Materials and Design 31 (2010) 564–569

Contents lists available at ScienceDirect

Materials and Design

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

Short Communication

Influence of cryogenic treatment on load bearing ability of interference fitted assemblies

Irappa Sogalad [a,*], N.G. Subramanya Udupa [b]

[a] Department of Studies in Mechanical Engineering, University BDT College of Engineering, Davangere-577 004, India
[b] Department of Mechanical Engineering, Nagarjuna College of Engineering and Technology, Bangalore, India

ARTICLE INFO

Article history:
Received 22 April 2009
Accepted 7 July 2009
Available online 9 July 2009

ABSTRACT

The objective of this paper is to study the influence of cryogenic treatment of pin on load bearing ability of interference fitted assemblies. En8 steel was used to prepare the pin and bush. The pins were soaked in liquid nitrogen (cryogenic temperature) and ice for different time periods. The bushes were heated and then assembled without applying the external pressure. The assemblies were tested for their strength. A comparative study on results of experimental and Lame's approach has been carried out. The results reveal that assemblies with cryogenically treated pin exhibits higher load bearing ability. The degree of increase in load bearing ability with increase in soaking time at cryogenic temperature is small. The variation in load bearing ability obtained through experimental investigation is in agreement with that of Lame's approach.

1. Introduction

The performance of pin and bush assembly depends on the type of fit between the mating parts. The mating surfaces of the parts must fit together to fulfill the purpose for which they have been designed. By varying the sizes of two mating parts, numerous types of fits can be obtained. Depending upon the actual limits of the hole and shaft the fits are classified into clearance fits, transition fits and interference fits. The clearance fit provides a relative motion between pin and bush. Transition fit can produce clearance fit or interference fit and interference fit gives a tight joint between pin and bush [1].

Interference, in an interference fitted assemblies provides tight intimate contact between mating parts, intended to be held permanently as a solid component and it produces a high joint strength by establishing radial pressure on both the contacting surfaces. The absence of clamping makes them compact and aesthetic in appearance. They have an excellent load bearing ability under static as well as dynamic loading conditions. These assemblies find wide engineering applications. such as bearing bushes, pump impeller on shaft, small end bush in connecting rod, a crank pin in a cast iron web, cylinder liners, valve seats, gears, locomotive wheel on axle, stator of a fan, fitting rotors of turbines and compressors on shafts, mechanical drives and assembling of bearing races. Hence, it is worth to study the strength of the interference fitted assemblies. The load bearing ability of interference fits depends on various parameters such as amount of interference, physical dimensions, material properties, geometrical inaccuracies and surface condition of the mating members. Investigations were carried out to study the effect of various parameters on load bearing ability of interference fits. Further, different methods were suggested to improve the load bearing ability of the interference fits [2].

Berto et al. [3] studied the stress distribution under fatigue condition in fork-pin assembly of motorbike using finite element analysis and compared with that obtained experimentally using strain gauge mounted on the external surface of the hub during assembly. Kanber [4] investigated the Von Mises stress distribution at the interface of shaft and hub using finite element analysis and boundary element technique and found that boundary element technique is more suitable to analyse the stress distribution in interference fit problems. Sen and Aksakal [5] studied the stress distribution in interference fitted shaft–hub assembly in relation to the ratio of contact length-shaft diameter using the finite element method. During heating and cooling the transient conduction heat transfer state was considered in which the boundary conditions of the system are continuously changed. In such interference fitted connections the occurrence of plastic deformation zone and its distribution were evaluated. It was shown that the results will help the designer in force in transferring assemblies such as shaft–hub fitting coupled with pulley and gear systems in terms of dimensional analysis, tolerance and controlling the cooling conditions.

In other studies, Lewis et al. [6] used ultrasound as a tool to determine the contact pressure at the interface of interference fit.

* Corresponding author. Fax: +91 8192 233412.
E-mail address: sogaladirappa@yahoo.com (I. Sogalad).

0261-3069/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2009.07.007

For the purpose, a spring model was used to determine maps of contact stiffness from interference fit ultrasonic reflection data. A calibration procedure was then used to determine the contact pressure and reported that magnitude of interface contact pressure obtained using ultrasound technique agrees with the Lamé analysis. Further, similar contact pressure was observed in both shrink and press-fit joints. Sekercioglu et al. [7] observed the significant decrease in static and dynamic strength of adhesively bonded cylindrical components with increase in bonding clearance. Further, the strength of the joint increases five times when specimens are applied with both interference and adhesive bonding. Castagnetti and Dragoni [8] investigated the stress state in interference fits under torsional and axial loading and suggested the optimal ratio between the inside and outside diameters of the hub as 0.5–0.7 for maximum load carrying capacity regardless of the frictional co-efficient (up to 1) for brittle or ductile material.

