Effects of surface topography and interference on the mounting curve of railway wheel-set press-fit assembly

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Abstract

Press-fit assembly of railway wheel-setshas been studied with the aim of defining the mechanical and physical parameters that cause deviations in the produced force-displacement mounting curve for seemingly consistent processes. This work investigates the role of surface finish and the obtained interference value on the joint strength, and how this affects the force-displacement curve used for active quality control. In order to interpret press quality, force-displacement curves, maximum press-mounting and maximum de-mounting forces of railway wheel-set assemblies have been investigated experimentally using the press apparatus at a Rolling Stock Wheel Shop in Dampier, Western Australia. It was found that for a given texture topography generated lathe machining of the contact surfaces, the resultant roughness has a notable influence on the fit strength and therefore the static friction coefficient. Surface deformation pre and post pressing have been investigated and the effect on the joint strength is discussed.

1. Introduction

In large scale mining, in-house manufacture of wheel-sets for rolling stock is necessary to optimise costs. The ultimate purpose of the assembly process is efficient and safe wheel-set production with high throughput, the challenge being to control the multiple variables affecting the process to achieve this. Any inability to repeatedly and successfully mount wheels onto axles creates delays and adds significant cost and risk to the business by nececessitating outsourcing of remanufacturing work whilst the problems are worked through in-house, reduced asset integrity, high scrap rates of parts damaged during failed wheel mounting, lost production, and increased safety risks. Incorrect wheel-set assembly due to insufficient or excessive press-fitting force can affect the wheel retention force on the axle seat, generating safety risks.

Wheel-set press-fit joints are rejected and reassembled simply because the pressing-on forces are outside the permissible range, or the Force-Displacement (F-S) mounting curve shape does not meet the specifications in railway standards (Figure 1) (AAR-G-II, 2004). The range of pressing-on forces achieved in practice can be greater than the boundary limits defined by standards, despite the geometrical and technological assembly parameters being apparently constant and well within the recommended range. When experimental pressing-on forces do not match the recommended values from the standards, it does not mean that the joints have inadequate exploitation characteristics for deployment in service (Stamenković et al., 2011).

To investigate this issue and to acquire more knowledge about the tribological parameters and their influence on press-fit joints, this paper will discuss the effects of surface topography and interference value on the shape of the mounting curve.

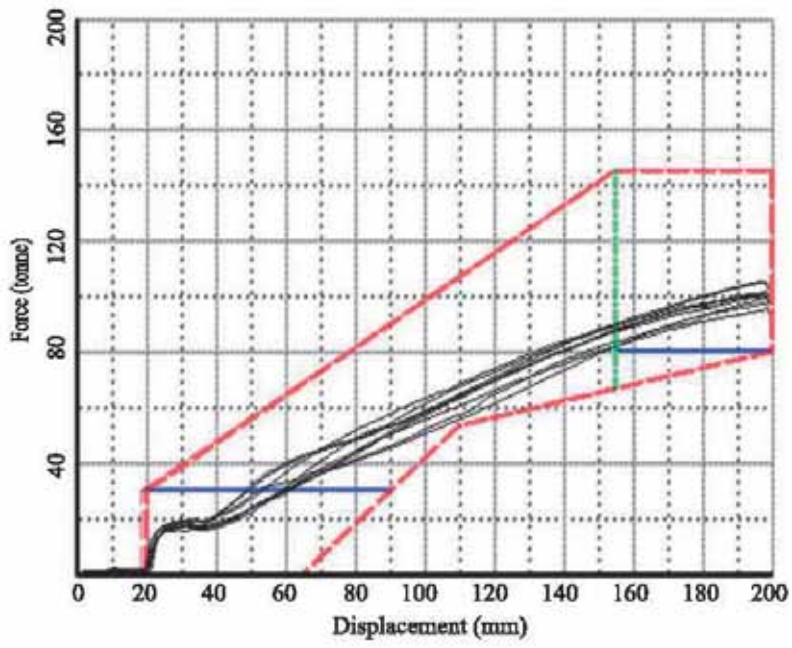

Figure 1 Experimentally obtained F-S mounting graphs for repeated sample joints (black) with consistent mounting parameters. The red dotten line indicates the force limits from AAR-G-II. Graph from the RTIO Wheel Shop, 2017.

