Tests of the railway components

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Abstract: The standards for the railway components are divided to three mounting types which include the vibration and shock tests. The levels of vibration and shock amplitudes depend on the mounting type. The highest levels are defined for the axle mounting components like brakes. The claims for the test conditions are mandatory for the testing platform development and the mounting design of the tested component which simulates the real locations. There is necessary to check the modal analysis of the mounting design cause of the Eigen modes of the fixed railway component inside the standardized vibration spectrum.

Keywords: railway, vibration, shock.

1 Introduction

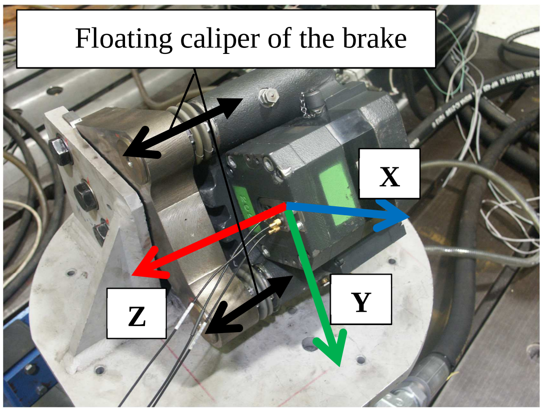
The levels of the test loading are divided according to the mounting location like axle, chassis and cabin. The highest levels are defined for the axle mounting where the acceleration RMS of the white noise signal are close to the 150 m/s^2 with peaks like Normal distribution according to 3*RMS. Shock amplitude is defined as half of the sinus period with amplitude 1000 m/s^2 with 6ms duration [1,2]. The testing component is the brake system made by DAKO-CZ. We cooperate with DAKO-CZ since last year in term of durability testing and mechanical design. The mass of the brake component is 50kg. The mounting design must correspond with the real conditions and the mass limit of the whole tested system (testing brake with mounting) is 100 kg. These limitations are defined cause of the used hydraulic system with maximum oil flow of the oil unit. The optimization of the mounting system is necessary and virtual modal analysis is used.

2 Durability tests description

The vibration test signal is the pseudo stochastic signal like white noise. The prescribed spectrum is defined as the frequency spectrum of the Power Spectral density from 20 to 100 Hz and with 6dB decrease till 500 Hz which corresponds with mass of the brake. The vibration durability test takes 5 hours in each global axis (total 15 hours). Before the durability test was made the additional measurement to analyze the floating caliper modes of the brake system. The acceleration sensor is mounted to the piston of the exciter and represents the input mechanical vibration to the testing component. The testing measurement with the additional accelerometer sensor mounted to the railway brake is described on Figure 1.

The vibration control is based on the frequency domain iteration methodology described in [3]. The displacement feedback is used with acceleration control signal. The disadvantage is that is when the exciter system increases its temperature and friction, oil, etc. behavior occur the different response. There is allowed to stop the test cause of the high exciter temperature by the standard [1, 2]. The frequency analysis of the additional acceleration is used for the comparison with virtual modal analysis. There is mandatory that the modes are outside of the testing vibration spectrum. If there is not possible to fulfil this condition the control system needs to suppress the modes of the testing component with the mounting construction.

The shock test represents the prescribed acceleration signal for the piston of the exciter. The shock tests by using hydraulic system are difficult to control cause of the oil injection delay which is around 2ms. The acceleration peak is effective to perform with the displacement reversing of the piston. The servo valve opening is necessary to check during the test cause of the stability during 100% servo opening.



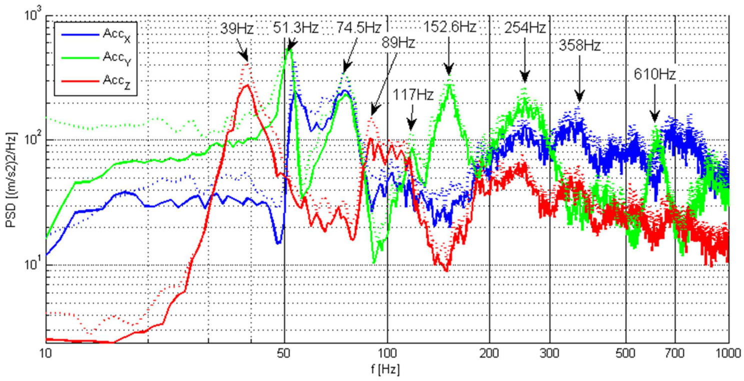


Fig. 1 a) Brake DAKO-CZ with acc. sensor

b) Frequency modes of the additional acc. sensor

3 Optimization

The mounting design for the vertical tests needs to be optimized for the transverse and longitudinal direction tests. The hydraulic system does not use the vibration table and the testing component is mounted to the rotated piston flange in the tested direction. The vertical test mounting design is used for the modal analysis of the floating caliper of the brake system. The Eigen modes of the mounting system have to be outside the Eigen modes of the floating caliper (up to 150 Hz described on Fig. 2). The first two Eigen modes of the vertical mounting design analyzed by the virtual modal analysis are 187 Hz (real mode 190 Hz) and 369 Hz (real mode 343 Hz) and fulfil this condition (Figure 3a and 3b).

