ULTRASONIC MEASUREMENT OF WHEEL HUB/AXLE INTERFERENCE FIT PRESSURES

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INTRODUCTION

Interference fits are a commonly used mechanical attachment mechanism. They represent a flexible and cost effective method for joining components having cylindrical geometry. An interference fit is constructed when a bush is shrunk and/or pressed onto a shaft with an interfering radial dimension. The strength of the interference fit assembly depends on the shaft and bush dimensions, and must be sufficient to withstand the force or torque reached during normal service.

One common example of the use of interference fits is found on railway wheelsets. In this case the wheel is press-fitted onto the axle using a wax lubricant. Railway wheels occasionally fail by fretting fatigue, and this failure often initiates at the interference fit. Thus a quantification of contact pressures and their distribution in the wheel/axle fit is essential.

Previous work [1] has shown the validity of a non-intrusive ultrasonic reflection based technique for measuring the contact pressure distribution in an interference fit. Here the work is advanced applying the technique to an actual railway wheel/axle interface. The contact at the interface is partially lubricated in this study, in contrast to the dry fits previously analysed.

ULTRASONIC REFLECTION FROM A ROUGH SURFACE CONTACT

When an ultrasonic wave is focused on a rough surface interface it passes through regions of asperity contact and is reflected back at air gaps. A reflection coefficient, $R$, is defined as the proportion of the incident signal amplitude that is reflected from the interface.

It has been shown that the reflection coefficient can be defined in terms of the interfacial stiffness, $K$, using a spring model of the interface [2]:

$$|R| = \frac{1}{\sqrt{1 + (2K/\omega z)^2}}$$  \hspace{1cm} (1)

where $\omega$ is the angular frequency ($= 2\pi f$) of the ultrasound wave and $z$ is the acoustic impedance (the product of the wave speed and density). Tests at low pressures using typical machined surfaces showed that the contact pressure is proportional to the interfacial stiffness [3]. This means a simple calibration can be carried out to relate the two parameters.

The same principle can be applied to a partially lubricated contact [1]. The pockets of air previously at the interface are now filled with lubricant.

For a partially lubricated interface the following equation for total stiffness, $K_T$, applies:

$$K_T = K_L + K_S$$  \hspace{1cm} (2)

where $K_L$ is the stiffness of the constrained lubricant, and $K_S$ the solid stiffness from the asperity interaction. The stiffness of the lubricant film, $K_L$, is:

$$K_L = \frac{\rho_L c_L^2}{h}$$  \hspace{1cm} (3)

where $\rho_L$ and $c_L$ are the density and speed of sound in the lubricant respectively, and $h$ the average separation of the interface surfaces.

The presence of the lubricant increases the stiffness of a given rough surface contact at each and every contact pressure when compared to the un-lubricated case. This is due to the addition of the lubricant stiffness to the existing solid stiffness. The spring model shown in Equation 1 is still applicable to find the total interface stiffness from a lubricated contact [4]. If the lubricant stiffness is subtracted from the overall value, the solid stiffness may be determined, the solid stiffness as for the dry case is proportional to contact pressure. In this way contact pressure can be determined using ultrasonic reflection data from a lubricated contact.
ULTRASONIC MEASUREMENTS

A 10 MHz focusing transducer was used to investigate the wheel/axle interference fits. This was mounted on an arm which was attached to a scanning table automated for x, y scanning (see Figure 1). The hollow axles were partially filled with water to act as a couplant for the ultrasound and the signal was focused on the interference fit interface. Line scans were recorded at a step size of 0.5mm at 10-degree intervals around the fit for two different wheels.

Figure 1. Schematic of Wheel/Axle Scanning

Reflected ultrasonic signals from the wheel/axle interface were recorded during the scanning. A reference trace was also recorded; this was measured from the groove on the interface indicated on Figure 1 (the groove is used as a cavity through which high pressure oil is pumped when removing the wheel from the axle). Dividing one by the other gave the fraction of ultrasound incident at the interface that is reflected from it (the reflection coefficient, $R$). Applying Equation 1 to the reflection coefficient data produced values of total interface stiffness for the partially lubricated contact. The value of the lubricant stiffness was then calculated using Equation 3 and subtracted from the total stiffness to give the solid stiffness, which is proportional to the contact pressure.

Figure 2 shows the contact pressure profile for one of the wheel/axle interference fits. The scan shows the relative magnitude of pressure in the contact. The contact pressure along the length of the interface is not constant. Contact pressure rises at the edge of the interference fit before falling away again. The edge of the interference fit magnifies the contact pressure, as it is a stress-raising factor. However, the wheel hub is also tapered at the edge of the fit with the interference reducing. The reducing interference acts to lower the contact pressure. These two factors lead to the observed initial increase then subsequent decrease in the contact pressure at the edge of the fit. Similarly, the contact pressure rises near the edge of the no contact groove. However, here the pressure rises to a higher value than that at the edges of the fit. This is because at the groove there is no tapering to counteract the stress raising effect of the discontinuity. A second wheel scanned had a different web design and gave a markedly different pressure profile.

Figure 2. Scan of Wheel/Axle Interference Fit Pressure Profile

CONCLUSIONS

A method has been established to determine interface pressure profiles in two wheel/axle interference fits. The method relies on the measurement of reflected ultrasonic signals from the contact.

Contact pressure was seen to increase at the discontinuities at the edge of the fit and internal groove. Elsewhere the pressure showed a constant deviation about a mean value.

A full calibration is now required to produce a complete map of contact pressure for the wheel/axle interference fits.

REFERENCES