of computing the quality loss function from their S-model.

In [7] allocates tolerances based on profit maximization. The quality loss function is used to determine the reduction in value due to an off-target product, which is then balanced against reductions in manufacturing cost. Optimal profit occurred when the derivatives of the quality loss and manufacturing cost functions were equal, but only with respect to design tolerances and not manufacturing processes. Again, this introduces the likelihood that the manufacturing tolerances will be too tight as a result.

In [8] developed a quality loss function based on component lifetime. Total component lifetime represents the customer's objective, and a function is developed from physical relations between critical dimensions and lifetime. The total loss function for the customer is then determined by including component price. Jeang (1995) developed a few general mathematical models to determine product tolerances minimizing the combined manufacturing costs and quality losses (but not considering alternative manufacturing processes selection), using quadratic and geometrical decay functions. The models were also formulated with multiple variables, which represented the set of characteristics of a part.

In [9] presented a procedure to incorporate quality loss concepts into the optimal tolerance allocation process. Manufacturing cost and estimated quality loss were considered simultaneously. Xue et al (1995) developed a method that uses functional performance rather than quality loss. They provided a method to jointly evaluate and optimize the combined effects. However, establishing a usable and accurate representation of the functional performance is difficult and requires further study. Thornton (1999) proposed a method of decision making that balances the cost of reducing variation against the cost of reworking parts. The cost of variation reduction is similar to Taguchi's quality loss function curve. The cost of rework is a traditional pass/fail measure. The method focuses on decision making rather than tolerance synthesis. Ye and Salustri (2003) presented a general optimization model for simultaneous tolerance synthesis for manufacturing and quality. The deviations are controlled by tolerances. The quality loss function transforms the degradation into a cost to society that can then be included in an objective function along with manufacturing costs.

4. RESEARCH METHODOLOGY

Basic principle of fuzzy modeling is based on Zadeh‟s extension principle (Zadeh1965). For a mathematical model if all input parameters are known with defined dependent variables which are crisp values and it is assumed that the input parameters are precise and are represented as fuzzy numeric, then the resulting output of the model will also be fuzzy numeric characterized as membership functions. Fuzzy numbers are very useful in modeling of functional tolerances. Fuzzy Logic is based on the concept of representing knowledge linguistically instead of mathematical form of representation. The transfer of from one category / concept, idea, or problem state - to the next is gradual with some states having high or low membership in one set and then another. Most design problems are deceptively complex. Fuzzy rules have been advocated as a key instrument for communicating bits of information in "fuzzy logic". The tolerance analysis is made by comparison of geometric features to the manufacturing capability of a workshop. Fuzzy analysis is based on comparison of availability of workshop capabilities to geometrical tolerances. The fuzzy analysis is done by using the binary table for fit is shown in Table 3.1. The fuzzy linguistic variable is subdivided in the categories as best fitting quality, better fitting quality, good fitting quality, priority based acceptable fitting, maximum clearance fitting quality.

3.1.1. Basic Concept of Fuzzy Set Theory

The necessary background and notion of fuzzy set theory is reviewed. Definition: X is a universal set. Then fuzzy subset A {X} is defined by

μA= X → [0, 1] (3.1)

Which assign a real number x element μA(X),

where the value of μ A (X) x in A.

X in the interval [0, 1], to each at demonstrates the evaluation of enrollment of

3.1.2. FUZZY BINARY RANGE APPROACH (FBRA)

Step 1: Fixation of levels for L1, L2, L3, L4, and Ln values in [0-1] condition to be specific, binary range allocation strategy. In this method L values are in between the range of 0 to 1.This binary iterative allotment method is viewed in Table 3.1.

Step 2: Turn the estimations of d according to necessity of customer's view or requirements. This rotation of values is mainly dependent on accuracy. Here 0.1 is the rotation value.

3.1.3. FBRA PROGRAM DEPENDENCE GRAPH (PDG)

The monolithic programs are useful for engineering operations such as computation of program metrics and scheming and are represented by suitable program dependence graph is shown in Figure 3.1.

