ABSTRACT

Title: Studies on Tolerance Design of Machined parts and Assemblies

One of the key elements identified by industry in order to increase the productivity is the proper selection of dimensional tolerances for manufactured parts at the design stage. Even small efforts in this area, tend to yield high quality and significant cost savings with little capital investment, and serves as a prime example of including manufacturing and assembly considerations early in the design process. With the advent of globalization, this assumes even greater significance as local manufacturing costs are benchmarked with manufacturers on a global scale, and even incremental savings in cost or incremental improvement in performance may determine the success of the product.

The impact of the magnitude of tolerances specified on engineering drawings is profound as can be seen from the various concerns of the personnel involved from bringing a product from concept to reality. For instance, designers are concerned with critical dimensions affecting product performance & assemblability, process planners in the selection of manufacturing processes, manufacturing engineers recognizing the higher cost involved in maintaining tight tolerances and process capability. This study is known as Tolerance Design.

In order to effectively optimize the allocation of tolerance in an assembly, a mathematical model is essential. It enables the engineer to determine the cost of manufacture to a specific tolerance. Several empirical cost tolerance relationships have been developed for minimum cost tolerance allocation over several decades. However, this cost versus tolerance data is not readily available and very scarce. Very few companies/agencies attempt to gather this data, and those who do so, do not publish it, as it is considered proprietary. Further, the data available for estimation of costs are from abroad and are relative costs. In addition, they do not represent the cost of Indian manufacturing industry. Hence the cost in Indian Rupees for various tolerance values (not available thus far) would prove invaluable in application of tolerance design and comparison of costs with those abroad for Indian industries.

Research presented in this thesis focuses on job shop type industry in India, as this provides the minimum cost involved in machining as well as being oriented toward the growing trend of outsourcing. The cost of machining to a specific tolerance in Indian Rupees was collected for typical metal removal processes, modeled using mathematical equations and the best curve fitting model was selected. In addition, the relative cost of machining between tolerances as well as across machining processes was determined (to eliminate effects of inflation) and

compared with various industry types (job shop 1, job shop 2, and organized industry), and those available from abroad, with the base cost as the job shop 1 type.

Further, keeping in mind the effects of tolerance on assembly, a methodology has been developed that combines the use of Design for Assembly and Six Sigma techniques to select the better design from a basket of designs based on ease of assembly, the number of process steps in manufacturing, the yield, and the relative cost of machining based on the cost versus tolerance data. Design for assembly leads to a product that is easier to assemble, while six sigma aids in identification of defects based on process steps, alternative processes involving higher costs and selection of process capability to maintain desired level of yield.

In addition, an inquiry based questionnaire has also been introduced to illustrate the benefits of feedback for designers by capturing the voice of the customer that can be used as a database for future designs.

The comparison of relative cost(s) of machining in India with those available from abroad, are similar, providing insight to the fact that manufacturing labour costs are similar to those in the United States, available in literature. It shows that the cheaper labour rates exist due to differences in the value of currencies and also due to the basic labour rate per hour.

The cost versus tolerance data for Indian industries, along with the DFA-Six sigma methodology, and inquiry based questionnaire has created a comprehensive systematic step by step approach to tolerance modelling, design and manufacturing using familiar engineering elements. The aforementioned techniques can be used by the engineer at the early stages of design concept, as well as for comparison or benchmarking of products that exist, within the product family as well as those of the competition.

In summary, contributions from this thesis include:

1) Development of Cost versus Tolerance data for various machining processes for Indian Job shop in Indian Rupees & modeling of data.
2) Determination of the relative cost of machining within a machining process (e.g. tolerances within a turning process) and across machining processes, with the cost for turning as the base cost.
3) Comparison of the relative cost of machining for different processes across various industry types (job shops and organized industry), and those available from abroad, with the base cost as the job shop 1 type.
4) A methodology to enhance the designer's toolkit in the selection of the better design, by superimposing the process complexity and relative machining cost of process, following the application of the DFA technique for an assembly.

5) A feedback tool for the designer to capture the voice of the customer and evaluate the performance of a design in terms of functionality, serviceability, etc, with the help of an inquiry based questionnaire.