1.1 Railway Standards and Practical Experiences for Wheel Mounting

A recommended range of input machining parameters are typically provided by standards. AAR states that if the interference fit is adequate, taper is correct, lubrication is proper, alignment is true, and wheel and axle finishes are compatible, tonnage will increase smoothly and almost linearly from the beginning to the end of the mount at a slightly decreasing rate (AAR-G-II, 2004). However, this is not always observed in practice, the resulting mounting curve can be inconsistent despite apparent unchanging input parameters.

The standards do not recommend target surface roughness for the contacting surfaces of the axle and bore, nor does it provide insight to the likely stochastic variation of the curve shapes. Press-fit joint strength depends on the joint geometry, the contact pressure and the friction coefficient. From previous studies, we can summarise the factors affecting these dependencies in Figure 2. A small variance of one of these factors can dramatically change the press-fit force. For this reason it is important to closely control the mounting process to avoid large differences in the product.

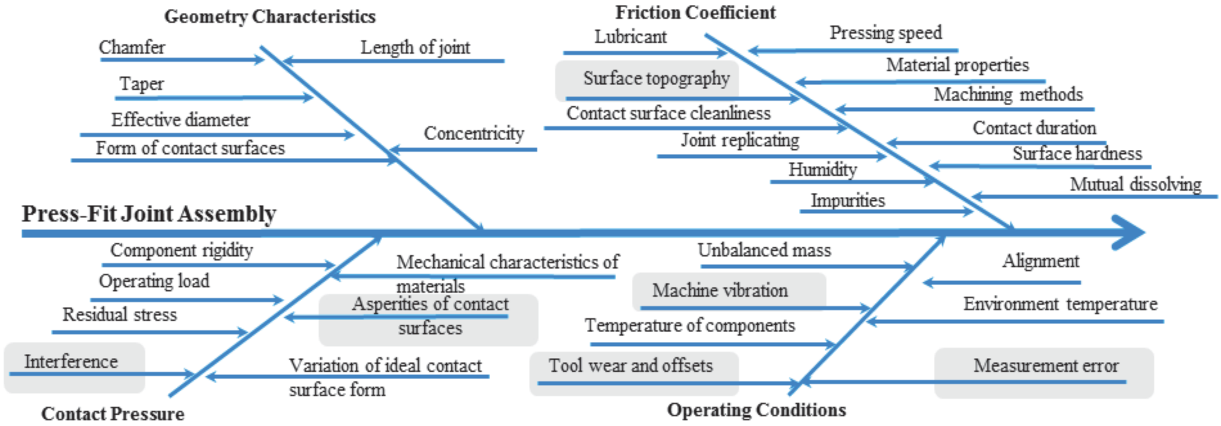

Figure 2 **Factors that influence press-fit assembly – Ishikawa diagram adapted from (Stamenković et al., 2011). The highlighted factors are investigated in this report.**

2. Process

All experimentation was conducted at the Rio Tinto Iron Ore (RTIO) Automated Wheel Remanufacturing Facility in Dampier. The test specimens used were heavy-haul ore car axles and wheels. 46 wheels and 23 axles were carefully prepared, controlling machining feeds, speeds, diameter, lubrication and surface finish for 46 press-on and 20 press-off processes (Figure 3). Interference fit, press-fit curves and maxinum forces were examined for each. Surface topography was measured using a surface profilometry tool on the mating surfaces before pressing-on and after demounting of wheels from their axle.