The mechanical properties such as strength, hardness and wear resistance of steels will increase with decrease in temperature. Hence, cryogenic temperature has captured many industrial applications such as high temperature super conductors, the super conducting super collides, cryobiology, magneto hydrodynamic drive systems for ships, nuclear and electrical applications, cutting tools, dies, gauges, surgical scissors, bearings, racing engines, gears, automotives and knives [9,10]. The cryogenic treatment of tool steels increases the hardness and wear resistance. This increase is due to transformation of retained austenite to martensite at cryogenic temperature [11]. The cryogenic treatment of steels facilitates the formation of fine eta carbides in the martensite structure. The iron or substitutional atoms expand and contract. Further, the carbon atoms shift slightly due to lattice deformation as a result of cryogenic treatment thus, enhances the wear resistance [12]. Huang et al. [10] studied the change in microstructure of tool steel before and after cryogenic treatment. Cryogenic treatment can facilitate the formation of carbon clustering and increase the carbide density in the subsequent heat treatment. This result in increase in wear resistance of tool steels. Mohanlal et al. [13] reported that cryogenic treatment is an inexpensive one time permanent treatment affecting the entire section of the component unlike surface coatings and improves wear resistance and tool life.

In view of the above, an attempt has been made in this investigation to study the effect of cryogenic treatment on pin and amount of interference on load bearing ability of interference fitted assemblies. Further, a comparative study of experimental and Lame's approach has been carried out.

2. Experimental procedure

2.1. Specimen

The size of the pin and the bush [2] were selected in such a way that they cover the actual dimensional ranges in many practical applications. Assemblies were tested using Universal Testing Machine (UTM). The pins and bushes were prepared using En8 steel and the details shown in Fig. 1. The pins were turned and then ground on a cylindrical grinding machine. The bushes were prepared by drilling and reaming followed by internal grinding operation.

2.2. Measurements

With the help of slip gauges the sizes of the specimens (outer diameter of pin and bore diameter of bush) were measured using 1 μm accuracy dial and bore gauges. The surface roughness of the pins and bushes were measured using a Taylor Hobson Form Talysurf. The average R_a value obtained was 0.5 μm. To determine

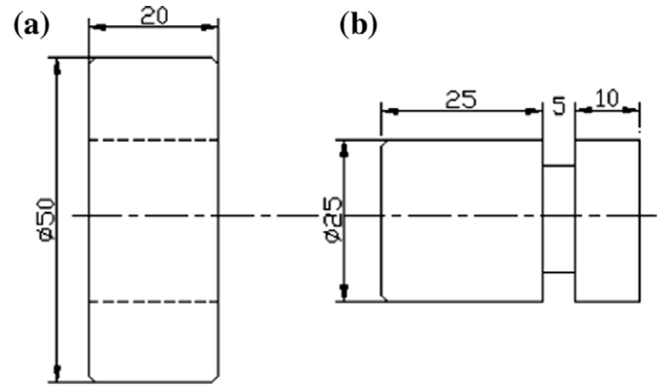

Fig. 1. Dimensions (mm) of (a) bush and (b) pin.

the hardness of material before and after cryogenic treatment, the different sets of specimens with 25 mm diameter and 20 mm thickness were prepared and were soaked in cryogenic temperature for different time hours. Subsequently they were allowed to reach room temperature gradually. The hardness of pins at five different points on the diametral (mating) surface was determined to circumvent the possible errors using Brinell hardness testing machine and an average value was used for the analysis.

2.3. Assembly and testing

Reversible changes in dimension are simple functions of temperature change and are based on the co-efficient of thermal expansion/contraction of the material. The interference in interference fitted assembly is the difference between pin diameter and bore diameter of the bush. During assembly the pin was cooled and bush was heated to a temperature such that the clearance produced by thermal expansion/contraction is sufficient for assembly of the parts. The interference can be obtained using the relation [14].

$$\delta = d_p[1 + \alpha(T_c - T_r)] - d_b[1 + \alpha T_h - T_r] \quad (1)$$

where δ is the interference (mm), d_p the diameter of pin (mm), d_b the bore diameter (mm) of the bush, α the co-efficient of thermal expansion/contraction of the material and T_c, T_h and T_r are the temperatures to which pin is cooled, bush is heated and room temperature, respectively. Assembling was done by heating the bush and cooling the pin. Digital display electrical oven (muffle furnace) was used to heat the bushes. Initially supply wires were connected to the supply point and instrument becomes 'ON' after pressing the 'MAINS ON' switch. Subsequently bush was kept in a muffle of size 6 in. × 6 in. × 9 in. and the door was closed. Required temperature (250 °C) was set using the controller by pressing the set key and rotating the knob in clockwise (to increase) or in anticlockwise (to decrease) direction. Further, pins were cryogenically treated (−196 °C) in cryogenic temperature. The pins and bushes were chosen from a group of pins and bushes to achieve the desired amount of interference. The assembling was done without applying external force and assemblies were allowed to cool in room temperature. The Time–Temperature response curve for assembly of pin and bush is shown in Fig. 2. Where t_c and t_s represents time to reach cryogenic temperature and varying soaking time of pin and t_h is the heating time of bush. t_a is the time required to assemble pin and bush. The assemblies were allowed to cool at room temperature T_r.

The tests were conducted to measure the load bearing ability of the assemblies. While conducting the axial loading test on assemblies, bush was supported by two parallel blocks on either side and an axial load was applied on the pin by UTM [2]. The applied load