Measurement of displacement between axle and wheel during rotating bending as a tool for evaluation of potential fretting fatigue damage under press fit

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Abstract

Wheelsets are components extremely dynamically loaded in service, by a very high number of cycles, usually more than 109 during the life. That is why fatigue resistance of these components have to be adequately proved during the certification process, when such proves are strictly requested Two or three characteristics are defined in the standards, which have to be proved, namely (i) fatigue resistance of the smooth part of the axle body on its free surface, so called characteristics F1 and (ii) fatigue resistance under press fit (or shrink fit) - characteristics F3.

This contribution describes, after an initial evaluation of fretting fatigue cracks under press fit, a new experimental approach for verification of press fitting quality and homogeneity by measurement of mutual circumferential displacements between the axle and wheel hub during the full scale fatigue test. Though the press fit of the tested wheelset met standard requirements for the press fitting diagram in terms of minimum and maximum forces, the mutual microscopic displacements under the press fit were not homogeneous for the whole circumference, the maximum value being almost twice as much higher than the minimum one. Another effect was a dependence of these displacements on number of cycles during rotating bending fatigue tests. The results are discussed considering circumferential dynamic stresses on the axle surface and the fact that fretting fatigue damage is very sensitive on both displacement values and contact forces under press fit.

MEASUREMENT OF DISPLACEMENT BETWEEN AXLE AND WHEEL DURING ROTATING BENDING AS A TOOL FOR EVALUATION OF POTENTIAL FRETTING FATIGUE DAMAGE UNDER PRESS FIT

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Introduction

- Railway wheelsets and axles are safety-critical components
- Wheelsets are components extremely dynamically loaded in service in terms of a very high number of cycles, usually more than 10^9 during the life, corresponding to several tens of service years.
- In spite of that axle failures occur relatively infrequently, consequences are usually very serious, from financial damages to heavy casualties.

Introduction

Introduction

- Though strict standard criteria for the press or shrink fitting methods exist like **overlapping dimensions** of the axle seat diameter and wheel hole, dependence of **press forces** during the press fitting process, press fits still remain one of the critical areas where possible cracking occur.
- Another problem is that unlike fatigue resistance of most of metallic materials without defects on free smooth surface increases with increasing static material strength, in case of **fretting fatigue mechanism this need not be true**.

Introduction

- A comprehensive experimental programme, which included rotating bending tests of press fitted axle models reduced to the scale 1 : 5 showed that resistance to fretting fatigue under press fit of high strength railway axle steels is comparable or even worse than the standard EA1N normalized steel with the lowest strength.
- Endurance limit of the models of different steels was comparable and it was indicated that **retardation and arrest of initiated microcracks or short fatigue cracks in compressive residual stress field are crucial mechanisms** deciding, whether the main fatigue crack will be created and final failure occur

Introduction

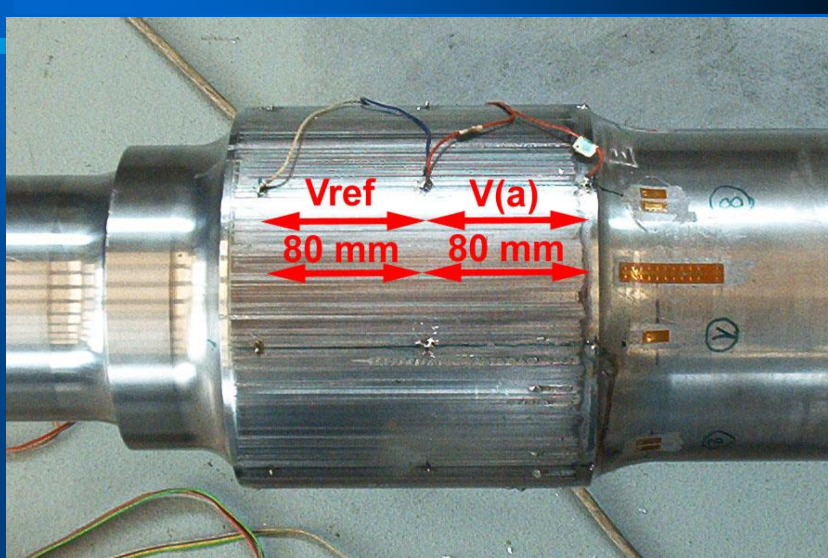
- Fatigue resistance of these components have to be adequately proved during the certification process, when such proves are strictly requested
- Two or three characteristics are defined in the standards, which have to be proved, namely