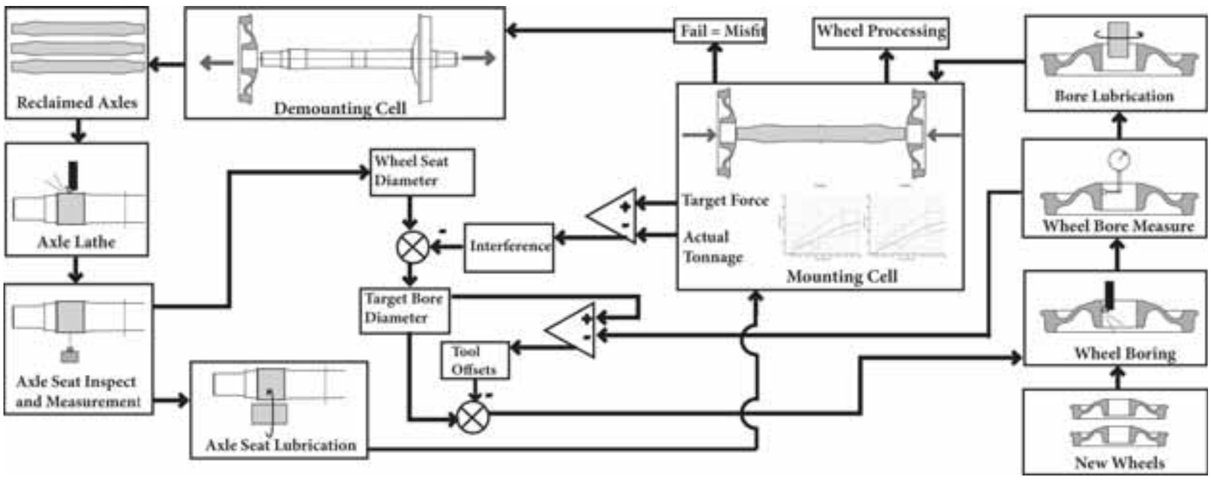

Figure 3 **Adapted Process Control Diagram from (David William Davis et al, 2012(IHHA)) for Closed Loop Ore Car Wheel-set Mounting for the RTIO Dampier Facility.**

3. Results and Discussion

The procedure from DIN 7190 for interference fit tolerances and design has been used to calculate the predicted mounting force, using actual measured values of interference, surface roughness and the value of the static friction coefficient (μ=0.1, as recommended by the lubrication manufacturers).

The experimentally measured values are compared to the predicted forces, and to the bounding permissible values from three railway standards (Figure 4):

1. Association of American Railroads Standard (AAR) GII-2012
2. NSW Transport RailCorp Engineering Standard ESR-0331
3. International Union Railways Leaflet UIC 813-2003

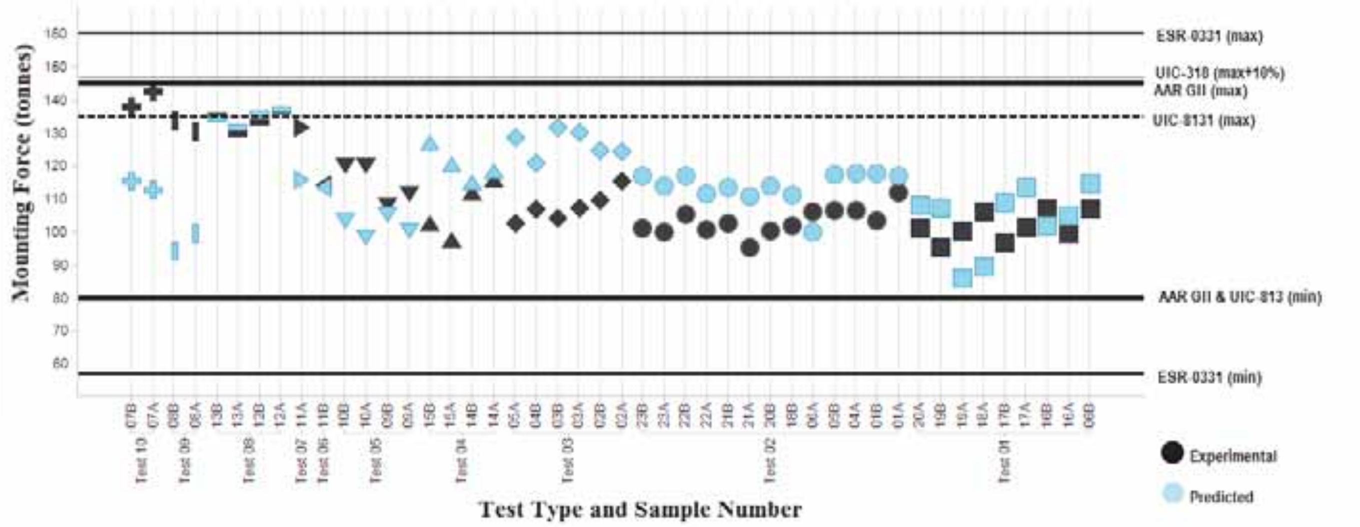

Figure 4 Distribution of the calculated and experimentally obtained press mounting forces.

