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Advantages and Disadvantages Strain Gauge Hole Drilling and X-Ray Diffraction Methods for Certification Railway Wheelsets

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Abstract: Measurement of residual stresses in the rail industry is described in the relevant industry standards. When selecting measuring points, the number and specific locations in practice adjusted according to specific customer requirements. The authors of the article provides practical experience in the application of two basic ways to determine residual stresses in railway wheels and axles i.e. semidestructive strain gage hole drilling method and nondestructive methods using X-ray diffraction analysis.

Keywords: Hole Drilling Method; X-Ray Diffraction; Residual Stress; Wheel; Axle.

1 Introduction

Residual stresses can be both useful and harmful. To the first belong operating pressures on the surface layers of metals and alloys where they increase levels of fatigue strength and corrosion resistance. The negative effects of tensile stress result in making cracks, corrosion under tension and decrease of level of fatigue. In the production of railway wheelsets residual stresses are one of the most monitored values. With regard to the fatigue in wheels and axles residual stress is required in these parts.

2 Residual stress in railway standards

Requirements for railway wheelsets are described in European Standard EN 13260 [1]. This standard prescribes the maximum residual stress in on seats of axles. The European Standard EN 13261 [2] provides requirements for railway axles. This standard also prescribes the maximum residual stress, moreover, it prescribes the maximum allowable difference of residual stress at a depth of 2 mm below the surface. Both of these standards allow measurement of strain gauges or X-ray diffraction. For railway wheels are the requirement summarized in the European Standard EN 13262 [3]. In this standard is stated acceptable level of peripheral compressive stressed near the surface rim of solid wheels. To verify keeping these requirements destructive (shredded) strain gage and nondestructive (UZ) method is used. This standard doesn't affect values of residual stress on the surface on the wheel which plays an important role regarding fatigue life EN 13979 Annex D [4].

3 Measuring principle

X-ray diffraction allows the determination of crystallographic parameters like lattice plane distance d or lattice constant a using Bragg's law. The residual stress measurement by X-ray diffraction is based on the determination of lattice strains in consequence of residual stresses in the crystallographic lattice. The measurement principle is based on the determination of the lattice plane distance d as function of the angle ψ. The strain which is determined by d can be calculated according to relation 1 as function of $\sin^2\psi$. The stress is determined by calculating the slope from the plot ε over $\sin^2\psi$ (see relation 1) and using young modulus and

poison ratio. The ε-sin$^2\psi$ or d-sin$^2\psi$ – plots can show various appearances. In case a and b the stress components can be determined by using relation 1. When is material textured and the simple d-sin$^2\psi$ – method cannot be applied.

$$\varepsilon_{\varphi,\psi} = \frac{1+\nu}{E} \cdot \sigma_\varphi \sin^2\psi - \frac{\nu}{E} \cdot (\sigma_1 \cdot \sigma_2) \tag{1}$$

Hole drilling method consists of measuring deformation gage rosette after drilling a blind hole. For the main stress rectangular strain gauge rosette applies relationship [5]:

$$\sigma_{min,max} = \frac{\varepsilon_1 + \varepsilon_3}{4A} \pm \frac{1}{4B} \cdot \sqrt{(\varepsilon_3 + \varepsilon_1)^2 + (\varepsilon_3 + \varepsilon_1 + 2\varepsilon_2)^2} \tag{2}$$

$$\tan 2 = \frac{\varepsilon_1 - 2\varepsilon_2 + \varepsilon_3}{\varepsilon_1 - \varepsilon_3} \tag{3}$$

4 Preparation of measurement

Strain gauge hole drilling method requires thorough preparation of the surface. The surface to which the strain gauge is stuck must be perfectly clean and smooth to allow a complete adhesion of the strain gauge. Preparing the surface should not result in loss of stress by thermal modification or elimination of surface elements. Subsequently solder power cables are soldered, unprotected parts must be secured to avoid cut-offs. The last step of preparation is precise alignment and bonding hole drilling set.

In light of preparation before measurement diffraction method requires only degreasing and cleaning a surface. Next there is only a need to find operative extent of a measuring head and a collimator.

5 Conclusion

For evaluation of residual stress in railway wheelsets both methods have their use. Semidestructive strain gauge hole drilling method is preferably applicable to the evaluation of the depth profile stress, e.g. uniformity of heat treatment of the evaluation of axles at a depth of 2 mm. In contrast, X-ray diffraction is indispensable for assessing the impact of technology of processing residual stresses on the surface and in its closest distance. The advantage of measuring by X-ray diffraction compared to the strain gauge method is significantly easier preparation of the surface component to be measured which rapidly speeds up preparation for measurement. This method, however, uses restricted depth for etching.

References

[1] EN 13260: 2009+A1, October 2010, CEN.

[2] EN 13261: 2009+A1, December 2010, CEN.

[3] EN 13262: 2009+A1, December 2010, CEN.

[4] EN 13979-1: 2003+A2, March 2011, CEN.

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