➔ (i) fatigue resistance of the smooth part of the axle body on its free surface, so called **characteristics F1** and

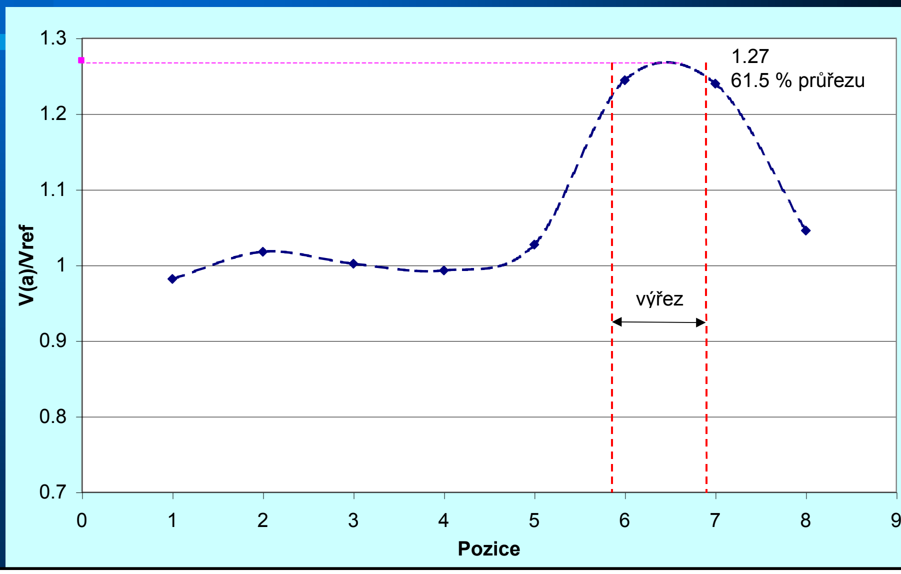
➔ (ii) fatigue resistance under press fit (or shrink fit) - **characteristics F3**.

Experimental programme

Experimental programme



Experimental programme - DCPD results



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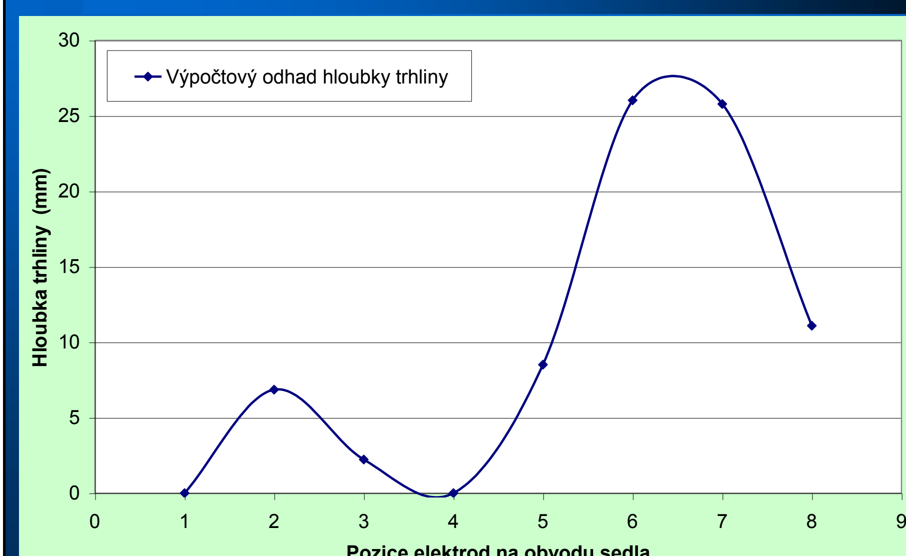
Experimental programme - crack depth calculation from DCPD