Table 3.1Binary table for FBRA

Row. No.	L_1	L_2	L_3	L_4
1	0	0	0	0
2	0	0	0	1
3	0	0	1	0
4	0	0	1	1
5	0	1	0	0
6	0	1	0	1
7	0	1	1	0
8	0	1	1	1
9	1	0	0	0
10	1	0	0	1
11	1	0	1	0
12	1	0	1	1
13	1	1	0	0
14	1	1	0	1
15	1	1	1	0
16	1	1	1	1

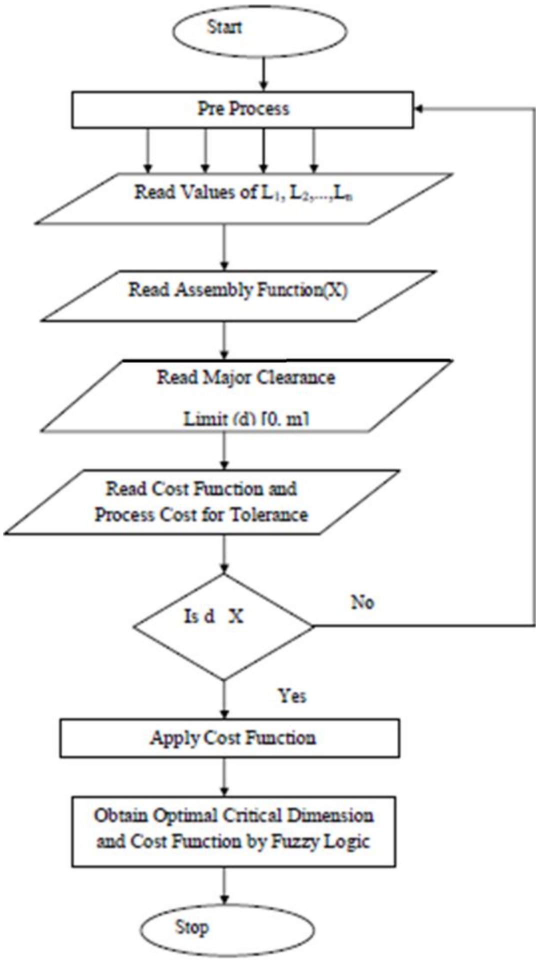

Figure 3.1Program Dependence Graph (PDG)

3.1.4. FBRA ALGORITHM

Step 1 : Assign d=0
Step 2 : Input the values (L_1, L_2, L_3, L_4, and L_n), m
Step 3 : Assign Assembly function [$X=L_1-(L_2+L_3+L_4, L_n)$]
Step 4 : If X<0 Print Interference Fit
Else
If X=0 Print Transition Fit
Else
If $X \leq d$ Print L_1, L_2, L_3, L_4, L_n& X
End If;
End If;
d =d+i
If $d \leq m$ then go to step 2
End If;
End If;
Step 5 : Apply Cost function

3.2. HYBRID FUZZY-MONTE CARLO METHOD

Monte Carlo Simulation is a powerful tool for analysis of tolerance of mechanical assemblies, for abnormal way of distributions and nonlinear assembly functions. Random number is generated to simulate the manufacturing effects of variations in assembly. The mathematical modelling of assemblies provides a quantity based evaluation for specifications and design variations of tolerances. Most commonly design engineers face the problem of tolerance allocation which is considered as a most important distinction. In tolerance allocation, the tolerance of assembly component is known from requirements of design. The required magnitude is unknown for component tolerances. The existing assembly tolerance must be allocated or distributed among the component parts in a rational manner. This manner of distribution or allocation is established in assembly tolerance distribution among component parts. Here the hybrid Fuzzy Monte-Carlo method is used for tolerance allocation. The algorithm is shown in figure 3.2.The Fuzzy Monte Carlo simulation procedure is as follows:

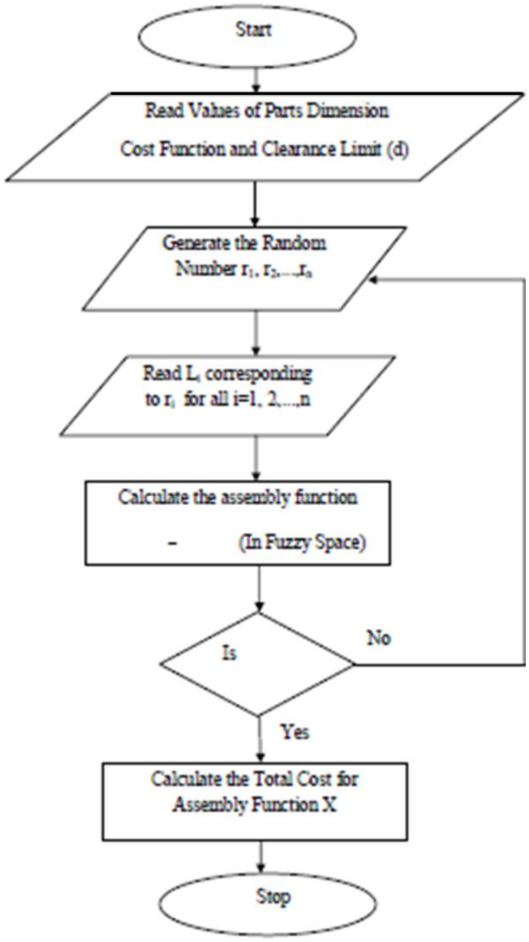

Figure 3.2 Hybrid fuzzy Monte Carlo graph

4. RESULTS AND DISCUSSION

It the major dimension of part 1 (L_1) is not only greater than subassembly dimension of part 2 (L_2), Part 3 (L_3) and Part 4 (L_4) also stands for the suitability of good fitness with minimum cost (Table and Figure 4.1)

Table 4.1 Good fit for gear box assembly

Sl. No	L1	L2	L3	L4	X
1	0.6	0.1	0.1	0.1	0.3
2	0.7	0.1	0.1	0.2	0.3
3	0.7	0.1	0.2	0.1	0.3
4	0.7	0.2	0.1	0.1	0.3
5	0.8	0.1	0.1	0.3	0.3
6	0.8	0.1	0.2	0.2	0.3
7	0.8	0.1	0.3	0.1	0.3
8	0.8	0.2	0.1	0.2	0.3
9	0.8	0.2	0.2	0.1	0.3
10	0.8	0.3	0.1	0.1	0.3
11	0.9	0.1	0.1	0.4	0.3
12	0.9	0.1	0.2	0.3	0.3
13	0.9	0.1	0.3	0.2	0.3
14	0.9	0.1	0.4	0.1	0.3
15	0.9	0.2	0.1	0.3	0.3
16	0.9	0.2	0.2	0.2	0.3
17	0.9	0.2	0.3	0.1	0.3
18	0.9	0.3	0.1	0.2	0.3
19	0.9	0.3	0.2	0.1	0.3
20	0.9	0.4	0.1	0.1	0.3
21	1	0.1	0.1	0.5	0.3
22	1	0.1	0.2	0.4	0.3
23	1	0.1	0.3	0.3	0.3

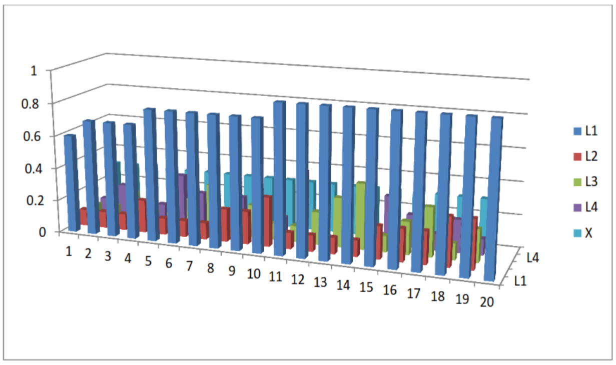

Figure 4.1. Good fit for gear box assembly

Fourthly, the major dimension of Part 1 (L_1) is greater than the subassembly dimension of part 2 (L_2), Part 3 (L_3) and Part 4 (L_4) ;and not equal to the addition of L_2,L_3 and L_4.This level provides acceptable clearance priority based on cost satisfaction(Table and figure 4.2)

