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Selection of Optimum Assembly Gap Tolerance for Motor Assembly

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Abstract: The parts in the motor assembly are divided into two types: fixed and variable. The tolerances of the fixed parts cannot be changed and the tolerances of the variable parts are calculated using three methodologies such as ME boost, ANFIS, and Cost function optimization.ME boost is an Excel add in used to calculate the tolerances of the variable parts. ANFIS is a neural network based optimization tool in matlab. Cost function is formulated for the variable parts in the assembly and optimized to calculate the tolerances. Then the tolerance for the assembly gap is calculated. The tolerances for the gap from the three methodologies are compared and optimum tolerance is considered for manufacturing.
Keywords: Motor assembly, Tolerance, Assembly gap, ME boost, ANFIS, Cost function Optimization.

I. INTRODUCTION

The acceptable variation in the dimension of a part is called tolerance. Tolerances are of two types: unilateral tolerance and bilateral tolerance. Unilateral tolerances are symmetric on both the sides of the dimension whereas bilateral tolerances are non-symmetric on both sides of the dimension. In this work unilateral tolerances are considered. Gap is formed in few assemblies due to variation in dimensions. The procedure to calculate the tolerances for the gap is discussed in this paper. There are two types of parts in the assembly: fixed parts and the variable parts. In this paper three methodologies are used to calculate the tolerances for the variable parts. A loop diagram is used to represent the assembly gap along with the parts of the assembly. The dimensions of the parts from left to right in the loop diagram are considered positive and the dimensions of the parts from right to left in the loop diagram are considered negative.

In this paper,

1) The tolerances for the variable parts are calculated using three methodologies
2) Tolerance for the gap is calculated
3) The tolerances calculated using different methodologies is compared and optimum tolerance is selected.

II. RELATED WORK

Many researchers have been working on this topic since last two decades. A lot of literature is available and some related work is presented here. A workable analytical method for locating the optimum set of dimensional tolerances that minimizes the manufacturing costs is presented by Speckhart (1972) [3]. The technique of applying statistical methods to tolerance analysis of assemblies is described by Nigam and Turner (1995) [4]. An approach based on a new method called fuzzy comprehensive evaluation method and optimization through genetic algorithm is proposed by Ji et al. (2000) [5]. The distribution of tolerance on the component dimension of a complex assembly is found by Kumar et al. (2009) [8]. A new method called as decision support process along with Taguchi loss function to calculate the assembly gap tolerances is proposed by Abhishek Kumar et al. (2010) [6][7].

III.METHODOLOGIES

A. ME Boost

ME boost is an excel add-in and has several modules such as Strength of materials, Mechanical design, Kinematics & Dynamics, Fluids, and Unit conversion. It covers a wide range of Mechanical Engineering areas. In the Mechanical design module of ME boost there is a sub module called tolerance calculator. The tolerance calculator interface is shown in the figure 1.