Experimental programme

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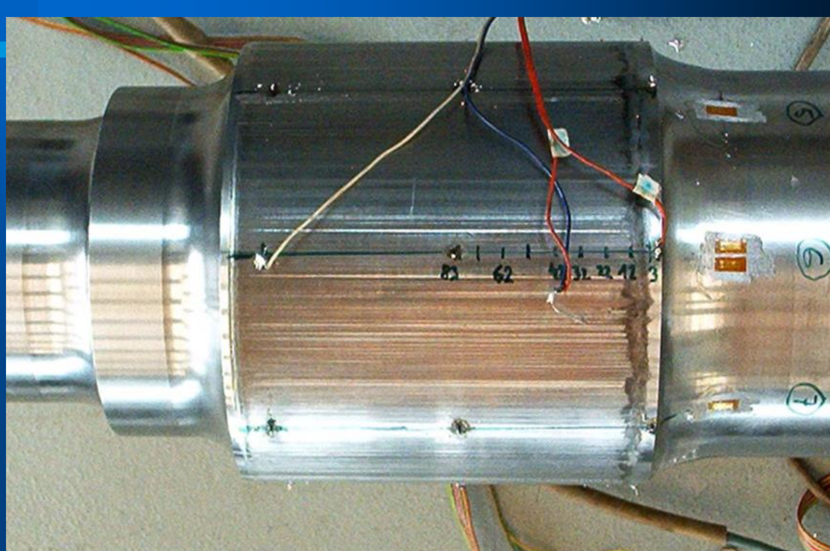
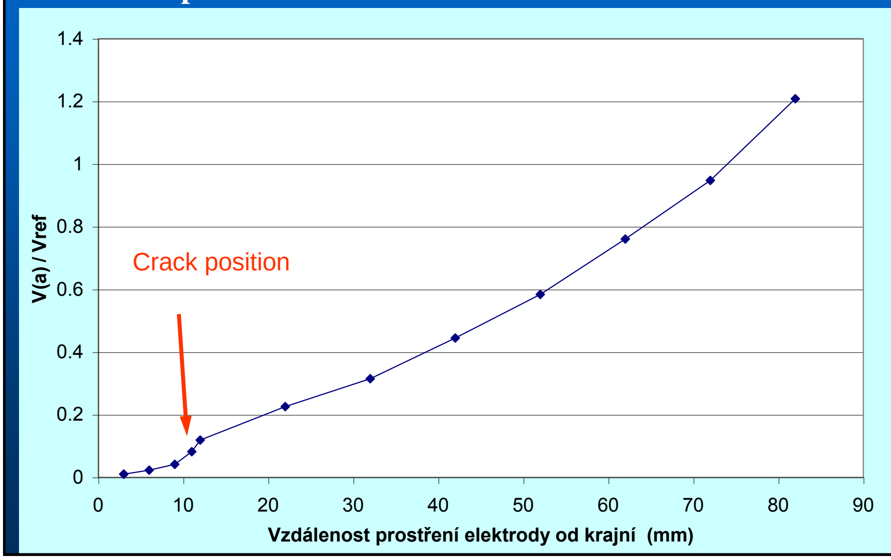
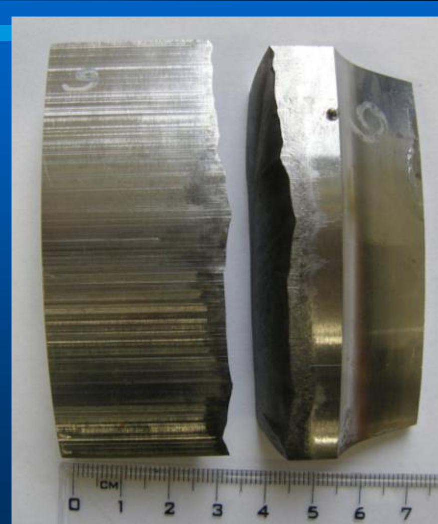


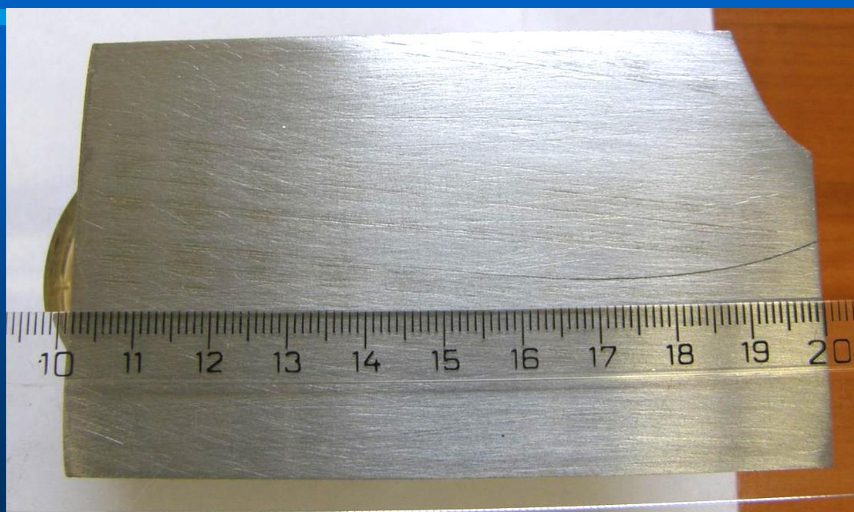
Experimental programme - dependence of DCPD on the central electrode position



