Determination of dynamic track properties by means of excitation hammer testing

When investigating the dynamic behaviour of a railway track, it is necessary to look at its dynamic properties. At the TU Delft a test method has been implemented whereby an instrumented excitation hammer is used to quickly determine the dynamic properties of a railway track. The excitation hammer technique has been derived from a method developed for laboratory testing of the dynamic properties of rail pads [1].

This article looks at the method of testing of the excitation hammer technique, and gives some results that have been obtained during field measurements of a light rail track.

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Test method

Measurements are carried out by hitting the rail head with a large instrumented excitation hammer and by recording the subsequent vibration of certain components. Subsequently, the relevant dynamic parameters are determined, by means of a curve-fitting optimisation procedure, on the basis of a mathematical model which adequately describes the dynamic behaviour. This method does not require any vehicle loading.

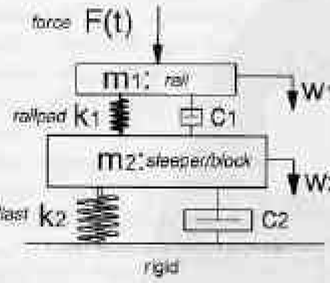

Fig. 1: Two-degree-of-freedom model

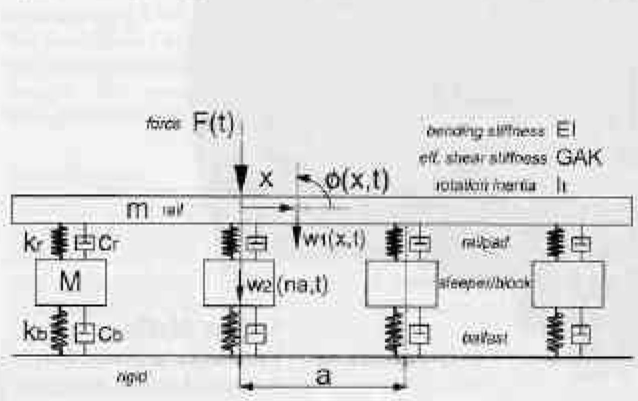

Fig. 2: Discretely-supported continuous rail model

Track modelling

In order to determine the dynamic properties of rail support and sleeper/slab support, two models are used:

— a two-degree-of-freedom model (Fig. 1); and

— a discretely-supported continuous rail model (Fig. 2).

Both models describe the vertical dynamic behaviour of the railway track. It should be noted here that the two-degree-of-freedom model makes use of certain parameter values which compensate for the absence of a continuous character of the track in this model.

Analysis of measured signal

Generally, two signal analysis approaches are applied to determine the relevant parameters from a measured signal, namely:

— in the frequency domain: the frequency response function (FRF). This is determined via auto and cross spectral density functions of both the acceleration response and the force input [1], [2];

— in the time domain: the state-space modelling. This is a new method developed for analysing measured test data [3].

Experience gained so far has proven that for some systems these two approaches yield similar results.

An automatic curve-fitting optimisation procedure has been developed for the two-degree-of-freedom model which enables the determination of the dynamic parameters. Automatic optimisation with respect to the discretely-supported continuous rail model is currently being developed. In the meantime, in order to obtain some estimates with respect to the parameter values of the discretely-supported continuous rail model calculations based on the Rayleigh method are applied.

Field measurements

Recently, a powerful notebook computer with data-acquisition facilities has been added to the excitation hammer test equipment. This enables fast and self-supporting field measurements of railway track to be carried out.

Fig. 3: Large excitation hammer and accelerometers used on twin-block supported light rail track

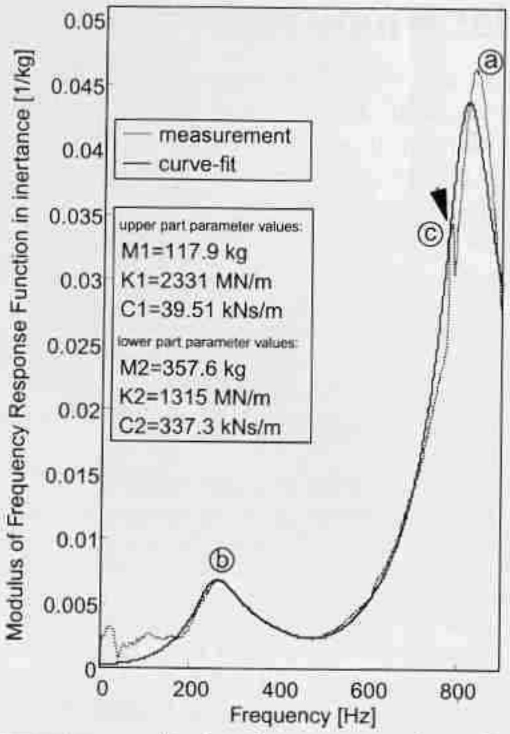

Fig. 4: Frequency response function of measurement and curve-fit result with respect to a two-degree-of-freedom model

For instance, it has been applied to determine the dynamic properties of a light rail track consisting of S49 rails supported by concrete twin-block sleepers (Fig. 3). Fig. 4 shows some results obtained. Two resonance frequencies can clearly be observed: the frequencies of 250 Hz (b) and 820 Hz (a) denote the vertical in-phase and out-of-phase resonances of the rail and sleeper track construction, respectively. The small peak near 770 Hz (c) is due to the so-called 'pin-pin' resonance. Fig. 4 also shows the parameter values found according to the two-degree-of-freedom model. These can be converted to the parameters of a discretely-supported continuous rail model comprised of a Timoshenko beam. This will yield more realistic values due to the addition of bending and shear stiffness of the rail.

Concluding remarks

The excitation hammer test method has the following advantages:

— it is a mobile, self-supporting, non-destructive test method;
— it can quickly determine relevant dynamic track parameters;
— it can be used without causing any traffic hindrances.

References

[1] Zand J. van 't: 'Assessment of dynamic characteristics of rail pads', Rail Engineering International, Edition 1994, Number 4, pp. 15-17.

[2] Esveld C., et al: 'Dynamic behaviour of railway track', Rail Engineering International, Edition 1996, Number 2, pp. 17-20.

[3] Verhaegen M.: 'Subspace identification approach to identify multivariable dynamic systems', TU Delft, Department of Electrical Engineering, 1995.