Materials and Design 32 (2011) 3692–3701

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Modeling of interference fits taking form defects of the surfaces in contact into account

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ARTICLE INFO

Article history:
Received 22 November 2010
Accepted 25 March 2011
Available online 31 March 2011

Keywords:
C. Machining
D. Mechanical fastening
E. Shrinkage

ABSTRACT

The technique of assembly by shrink fit is increasingly used today. However, the methodology of parts sizing has not changed in 50 years. Assembled parts are assumed to have accurate dimensions and very low form defects. This has the disadvantage of increasing the cost of parts production. To reduce manufacturing costs, the study of the influence of form defects on the characteristics of assembly strength is essential. Taking default form into account assumes that the tightening (difference between the diameters of the shaft and the bore) is defined. In the case under consideration, the tightening depends locally on the radius. Two definitions of the tightening are proposed: maximum tightening and mean tightening. It is shown that the form defect is not detrimental to the assembly strength: the mean pressures are nearly equivalent to the classical case of surfaces without defects. Various finite element simulations were performed. The influence of the value and the type of defect have been studied for conventional tightening (elastic materials) and more intensive tightening (elasto-plastic behavior) in the case of axisymmetrical and non-axisymmetrical parts. The theoretical results correlate well with those obtained through experiments. However, for intensive tightening, the behavior of the roughness is not negligible.

1. Introduction

Shrunk parts assemblies have been performed for a long time, for example to give wooden wheels a more resistant rolling surface. These hoops were put in place by force or by thermal expansion. No accuracy was necessary because of the high elasticity of the assembled parts.

Machining methods having advanced, it was then possible to assemble metal parts that required greater accuracy to guarantee a given strength and geometry, as in the case of wrapped guns, or to transmit higher power with sprockets keyed on their shafts.

Actually, this mode of assembly is widely used and has almost replaced other methods such as securing parts by inserting a pin in a groove.

For requirements of optimizing characteristics, mechanical progress requiring use of materials as close as possible to their limits has led to the development of the study of this assembly method using theoretical studies, computer generated calculations and experimental trials.

However, in the literature, few studies have been done and the calculation rules contained in the standard have not changed in 50 years [1]. They are based on the classical solution of the thick-walled tube with internal pressures developed by Timoshenko [2].

This model is still limited to simple cylindrical parts which do not allow us to simulate the behavior of most industrial cases.

Some recent studies show the advantage of higher resolution models to understand interference-fits joints better.

Zhang et al. [3] have studied the stress distribution at the interface of a ball bearing in particular on the edges with finite element method. They established a strength criterion based on two safety factors λ_s (factor of safety to ensure component strength) and λ_p (factor of safety to ensure no slippage on mating surfaces).

Eyercioglu et al. [4] used finite elements modeling to design a tool for forging shrunk parts to ensure the final dimensions of the finished product.

Truman and Booker [5] have analyzed the effect of loading clamps on micro-slidings during the shrinking phase of a gear having a non-constant radial stiffness on an axis to predict fracture.

By studying the strengthening of local resistance by heat treatment with laser, Sniezek et al. [6] have shown that it is possible to increase the resistance by 50% by producing a geometric dephasing of treatment on the shaft and on the bore.

Adnan et al. [7] note the need to simulate the assembly process, for example in the case of insertion of a flexible joint, to improve design of this kind of assembly. Sun et al. [8] used simulation to validate the deformations due to heating of a crankshaft during

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doi:10.1016/j.matdes.2011.03.059