DESIGN AND ANALYSIS OF OPTIMAL TOLERANCE IN MECHANICAL ASSEMBLIES USING FINITE ELEMENT TECHNIQUES

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ABSTRACT

Tolerance design plays an important role in the modern design process by introducing quality improvements and limiting manufacturing costs. Tolerance synthesis is a procedure that distributes assembly tolerances between components or distributes final part design tolerances between related tolerances. Traditional tolerance design assumes that all objects have rigid geometry, overlooking the role of inertia effects on flexible components of assembly. The variance is increasingly stacked up as components are assembled without considering deformation due to inertia effects. This study deals with the optimal tolerance design for an assembly simultaneously considering manufacturing cost, quality loss and deformation due to inertia effect. An application problem (motor assembly) is used to investigate the effectiveness and efficiency of the proposed methodology. The technological and financial limitations in the manufacturing process are the reasons for non-achievability of nominal dimension. Therefore, tolerance allocation is important in assembly. CAD/CAM/CAE integration plays a major role in tolerance allocation. It utilizes the required functional characteristics and manufacturing cost of the product which had a great impact on determination of the process method, machine tooling, set up and process sequence of the part in the processing plan. In a mechanical design, geometric and dimensional tolerances are used to specify the range which a part geometry and size may vary while conforming to the functional requirem.

INTRODUCTION:

Traditional tolerance allocation techniques rely upon rigid body motions, translations or rotations, to account for small kinematic variations that occur in an assembly of parts. Vector loop method can be used to solve dimensional variations in the assembly that occur due to variation in length, form, or kinematic shift. However, in some applications there is measurable deformation in addition to kinematic shift. This is due to presence of at least one flexible part in the assembly. A part is called flexible when its stiffness is less relative to the other parts of the assembly. The flexible component undergoes significant deformation due to inertia effect (gravity, angular velocity, angular acceleration, etc.,) and due to temperature effect, which also strongly influences the performance and reliability of products. Exposure to a temperature that is higher or lower than that the product is designed to withstand, may result in the failure of the product to perform to specification, or in total failure.

CASE STUDY II:

PARAMETRIC TOLERANCE DESIGN OPTIMIZATION OF MECHANICAL ASSEMBLY CONSIDERING INERTIA AND TEMPERATURE EFFECT:

INTRODUCTION:

In this study, a cost – tolerance model based on neural network methods is proposed in order to provide product designers and process planners with
an accurate basis for estimating the manufacturing cost. Tolerance allocation among the assembly components is carried out to ensure that the functionality and design quality are satisfied considering the effect of dimensional and geometric tolerance of various components of the assembly by developing a parametric CAD model. In addition, deformations of various components of mechanical assembly due to inertia and temperature effects are determined and the same is integrated with tolerance design. The benefits of integrating the results of finite element simulation in the early stages of tolerance design are discussed. The proposed method is explained with an application example of motor assembly, where variations due to both dimensional and geometric tolerances are studied.

MODELING AND FINITE ELEMENT SIMULATION:

In order to determine the features which have an effect on clearance measurement, an abstracted feature parameter model was developed. In this model, all the features potentially involved in the stack are initially abstracted to the very basic geometric entities. Then these features are represented by corresponding parameters. Finally a standard set of distance and angular relation between the simplified feature entities are used to build a constraint model.

CONCLUSIONS:

Traditionally, the tolerance allocation is done based on the hypothesis that the assembly process deals with infinitely rigid bodies. The assembly functions are developed based on this hypothesis. The resultant tolerance of individual components obtained based on this hypothesis will be on the tighter side, thereby increasing the manufacturing cost. In reality all the components of the assembly are deformable bodies and they undergo deformation due to inertia effects. Through finite element simulation, the values of deformation due to inertia effects like gravity, angular velocity and temperature effect have been determined in the design and process planning stage itself. Due to this, the tolerance requirements of the given assembly are relaxed to certain extent for critical components, resulting in reduced manufacturing cost and high product reliability. In addition, predetermination of variation of assembly functional requirement in design stage reduces cost associated with quality loss. With this approach, the component tolerance values found are the most robust to variation during the product’s application. These benefits make it possible to create a high-quality and cost-effective tolerance design.

Case study I:

In this case study, the effect of inertia (self-weight) in tolerance design of mechanical assembly (piston-cylinder assembly) has been studied. Permissible variation of functional dimension of the assembly is ±0.27mm. The deformation due to inertia effect is found to be 0.04812mm using finite element analysis (Figure 1.6). Then optimal tolerance values are obtained by incorporating the deformation value in the tolerance stack up equation. Due to this the total manufacturing cost is reduced by 5.22%. Benefits of considering variation of functional requirement of an assembly in the design stage are found to be reduction in quality loss cost, reduction in rework time and wastage reduction. This methodology can be adopted for tolerance design of mechanical assemblies having flexible components.

Case study II:

In this case study, in addition to the inertia effect, thermal effect in tolerance design of mechanical assembly (gearbox assembly) has been studied. Permissible variation of functional dimension of the assembly is ±0.20mm. The deformation of assembly components for various operating temperature has been determined using finite element analysis. The relationship between the deformation and temperature has been determined. Then optimal tolerance values are obtained by incorporating the deformation value in the tolerance stack up equation. Due to this significant reduction of the total manufacturing cost is obtained .This methodology can be adopted for tolerance design of mechanical assemblies whenever there is significant temperature difference between assembly line and operating condition.

REFERENCES:

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