Experimental programme - sectioning



Experimental programme - actual crack at deepest point



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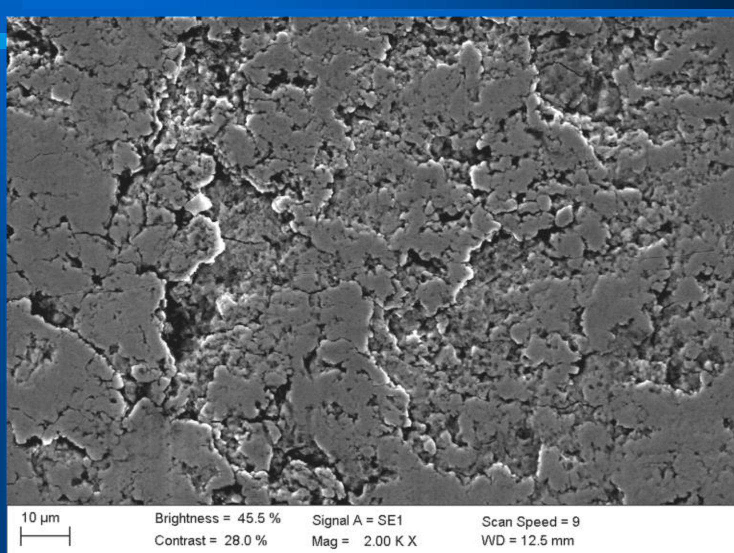
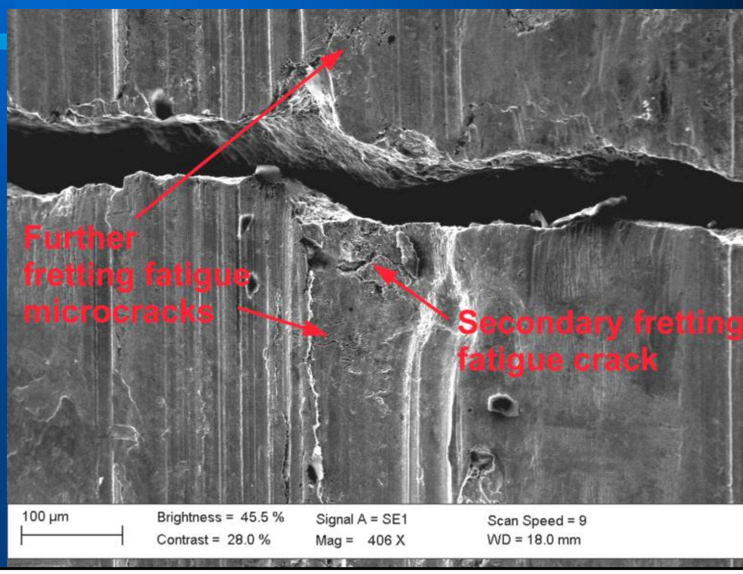
Experimental programme



Experimental programme



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Full scale axle fatigue testing - history...

Present time... mind several essential substantial changes

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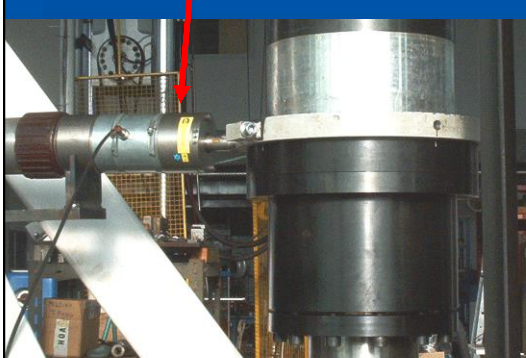
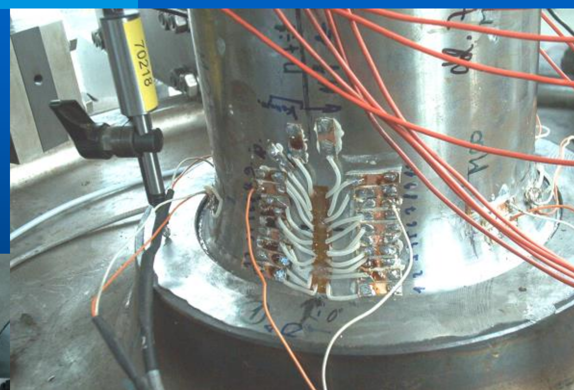
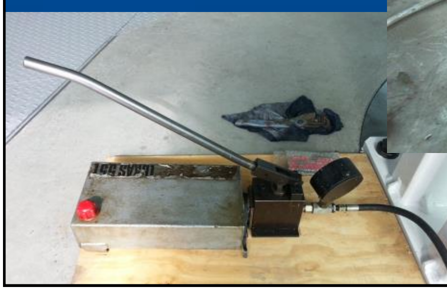
Experimental programme - calibration of bending moment using hydraulic cylinder with independently calibrated load cell