Table 4.2. Acceptable clearance with priority based on cost for gear box assembly

Sl. No.	L_1	L_2	L_3	L_4	X
1	0.7	0.1	0.1	0.1	0.4
2	0.8	0.1	0.1	0.2	0.4
3	0.8	0.1	0.2	0.1	0.4
4	0.8	0.2	0.1	0.1	0.4
5	0.9	0.1	0.1	0.3	0.4
6	0.9	0.1	0.2	0.2	0.4
7	0.9	0.1	0.3	0.1	0.4

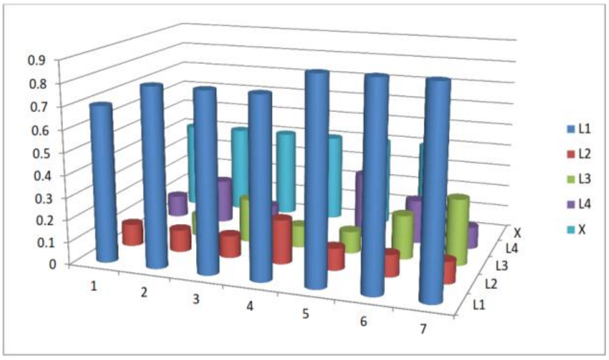

Figure 4.2. Acceptable clearance with priority based on cost for gear box assembly

Then the fifth one expresses a single argumentation that the major dimension of Part 1 (L_1) is greater than the subassembly dimension of part 2 (L_2), Part 3 (L_3) and Part 4 (L_4); and there is no another hands of the addition. This formula stands for the level of suitability is maximum clearance fitness with high cost. (Table and figure 4.3)

Table 4.3. Priority based maximum clearance fit with high cost for gear box assembly

Sl. No	L_1	L_2	L_3	L_4	X
1	0.9	0.1	0.1	0.1	0.6
2	1	0.1	0.1	0.2	0.6
3	1	0.1	0.2	0.1	0.6
4	1	0.2	0.1	0.1	0.6
5	0.8	0.1	0.1	0.1	0.5
6	0.9	0.1	0.1	0.2	0.5
7	0.9	0.1	0.2	0.1	0.5

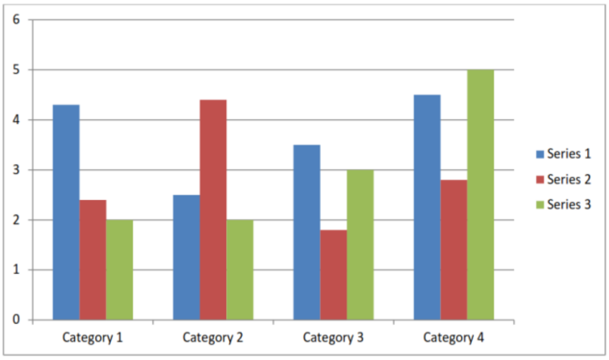

Figure 4.3. Priority based maximum clearance fit with high cost for gear box assembly.

Then, table 4.4 predicts maximum clearance with most expensive at the level of suitability.

Table 4.4 Maximum clearance with most expensive for gear box assembly

Sl. No	L1	L2	L3	L4	X
1	1	0.1	0.1	0.1	0.7

Finally, figure 4.4 shows fuzzy fitness with respect to critical dimension chart.

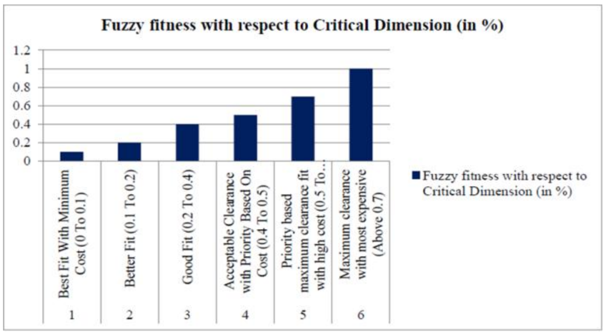

Figure 4.4 Fuzzy fitness with respect to critical dimension (in %)