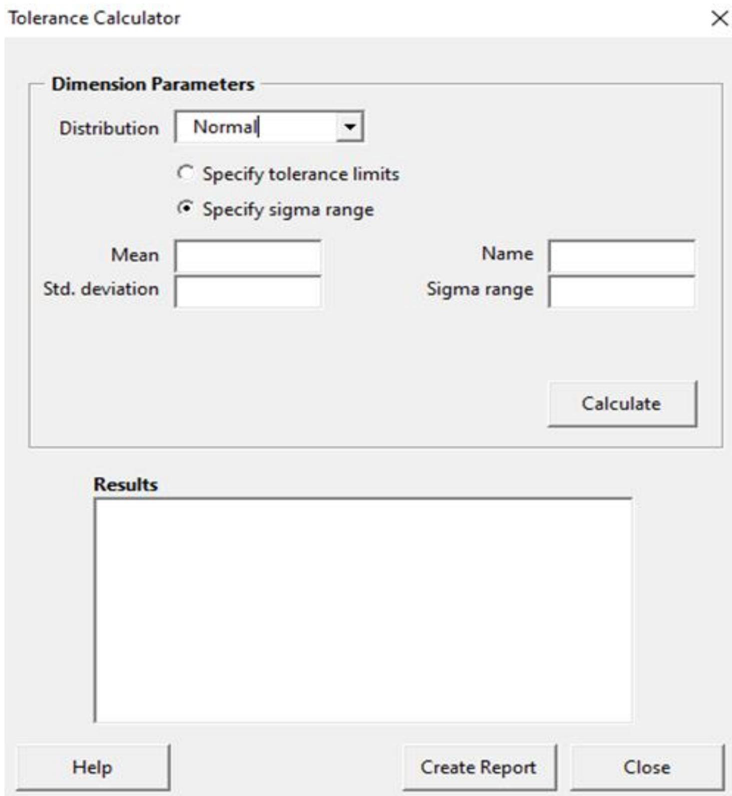

Figure 1: Tolerance calculator

The distribution of tolerances is assumed normal and the mean dimension, standard deviation, sigma range, and the name of the part are given as inputs to calculate the tolerance.

B. ANFIS

The abbreviation for ANFIS is Adaptive Network based Fuzzy Interface System. It was developed based on Takagi-Sugeno fuzzy interface system in the form of artificial neural network in 1995 by Jang. It comprises of fuzzy IF-THEN rules and it can learn all kind of functions and approximates them. In anfis, the ambiguity of decisions is converted to mathematical models. This helps in the easy interpretation of the decisions. It is user friendly and has fewer errors. It is an inbuilt tool in matlab and can be used using simple commands such as anfisedit and fuzzy. The anfis edit command is used to train the network and the fuzzy command is used to predict the output for given inputs. The mean dimensions and standard deviations of the fixed parts are the inputs and the tolerances of the fixed parts are the outputs.

C. Cost Function Optimization

The cost function is

$$C_T = C_i + \sum_{i=1}^{n} \frac{\psi_i}{T_i}$$

Subject to $l_i < T_i < u_i$, 1<i<n [6][2]

Where C_T is the total manufacturing cost of the part, C_i is the initial setup costs, and is a constant L = $\{l_1, l_2, l_3,\ldots..l_n\}$ and U = $\{U_1, U_2, U_3, \ldots\ldots.U_n\}$ are the constraint vectors for the upper and lower tolerance limits of variable parts. The cost function is optimized for minimum C_T

The comprehensive factor ψ_i for part i is $\psi_i = \frac{\zeta_i}{\xi_i^{2}}$, i=1, 2, 3,…….., n where ζ_i is the machinability of the part and ξ_i is the degree of importance or sensitivity factor.

The Fuzzy Comprehensive Evaluation method is used to calculate the machinability of the part ζ_i.

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D. Fuzzy Comprehensive Evaluation Method [2]

In the Fuzzy Comprehensive Evaluation Method, the following fuzzy factors are taken into consideration:

1) Dimension Size (DS): The total length of the part.
2) Geometric Structure (GS): The shape of the part.
3) Material Machinability (MM): Degree of the machinability of the part.
4) Process Accuracy (PA): The degree of machining accuracy of the part.

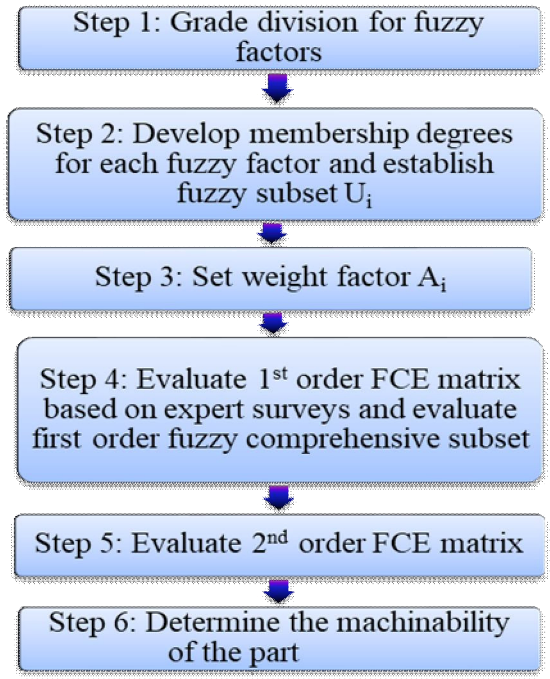

Figure 2: Steps involved in Fuzzy Comprehensive Evaluation Method [2]

Step 1: Grade divisions for fuzzy factors

The four fuzzy factors DS, GS, MM, and PA are divided into four different grades. The grade division of the fuzzy factors is presented in the table 1 below.