Experimental programme - calibration of bending moment using hydraulic cylinder with independently calibrated load cell





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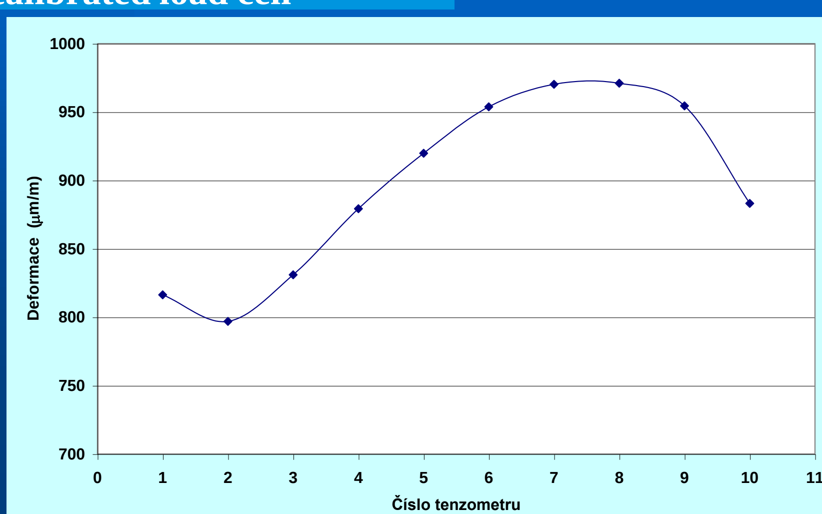
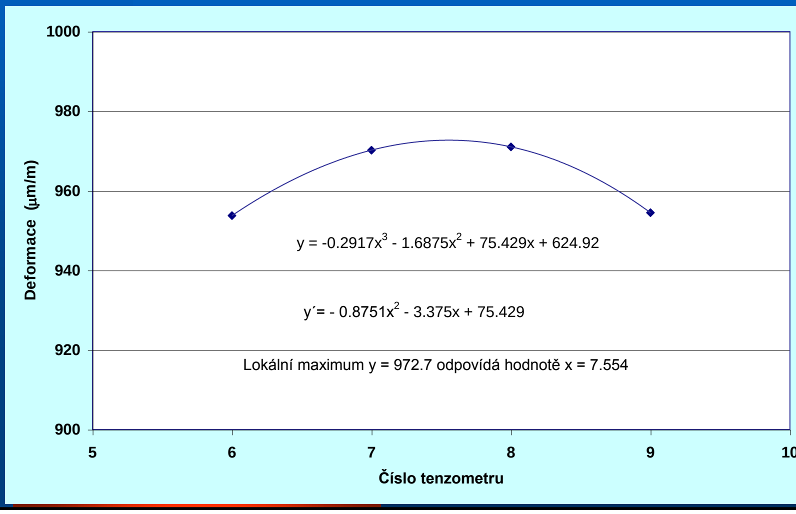


Experimental programme - calibration of bending moment using hydraulic cylinder with independently calibrated load cell