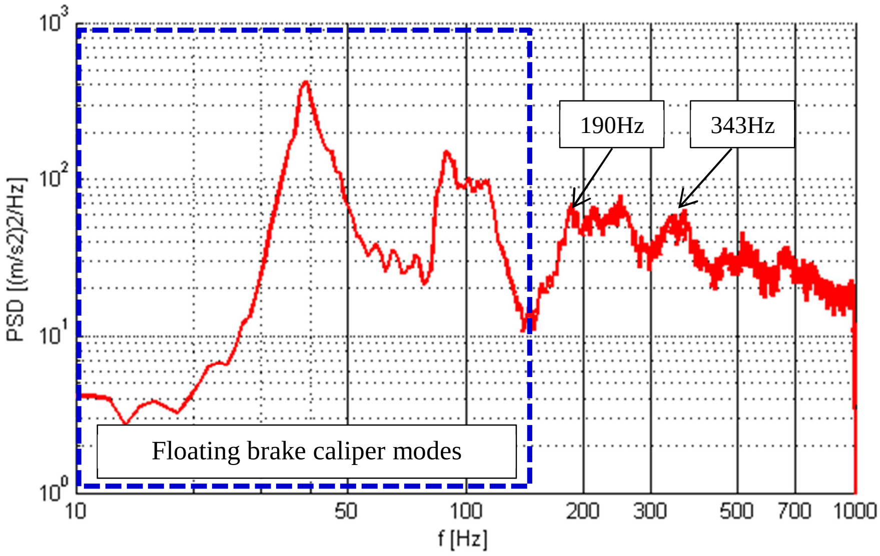
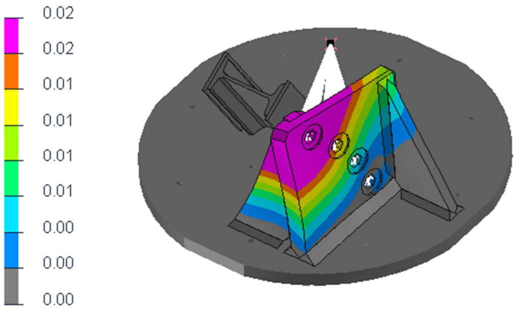


Fig. 2. Analysis of the transversal acceleration spectrum (AccZ) of the brake system



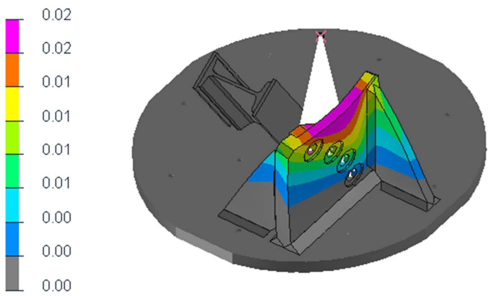


Fig. 3 a) First Eigen mode - 187 Hz

b) Second Eigen mode - 369 Hz

The universal mounting design was developed and optimized by using the virtual modal analysis (Fig. 4 and Tab. 1). The initial conditions are the mass limit 100kg and Eigen modes higher than 150Hz. The optimization of the components thickness and profiles helps to predict the real behavior. The brake system was simplified in the model to rigid body with prescribed mass and inertia moments. The floating caliper was not included into the model.