Table 1: Grade divisions for fuzzy factors [2]

	Grade 1	Grade 2	Grade 3	Grade 4
U_1(DS)	~0.5 inch	~2 inch	~3 inch	~4 inch
U_2(GS)	Easy to manufacture	Hard to manufacture	-	-
U_3(MM)	Poor	Medium	Good	-
U_4(PA)	Poor	Medium	Good	-

Step 2: Develop membership degrees for each fuzzy factor and establish fuzzy subset U_i

The fuzzy subset U_i for the membership values of the factors DS, GS, MM, and PA in each grade are defined as,

$$U_i = (u_{i1}, u_{i2}, u_{i3}, \ldots\ldots\ldots\ldots, u_{in})$$

where u_{ij} denotes the membership value of j^{th} grade for the i^{th} factor and n is the number of grades.

Step 3: Set weight factor A_i

The weight factor for the factors DS, GS, MM, and PA A_i, is defined as

$$A_i = (a_{i1}, a_{i2}, a_{i3}, \ldots\ldots\ldots\ldots, a_{in})$$

Where $a_{ij} = \frac{u_{ij}}{\Sigma u_{ij}}$ (j=1,2,……..n).

The level of machinability in Fuzzy Comprehensive Evaluation Method is divided between 0 and 1 into ten equally spaced levels.

$$\tau = \{0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1\}.$$

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Step 4: Evaluate 1st order FCE matrix based on expert surveys and evaluate first order fuzzy comprehensive subset
The 1st order FCE matrix calculated by experts is

$$R = \begin{bmatrix} k_{11} & k_{12} & . & k_{1p} \\ k_{21} & k_{22} & . & k_{2p} \\ . & . & . & . \\ . & . & . & . \\ k_{n1} & k_{n2} & . & k_{np} \end{bmatrix}$$

where k_{ij} is the membership of fuzzy grade i (i=1,2……n), in machinability level j (j=1……10). The 1st order FCE matrix is empirical and changes for different applications.

The first order Fuzzy comprehensive set for every factor i, B_i, can be calculated using

$$B_i = A_i \text{ o } R_i = (a_{i1}, a_{i2}, \ldots\ldots\ldots, a_{in}) \text{ o } \begin{bmatrix} k_{11} & k_{12} & . & k_{1p} \\ k_{21} & k_{22} & . & k_{2p} \\ . & . & . & . \\ . & . & . & . \\ k_{n1} & k_{n2} & . & k_{np} \end{bmatrix} = (B_{i1}, B_{i2}, \ldots\ldots\ldots, B_{ip})$$

p=10, After evaluating the fuzzy comprehensive set for each factor, all the calculated B_i matrices are merged to obtain the first order FCE matrix R_{new}.

$$R_{new} = \begin{bmatrix} B_1 \\ B_2 \\ . \\ . \\ B_n \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & . & B_{1p} \\ B_{21} & B_{22} & . & B_{2p} \\ . & . & . & . \\ . & . & . & . \\ B_{n1} & B_{n2} & . & B_{np} \end{bmatrix}, \ p=10.$$

Step 5: Evaluate 2nd order FCE matrix

The 2nd order FCE matrix is calculated using

$$B = I \times R_{new} = (b_1, b_2, b_3, \ldots\ldots\ldots, b_p)$$

where p=10. The weighted importance of each factor is represented by I= (i_{DS}, i_{GS}, i_{MM}, i_{PA}).