3.1 Wheel Mounting - Effect of Bore and Axle Roughness

Wheel mounting results show an upward strend for the Ra value (arithmetic mean of the profile) of the wheel bore resulting in an increased maximum press-on force. Similary, other profilometry parameters indicated an increase in press-fit force, although to a lesser extent.

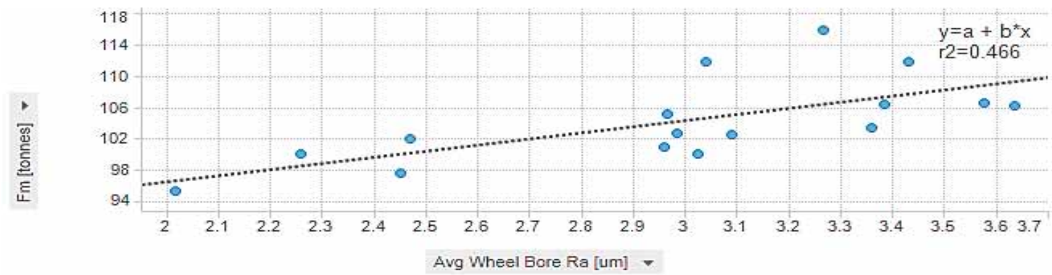

Figure 5 Maximum press-mounting force (F_m) as a function of the surface parameters of the wheel bore.

This may be explained by effect of sliding friction and strain energy. Interlocking of the surface asperities has often been cited as the reason for exhibiting higher load-carrying capacity with increased roughness (Ramamoorthy and Radhakrishnan, 1994). This continuous interlocking will create "shocks" of resistance force during sliding which will increase the sliding friction coefficient. Furthermore, these asperities in contact may cause some degree of plastic/elastic material deformation. Smoother bore surface finishes will have less micro-irregularities to deform to fit the equilibrium of the interference fit therefore requiring less pressure to create the joint.

3.2 Wheel Demounting - Effect of Bore and Axle Roughness

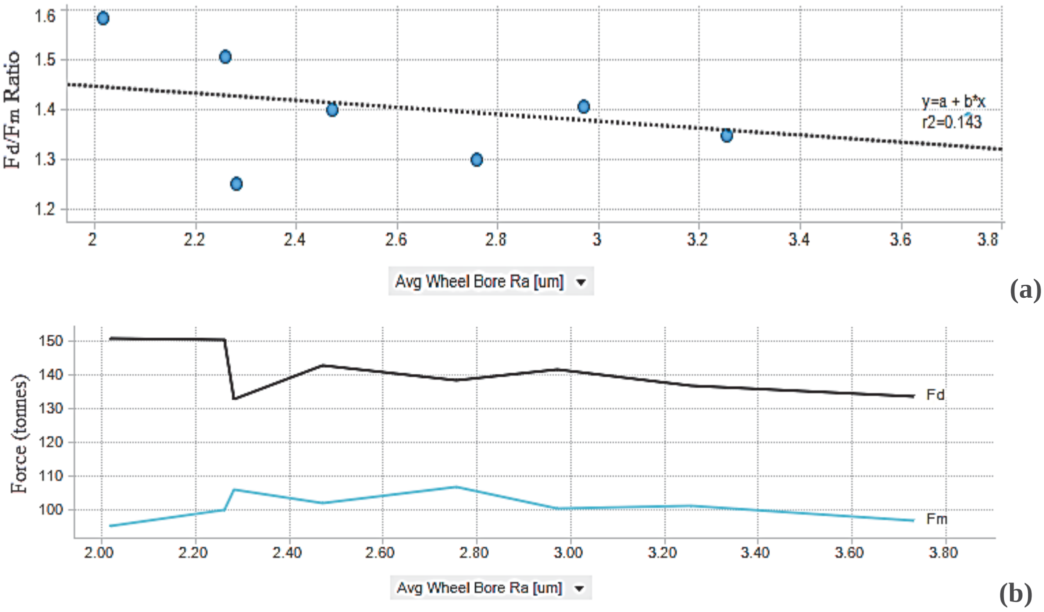

Figure 5 Ratio (a) of axial de-mounting force to mounting force against roughness values for press-fits, with their obtained force values (b).