Mode	f [Hz]
1	230
2	376
3	448
4	532
5	683
6	754
7	890
8	924
9	974

Tab. 1 a) Result and prescribe vibration limits

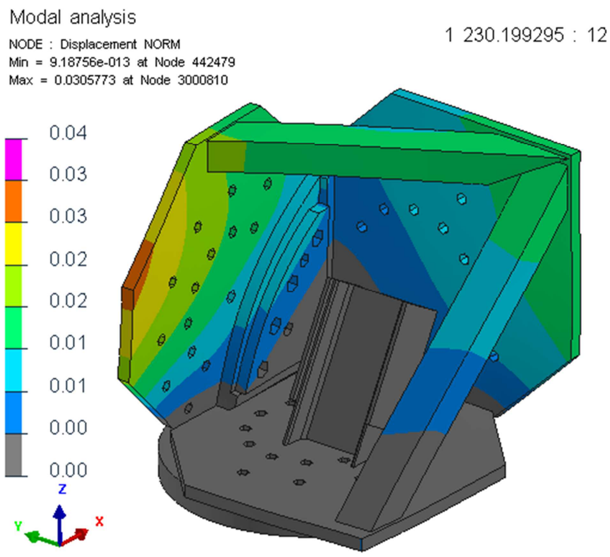


Fig. 4 Modal analysis of the optimized design

4 Durability tests results

The status of the durability test is if the integrity and functionality of the brake system is fulfilled without any failure. The prescribed vibration and shock test are on Figure 5a and 5b. The vibration testing limits are 3dB up and down the prescribed acceleration defined as the Power Spectrum Density of the acceleration. The acceleration results are in acceptable standardized limits.

There is not needed the additional acceleration sensor mounted to the brake system. The input acceleration is analyzed by the sensor mounted to the exciter's piston. This sensor is used for the results spectrum check during iteration method to control the target vibration spectrum. It is mandatory to identify the complete exciter system with the testing specimen or mechanism. It is possible to suppress natural frequencies of the hydraulic exciter and also testing specimen or mechanisms. It is recommended to use wider frequency range than prescribed spectrum. The common frequency response function (FRF) of the hydraulic exciter is used for identification. The next step is the original estimate of the input signal for the first step of iteration (the input signal response of the inverse FRF). The iteration methodology uses couple of steps to fulfil the prescribed spectrum by optimization of the inverse FRF function for the input signal of the hydraulic valve. The disadvantage of this method is the impossibility to control in real time. It is mandatory to check the result spectrum after every hour cause of the oil temperature dependency. The test breaks are allowed by the standards and are necessary in term of high temperature of the exciter system.

The best results for the hydraulic system as the shock exciter is described on Figure b. The hydraulic system behavior during the maximum peak is on the control stability limit cause of the 100% valve opening but still might be acceptable in term of fulfilling the acceleration lower limit in extremely short duration close to the 6ms.

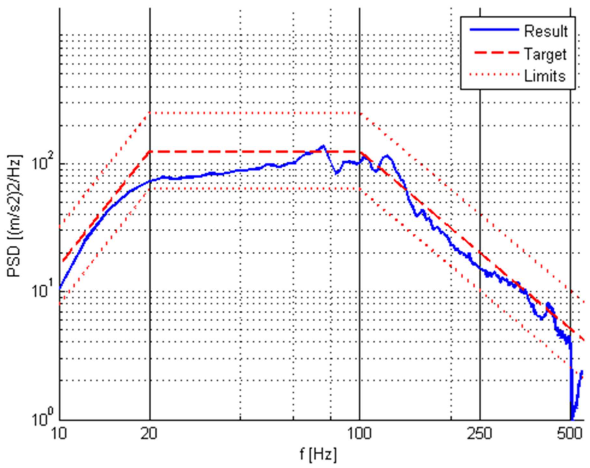
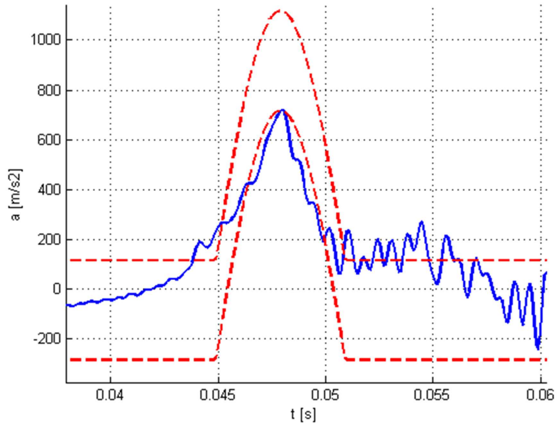


Fig. 5 a) Vibration durability test - PSD spectrum



b) Shock durability test acceleration peak

4 Conclusion

The frequency analysis is mandatory for the mounting system development with the floating caliper of the brake. The Eigen modes of the mounting system have to be outside the floating caliper modes. The mass limits were fulfilled – the mounting system for all directions is after optimization 49kg. The optimized design is possible to use for vertical, longitudinal and transversal tests without disassembly the brake system and fulfils both conditions – the first Eigen mode is 230Hz (floating caliper modes till 150Hz) and the mass of the whole test component mounted to the exciter piston is 99kg (mass limit of the hydraulic unit is 100kg).

There is necessary to use frequency domain iteration to control the hydraulic exciter system. The test results for the worst acceleration level are described on Figure 5 a). The result spectrum is acceptable in prescribed limits. The shock results are at the present time on the stability limits of the used hydraulic system (Fig. 5b).

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