Step 6: Determine the machinability of the part

The machinability can be calculated by

$$\zeta = \frac{\sum_{p=1}^{10} B_p \tau_p}{\sum_{k=1}^{10} B_k}$$

where B_k is the second order FCE matrix, τ_p is the machinability at level p.

IV. MOTOR ASSEMBLY

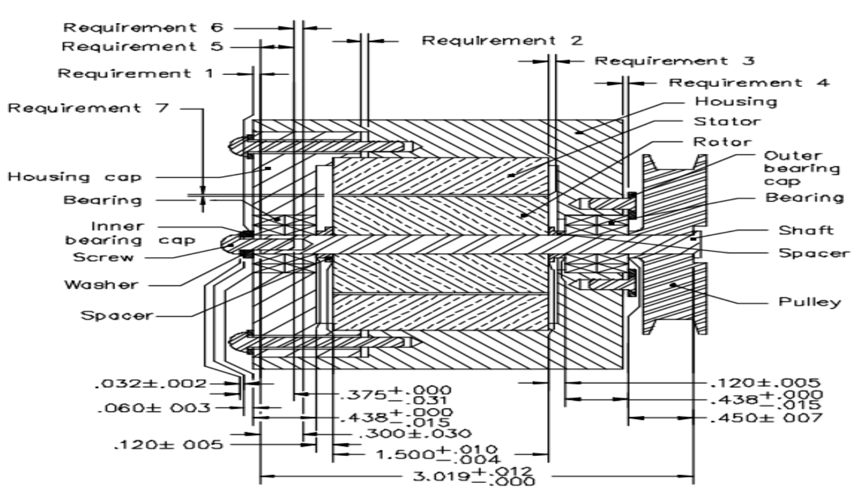


Figure 3 : Motor Assembly [1]

The loop diagram representing the gap along with the parts of the assembly is

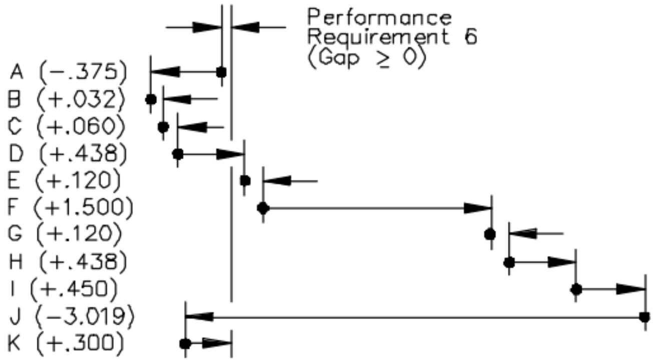


Figure 4: Loop diagram for motor assembly [1]

The parts A, B, D, F, H are fixed and the parts C, E, G, I, J, K are variable. The tolerances for the variable parts are calculated using three methodologies.
The nominal assembly gap is g_m=0 inch

A. *ME Boost*

The tolerances for the variable parts calculated using ME boost are

$$T_C = 0.00107$$
$$T_E = 0.00107$$
$$T_G = 0.00107$$
$$T_I = 0.00318$$
$$T_J = 0.00107$$
$$T_K = 0.0075$$

Tolerance for the gap = $-T_A + T_B + T_C + T_D + T_E + T_F + T_G + T_H + T_I - T_J + T_K$
= 0.02132

B. *ANFIS*

The network in anfis is trained using the mean dimensions and standard deviations of fixed parts as inputs and the tolerances of the fixed parts as output. The tolerances of the variable parts are predicted using their mean dimensions and standard deviations.
The tolerances of variable parts predicted using anfis are

$$T_C = 0.00204$$
$$T_E = 0.00211$$
$$T_G = 0.00211$$
$$T_I = 0.00734$$
$$T_J = 0.00122$$
$$T_K = 0.0119$$

Tolerance for the gap = $-T_A + T_B + T_C + T_D + T_E + T_F + T_G + T_H + T_I - T_J + T_K$
= 0.0218

