FORCE-BASED ASSESSMENT OF WELD GEOMETRY

ProRail introduced new welding standards

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Introduction

As per first of January 2005 ProRail in The Netherlands introduced new standards for the assessment of weld geometry. For the vertical geometry the versine is no longer decisive, but the force between wheel and rail. Delft University of Technology has developed a fast algorithm to estimate the vertical force along the weld [1]. The maximum force is then tested against a speed dependant force norm. To make everything more understandable the forces have been normalized by dividing them by the load norm. In this way a so called quality index is introduced (QI). This QI should be less than 1 to approve a weld (Figure 1).

The algorithm for the weld assessment in fact looks at the first derivative (inclination) of the weld geometry. The maximum allowable inclination for an operational speed of 40 km/h (marshalling yards) is 3.2 mrad, for 140 -200 km/h 0.9 mrad and for high-speed 0.7 mrad. High quality rails should fulfil the requirement that the peak to peak value over 3 m (circumference of the straightening rolls) should be less than 0.3 mm, i.e. an amplitude less than 0.15 mm. Theoretically this corresponds to a first derivative of about 0.3 mrad. Recent measurement have shown that actual values for new high-speed rails are better than 0.7 mrad.

Theoretical background

In principle the dynamic force between wheel and rail can be approximated by the simple formula based on the principle 'Force = mass times acceleration':

$$F_{dyn} = m_e \ddot{z}(t)$$

As for very short wavelengths not the total unsprung mass will accelerate the assumption was made that the effective mass is linear with the wavelength according to $m_e = M \cdot \lambda / \lambda_0$, with λ_0 being some reference wavelength (2 m). For a harmonic signal $z = z_0 \sin(2\pi vt / \lambda)$, it follows that:

$$F_{dyn} = M \frac{2\pi v}{\lambda_0} \dot{z}$$

Due to the assumption of a linear relation between wavelength and effective mass, this expression is independent of λ and holds for any arbitrary function z. Via $dx = v \cdot dt$ the relationship with the rail geometry (inclination) is found:

$$F_{dyn} = M \frac{2\pi v^2}{\lambda_0} \frac{dz}{dx}$$

So the force is proportional to the first derivative of the geometry and the square of the operating speed. The unsprung mass is set to 2,000 kg.

RAILPROF

For many years ECS produces the RAILPROF electronic straightedge. With the development of the new weld standards no longer a simple analysis algorithm could be used. Instead more sophisticated calculations were required. For this reason it was decided to use a PDA hand held computer (Figure 1).

All data such as Location, Track/Switch, Rail Left or Right, Weld Type, etc. can be keyed in before. Time and date are stored automatically. If the PDA is connected to a GPS antenna the location is also filed automatically.

With the PDA a command is given to start the measurement. After completion the RAILPROF transfers the raw measuring data to the PDA, which directly carries out the required analyses. If the standards are exceeded further finish grinding is necessary and again a measurement is done . This procedure is repeated until the weld is within specifications. At that time the vertical and lateral weld geometry are stored in the PDA.

References

[1] M.J.M.M. Steenbergen, C. Esveld. *Voorstel voor normering van lassen in spoorstaven*. Report 7-04-220-7, ISSN 0169-9288, TU Delft, Delft, 2004.

[2] http://www.esveld.com

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