Eight (8) samples with consistent interference fit, ranging from 0.305 to 0.316 mm, were analysed against their demounting forces and surface finish values of the wheel and the axle. The demounting force was poorly correlated with the axle seat roughness; therefore we have focused on the effect of the surface finish of the bore. The effect of wheel bore surface roughness on the ratio of demounting/mounting load (F_s/F_d) is shown in Figure 5. The ratio is larger for smooth bore surfaces and smaller for rough surfaces. For repeated tests performed, the disassembly forces were 153-159% larger than their maximum mounting force.

It is evident from this that is that precise control of assembly parameters in practical workshop environments can greatly reduce the variation of obtained F-S curves.

3.3 Surface Topograpy Deformations

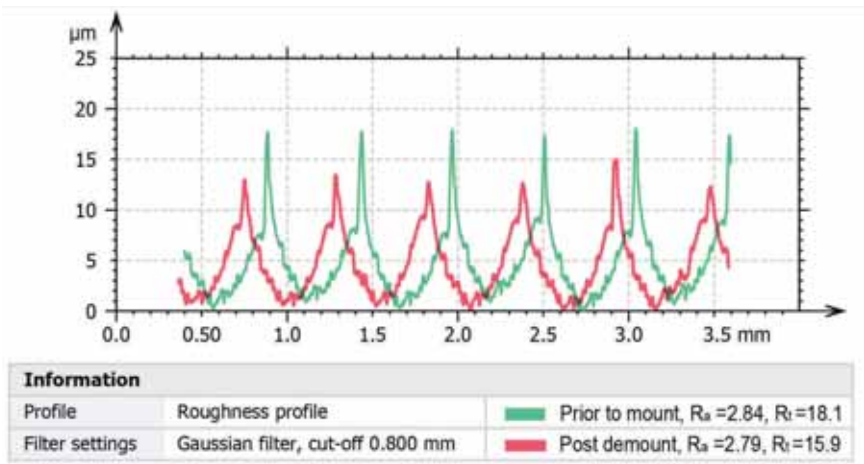

Figure 6 Observed profile modification of a wheel bore before press-on and after press-off processes for Press-Fit Sample 20A.

Surface profilometry results indicate little change of roughness parameters of the wheel bore, indicating that these surface asperities appear to persist during press-fitting.

To explore this result, RTIO company employees cut apart a wheel-set to visually inspect the contact surfaces of the bore and axle seat. Dried lubricant residue was observed in parallel lines matching the profile valleys created by lathe machining.

4. Conclusions and Future Work

The results indicate that the quality of wheel mounting operations is dependent upon the skill and care with which the boring mill operations are performed. It is evident from the experiment that process control and measurement accuracy, including machine vibration, tool wear offsets and size/type of measurement gauges, is crucial for consistent and reliable assembly results.

It is evident that the surface profile and its modification during the assembly strongly influence the strength of the joint. For interference values between 0.30-0.32 mm, there is minimal surface deformations and surface asperities of the bore [ersist during and after pressing.

Smooth bore topographies and low roughness lathe machined surfaces have poor lubrication retention, which can result in high frictional forces, and induce residual stresses likely to exceed material yield which may cause damage to components.

The results of this work provide the basis to believe that a very complex hydrostatic pressure system occurs at the interface of contacting surfaces, with contact occurring at discrete locations at profile asperities, with an incompressible liquid (lubricant) or air trapped in the joint. Finite Element Methods can be utilised to investigate this further, by mapping the micro-surface irregularities with a coupled solid-fluid model.

5. Acknowledgements

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