C. *Cost Function Optimization*

The machinability for variable parts calculated from fuzzy comprehensive evaluation method is
$\zeta_C = 0.576$, $\zeta_E = 0.0588$, $\zeta_G = 0.0588$, $\zeta_I = 0.4505$, $\zeta_J = 0.6315$, $\zeta_K = 0.4303$
The comprehensive factor for variable parts is
$\psi_C = 0.576$, $\psi_E = 0.0588$, $\psi_G = 0.0588$, $\psi_I = 0.4505$, $\psi_J = 0.6315$, $\psi_K = 0.4303$

The cost function is

$$C_T = C_i + \frac{0.576}{T_C} + \frac{0.0588}{T_E} + \frac{0.0588}{T_G} + \frac{0.4505}{T_I} + \frac{0.6315}{T_J} + \frac{0.4303}{T_K}$$

Subject to $0 < T_C < 0.004$, $0 < T_E < 0.1$,

$0 < T_G < 0.2$, $0 < T_I < 0.15$,

$0 < T_J < 0.12$, $0 < T_K < 0.11$

Consider C_i = Rs.100

After optimization,

$C_M = 1066.02$, $T_C = 0.002$, $T_E = 0.0019$, $T_G = 0.0019$, $T_I = 0.0059$, $T_J = 0.0021$, $T_K = 0.0018$

Tolerance for the gap = $-T_A + T_B + T_C + T_D + T_E + T_F + T_G + T_H + T_I - T_J + T_K$ = 0.0199

V. RESULTS AND DISCUSSION

Table 2: Results summary

	ME Boost	Anfis	Cost function
Tolerance for gap(inch)	0.02132	0.0218	0.0199

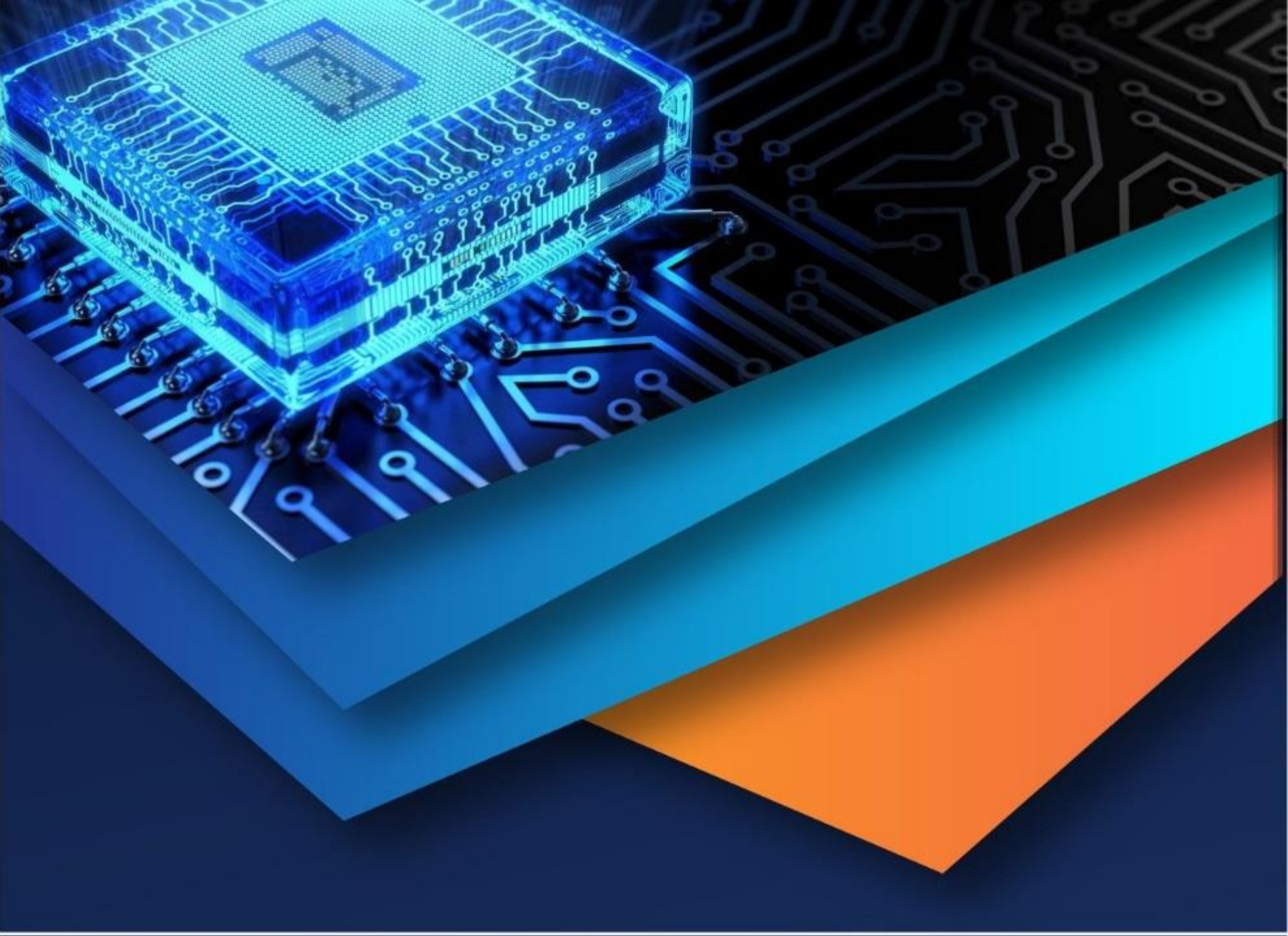
The tolerance for the gap is calculated using three methodologies: ME boost, ANFIS, Cost function optimization. In ME boost and anfis the inputs are mean dimension and standard deviation. In the cost function optimization, the cost function is formulated using the machinability calculated using fuzzy comprehensive evaluation method and the cost function is optimized for minimum cost.

