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DESIGN VERIFICATION THROUGH TOLERANCE STACK UP ANALYSIS OF MECHANICAL ASSEMBLY AND LEAST COST TOLERANCE ALLOCATION

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Abstract

Geometric dimensioning and Tolerancing (GDT) constitutes the dominant approach for design and manufacture of mechanical parts that control inevitable dimensional and geometrical deviations within appropriate limits. The stack up of tolerances and their redistribution without hampering the functionality is very important for cost optimization. This paper presents a methodology that aims towards the systematic solution of tolerance stack up problem involving geometric characteristics.Conventional tolerance stack up analysis is usually difficult as it involves numerous rules and conditions. The methodology presented i.e. generic capsule method is straightforward and easy to use for stack up of geometrical tolerances of components and their assembly using graphical approach. In the work presented in this paper, angularity tolerance has been considered for illustration of the methodology. Two approaches viz. Worst Case (WC) and Root Sum Square (RSS) have been used. An example of dovetail mounting mechanism has been taken for purpose of stack up of angularity. Based on the stacked tolerance, it can be verified with the design tolerance of the assembly. Based on the comparison, designer has to reassign the appropriate tolerances to fulfil the functionality if required. If the stacked tolerance is as per designer requirement, then reallocation of tolerances on individual components should be done. Costs versus tolerance data are available for each component. With optimization technique, the optimized cost has been calculated for the assembly.

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Keywords: GDT; Angularity; Stack up Analysis; Graphical Method; WC Approach; RSS Approach, Reallocation; Optimization Technique.

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1. Introduction

Tolerance is an essential part of design and manufacturing. Design and Tolerancing (DT) is used to specify the size, shape, form, orientation, and location of features on a part. Features toleranced with GDT reflect the actual relationship between mating parts. Drawings with properly applied geometrical tolerancing provide the best opportunity for uniform interpretation and cost effective assembly. GDT is used to ensure the proper assembly of mating parts, to improve quality and to reduce cost by proper selection of manufacturing process. Before designers can properly apply geometric tolerancing, they must carefully consider the fit and function of each feature of every part. Properly applied geometrical tolerancing ensures interchangeablity of the parts. Geometrical tolerancing allows the designers to specify the maximum available tolerance and consequently design the most economical parts. A properly toleranced drawing is not only a picture that communicates the size and shape of the part, but it also explains the tolerance relationships between features.

In this paper, angularity is taken for study. Tolerance stack ups of individual components and their assembly have been carried out using graphical approach. Based on the stacked tolerance, it can be verified with the design tolerance of the assembly. Based on the comparison, designer has to reassign the appropriate tolerances to fulfil the functionality if required. If the stacked tolerance is as per designer requirement, then reallocation of tolerances on individual components has been done. Quantitative estimates of thecost of components with respect to tolerances along with simultaneous selection of processes are carried out, which permits the selection of component tolerances in mechanical assemblies for minimum cost of production.

2. Literature Review

A lot of work has been done in the field of conventional tolerancing. Conventional tolerancing methods do a good job for dimensioning and tolerancing of size features and are still used in good capacity. But these methods do not cater precisely for form, profile, runout, location and orientation features as discussed by Cogorno (2006), Meadows (2009) and Drake (1999). GDT is used extensively for location, profile, runout, form and orientation features. In more theoretical terms, there are two types of tolerancing schemes i.e. parametric and geometric. Parametric tolerancing consists of identifying a set of parameters and assigning limits to the parameters that define a range of values which has been discussed by Requicha (1993). Singh et al. (2009) reviewed different methods of tolerance allocation and found mean shift models and the combination of the basic approaches. Singh et al. (2009) reviewed tolerance synthesis approaches for tolerance stack up i.e. the worst case and the root sum square approach. Swift et al. (1999) introduced a knowledge based statistical approach to tolerance allocation. In this approach, a systematic analysis for estimating process capability levels at the design stage is used in conjunction with statistical methods for the optimization of tolerances in assembly stack up. Chase et al. (1990) demonstrated that the methods for tolerance allocation for minimum production cost can be extended to include process selection from a set of alternate processes. Ngoi et al. (2010) discussed the stack up of geometrical tolerances using generic capsule method. Ngoi et al. (1997) presented an elegant approach by using the 'Quickie' technique towards tolerance stack up analysis for geometrical tolerances. Ngoi et al. (1999) also presented a straightforward graphical approach known as the "Catena" method for tolerance stack up, involving geometric characteristics in form control – flatness, straightness, circularity and cylindricity. He and Gibson (1992) developed an extension of computerised trace method to determine the relationship between geometrical tolerances and manufacturing dimensions and tolerances. This method minimizes the cost of scrapas the objective function which is a function of manufacturing tolerances. Requirements of design sizes, geometrical tolerances (both form and position) and machining allowances are expressed mathematically as constraints for the optimization. Shivkumar et al. (2011) presented a general new methodology using intelligent algorithms for simultaneous optimal selection of design and manufacturing tolerances with alternative manufacturing process selection. Mansuy et al. (2011) presented an original method that enables to solve problems for the case of serial assembly (stacking) without clearances. This method is based on the use of influence coefficients to obtain the relationship between the functional tolerance and the tolerances associated with the geometry of the mechanism's interface surfaces. Sahani et al. (2012) presented review of different techniques for stack up for flatness geometrical tolerances.