ABSTRACT

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 within which a part geometry and size may vary while conforming to the functional requirements. Assigned tolerances have a direct effect not only on the machining costs but also on the product quality. Unnecessarily tight tolerances results in high production costs, yet the tolerances should ensure that the functional performance requirements of the products stay within a satisfactory range. Tolerances which are too loose can affect the product quality and increase the scrap rate and production costs.

In general, designers allocate tolerances for parts based on their experience and on handbooks and standards which may at times lead to certain errors. Computer – Aided Tolerancing Design (CATD) has become an important research direction in integrated CAD/CAM/CAE systems. Tolerance allocation is one of the most important problems for CATD. Given a required tolerance for the assembly, the planner first faces the problem of
how economically he could allocate suitable tolerance values for the parts by considering the trade-off between functional requirements and machining costs. Most of the research studies have considered tolerance allocation as an optimization problem. However, the conventional tolerance allocation methods have some limitations. They are as follows; the cost tolerance model developed by regression analysis has fitting error. Further, the conventional tolerance allocation methods are limited by the assumption of the part rigidity. Every mechanical assembly consists of at least one or more flexible parts which undergo significant deformation due to inertia effect like gravity, angular velocity, etc., and due to temperature effect. The deformation of the various components is not negligible and they play an important role in tolerance design of assembly. Variations due to deformation of parts will accumulate and propagate along with the assembly process. Such accumulated variations will affect the final quality of the assembly. The variation due to deformation affects functional requirements of the assembly, which results in rework or wastage. It is thus an important task to predict the dimensional variations of a final assembly during the design and process planning stage.

The aim of the present study is to develop a parametric CAD model of machine assembly and to integrate tolerance design with finite element analysis. Finite element analysis is used to determine the deformation of components in an assembly due to inertia and temperature effect. Integration of tolerance design with finite element analysis will guarantee that the optimal tolerance values of various components of the assembly as will remain within
allowable variation. The solution to this problem is very important in several industries.

The difficulty in solving this problem is mainly due to the following factors:

(i) A parametric CAD model has to be developed by including the effects of dimensional and geometric tolerances of various components of the assembly.

(ii) In order to determine the deformation of components in an assembly due to inertia effect like gravity, angular velocity, etc., and due to temperature effect, nonlinear contact analysis of the assembly components has to be carried out.

(iii) In order to minimize the fitting error in cost – tolerance model, neural network model has to be developed to provide product designers and process planners with an accurate basis for estimating the manufacturing cost.

(iv) Finally, optimal tolerance design of mechanic assembly has to be carried out under manufacturing and design constraints.

The difficulties in solving the optimization problem are (i) the simultaneous selection of design and manufacturing tolerance and (ii) the interrelated dimension chain. Therefore, a large space with discontinuities and
nonlinearities must be searched for obtaining solution. In order to search the large space effectively and to determine the optimum values an intelligent search tool is used in this research work. It is Elitist Non-dominated Sorting Genetic Algorithm (NSGA-II).

This research work deals with development of generalized procedure to solve tolerance allocation of mechanical assembly as a Computer Aided Tolerancing Design (CATD) problem thereby enabling integration of CAD/CAM/CAE systems. In the first stage, a parametric CAD model of assembly is developed. In the second stage, finite element analysis of various components of the assembly is carried out to determine the deformation due to thermal and inertia effects. In the third stage, the optimization problem is formulated by integrating statistical tolerance design with finite element analysis. In the last stage (fourth stage) the optimization problem is solved using intelligent techniques viz., NSGA-II and the results are compared with that of conventional techniques.

The concurrent optimal tolerance design of the following mechanical assemblies with design constraints are presented in this work.

- Piston – Cylinder assembly
- Gear Box assembly
- Motor assembly
The following are the methodologies used in this research work:

- A parametric CAD model has been developed by including the effect of dimensional and geometric tolerance of various components of the assembly.

- Finite element analysis of the assembly components has been carried out in order to determine the deformation of components in an assembly due to inertia effect like gravity, angular velocity, etc., and due to temperature effect.

- A neural network model has been developed in order to minimize the fitting error in cost – tolerance model.

- An optimal tolerance design of mechanical assembly has been carried out under various constraints using intelligent techniques.