VI. CONCLUSION

This work shows the calculation of assembly gap tolerances using three methodologies and their comparison. The tolerance calculated using cost function optimization is less and it results in greater assembly quality with optimum costs. The tolerance calculated using ME boost and anfis have very less difference. These tolerances can also be considered for manufacturing.

REFERENCES

[1] Dimensioning and tolerancing handbook by Paul J. Drake, McGraw Hill publications.
[2] Madhavi Reddy G V, Sreenivasulu Reddy A, “Assembly gap tolerance calculation using ANFIS and Cost function optimization”, IJRASET, Volume 10, Issue II, 2022.
[3] F. H. Speckhart, “Calculation of tolerance based on a minimum costs approach”, Journal of Engineering for Industry, 5, pp. 447– 453, 1972.
[4] Swami D Nigam, Joshua U Turner, “Review of statistical approaches to tolerance analysis”, Computer Aided Design, Volume 27, Issue 1, January 1995.
[5] Ji, S., Li, X. and Cai, H., 2000. Optimal Tolerance Allocation Based on Fuzzy Comprehensive Evaluation and Genetic Algorithm. Manufacturing Review, 1 (1): pp. 50-59.
[6] Abhishek Kumar, Lorens Goksel, Seung-Kyum Choi. "Tolerance Allocation of Assemblies Using Fuzzy Comprehensive Evaluation and Decision Support Processes", Volume 1: 36th Design Automation Conference, Parts A and B, 2010.
[7] Abhishek Kumar, Seung-Kyum Choi, Lorens Goksel. "Tolerance allocation of assemblies using fuzzy comprehensive evaluation and decision support process", The International Journal of Advanced Manufacturing Technology, 2010.
[8] Kumar, M. S., Kannan, S. M., & Jayabalan, V. (2009a). A new algorithm for optimum tolerance allocation of complex assemblies with alternative processes selection. The International Journal of Advanced Manufacturing Technology, 40(7-8), 819-836.
[9] C. Qinghong, “Fuzzy comprehensive evaluation of design variables in mechanical reliability”, Fuzzy Techniques and Application (I), pp. 492–497, Beijing Aerospace University, 1994.



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