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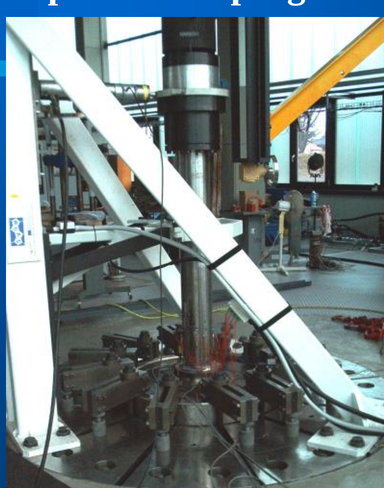
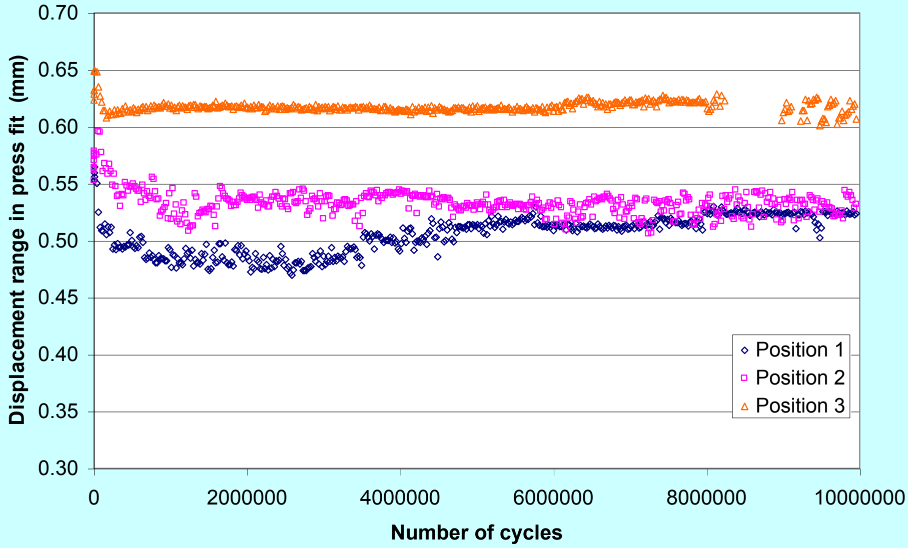


Total view of the axle prepared for fatigue test on the Sincotec machine

LVDT extensometers measuring displacement between axle and wheel

Results and discussion



Results and discussion

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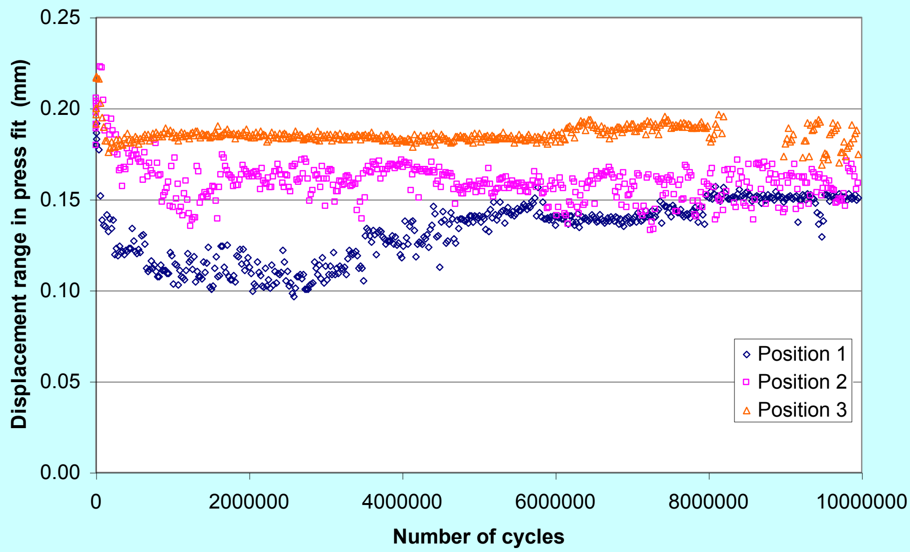

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Conclusions

- Rotating bending fatigue test of full scale railway axle press fitted in the disc simulating actual wheel was performed according to European standards to verify sufficient fatigue durability either on the axle shank or under the press fit.
- Beyond the parameters monitored according to the standard requirements, shear contact displacements between the axle surface and the hub along the axle circumference were evaluated and recorded. The main results can be summarised as follows:

Conclusions

- In spite of that the pressure diagram - the diagram of pressure forces during pressing the axle into the hub fully satisfied the standard criteria, the mutual displacements during fatigue loading along the circumference were far from ideal homogeneity, the maximum values being almost twice as high as the minimum values. This inhomogeneity was not affected by loading itself, which was almost ideally homogeneous along the circumference.
- The inhomogeneity of the shear displacements may unfavourably affect the fretting fatigue process, which is strongly dependent on both mutual shear displacement and contact pressure forces at the axle and hub interface.

Conclusions

- Another effect was a dependence of these displacements on number of cycles during rotating bending fatigue tests.
- The results were discussed considering circumferential dynamic stresses on the axle surface and the fact that fretting fatigue damage is very sensitive on both displacement values and contact forces under press fit.

Acknowledgement

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