4. CONCLUSION AND FUTURE WORK

The proposed FBRA algorithm gives essential possible answer for resistance distribution (leeway fit) in mechanical assemblies. Conventional methodologies don't accomplish the abnormal state of accuracy given by the proposed one. The proposed algorithm arranges the resilience fit into six distinct levels alongside ideal cost. In this methodology, the proposed method is based on Fuzzy Binary Range for Tolerance allocation by considering DFA and DFM. The methodology guarantees the accuracy of resilience structure and the machining costs. Case studies have been considered to demonstrate the proposed approach for mechanical assemblies of gear box assembly, rotor key assembly, hinge pin assembly and drive shaft assembly. The proposed FBRA algorithm gives a reasonable response for resilience distribution in mechanical gatherings and categorizes the tolerance fit in to six different levels along with optimum cost. Also this approach does not require any supposition about distribution of the part dimensions. Compared to various other approaches, FBRA requires less computational processing time with higher end accuracy in tolerance allocation. The existing get together resilience must be designated or dispersed among the segment parts in some objective way. The resistance of final assembly is analyzed through Monte-Carlo simulation process. In tolerance analysis, the upper and lower limit tolerances of the get together are resolved. In tolerance allocation, the part's tolerance has been determined by Fuzzy Logic method. This research work has mainly focused on the optimization of manufacturing cost for a simple linear assembly model. Hybrid Fuzzy-Monte Carlo has been implemented to find the minimized total cost. It is found and concluded that it is very efficient and easy to implement. In this exploration work, RP-E Hybrid model has been utilized to discover the manufacturing cost. Different optimization techniques may be used for various assembly problems to determine the minimum total cost.

REFERENCES

1. Fang H.F. & Wu Z.T. (1995). A research of concurrent design in computer aided design tolerance and process tolerance. China Mechanical Engineering; 06: pp. 25-7.

2. Narahari Y., Sudarsan R., Lyons K.W., Duffey M.R., Sriram R.D. (1999). Design for tolerance of electro-mechanical assemblies: an integrated approach. IEEE Transactions on Robotics and Automation; 15: pp. 1062-79.

3. Roy U., Pramanik N., Sudarsan R., Sriram R.D., Lyons K.W. (2001). Function to- form mapping: model, representation and applications in design synthesis. Computer-Aided Design; 33: pp. 699-719.

4. Dantan J.Y., Anwer N., Mathieu L. (2003). Integrated to leranclng process for conceptual deslgn. CIRP Annals Manufacturing Technology; 52: pp. 135-8.

5. Mantripragada R. & Whitney D.E. (1998). The datum flow chain: a systematic approach to assembly design and modeling research in engineering design. Research in Engineering Design; 10: pp. 150-165.

6. Dinesh Shringi & Kamlesh Purohit (2013). Analysis Of New Non Traditional Tolerance Stack Up Conditions, International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 2, March -April 2013, pp. 1419-1424.

7. Mathieu Mansuy, Max Giordano, Pascal Hernandez (2011). A new calculation method for the worst case tolerance analysis and synthesis in stack-type assemblies, International Journal of Science, M. Mansuy et al. / Computer-Aided Design 43, pp. 1118–1125.

8. Suyash Y. Pawar, Harshal A. Chavan, Santosh P. Chavan (2011). TOLERANCE STACK UP ANALYSIS AND SIMULATION USING VISUALIZATION VSA, International Journal of Advanced Engineering Technology, IJAET/Vol.II/ Issue I/January-March 2011/169-175.

9. Luc Laperriere, Hoda A. EIMaraghy Z. (2000). Tolerance Analysis and Synthesis Using Jacobian Transforms, Annals of the CIRP Vol. 49/1/2000/359-362

10. Paul Beaucairea, Nicolas Gaytona, Emmanuel Duca, Jean-Yves Dantanb (2013). Statistical tolerance analysis of over-constrained mechanisms with gaps using system reliability methods, Computer-Aided Design 45, pp. 1547–1555.

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