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Vibration and Shock Durability Test Control

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Abstract: Environmental random vibration and shock durability testing of mechanical, electrical and electronic equipment components that are mounted on rail vehicles is important part of the validation and certification of the new product. Manufactures use vibration testing for simulating the effect of the environment on a specimen. The shock tests predict the ability to endure repeatable and non-repeatable shocks. The laboratory simulation of the real conditions is possible to perform by electromechanical and hydrodynamic shakers. In our case we use specifically hydrodynamic cylinder INOVA designed for the vibration and shock testing. The control algorithms use iteration methods in time and frequency domain which depends on test prescription.

Keywords: Vibration; Shock; Test; Control.

1 Introduction

The correlation between prescribed level of vibration/shock and output acceleration signal mounted to the shaker is mandatory. The response of the hydrodynamic cylinder controlled by PID regulator is possible to identify as transmissibility function which is used for iteration method to optimize the command signal for hydraulic valves. The iteration methods are divided to frequency and time domain. The frequency domain iteration is very useful for vibration test with random (white noise) signal as the input for mechanical vibrations. The identification of the controlled system is mandatory and the iteration method modifies the spectrum of the hydraulic valve command signal. The level of the white noise is in most cases prescribed by the power spectral density and has to be fulfilled in each time step of the test. The time domain iteration is useful for harmonic signal with constant amplitude and frequency as the input for mechanical vibration. The main advantage is the easy controlling by the proportional component of the PID. The main disadvantage is the time delay (couple of iteration steps needs couple of periods) before it reaches the prescribed amplitude. The time domain iteration is possible also use limited for shock tests.

2 Test Equipment

The mechanical vibration in laboratory environment is possible to excite in different ways. The common approach is electromechanical, hydraulic, cam shaft system etc. Our laboratory is equipped with couple of hydraulic motors and sufficient hydraulic unit to fulfil prescribed energy of the standards. The current hydraulic system in the laboratory was not possible to perform prescribed limits. The main reason was the deficiency of the oil flow to the cylinder by the proportion valve and the limited maximal oil flow of the hydraulic aggregate (160 l/min). The current hydraulic aggregate seems to be adequate in compliance with certain conditions. The cooperation with INOVA Company (producer of the hydraulic system) facilitated with technical possibilities of the specification of the new hydraulic cylinder to fulfil the prescribed standards. The new specific hydraulic motor uses four parallel servo valves by MOOG Company to use the maximum oil flow by the hydraulic aggregate. The time response of the used valves is about 10ms. The maximum open of the slide valve is possible to use till 350 Hz but with the low mass specimen allows frequency range till 1 kHz.

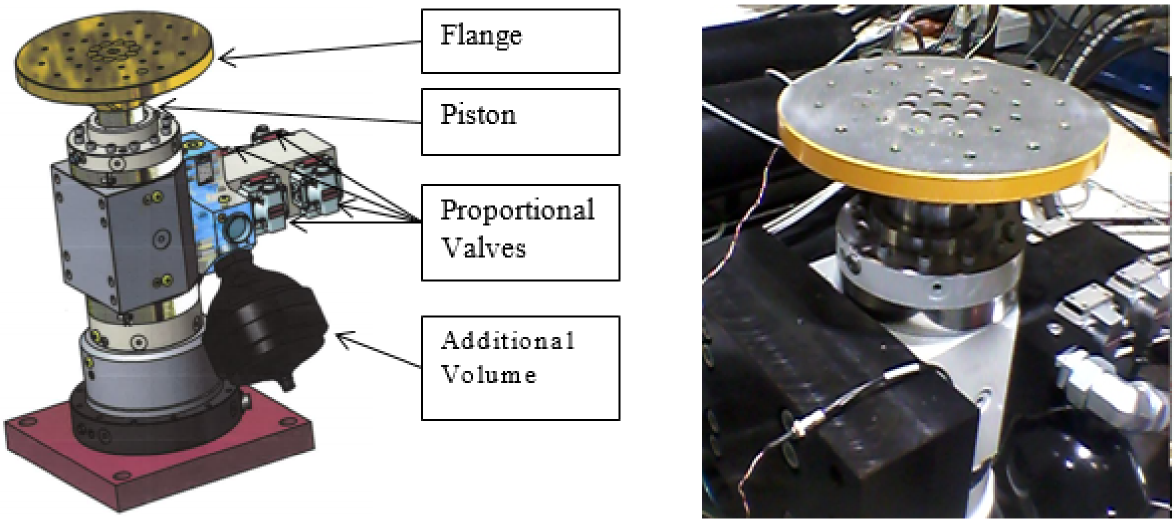


Fig. 1: Specific hydraulic vibration motor with four proportional valves.

3 Vibration Tests

The aim of the durability vibration testing is that the specimen fulfils the relevant functionality during the vibration loading. The tests are time consuming and may take up to tens of hours.

The control system uses the displacement sensor mounted inside the piston as primary feedback. The acceleration sensor mounted to the flange is used as control signal for iteration. The input signal of the mechanical vibration might be defined as the harmonic signal or in common cases as the noise signal with Gaussian normal distribution. The harmonic excitation is possible to control by the time domain iteration. The time domain iteration is not possible to use for noise signal and is necessary the different sophisticated approach. The optimization variable is the magnitude of the input signal and the control system compares the frequency response in acceleration.

3.1 Time Domain Iteration Control

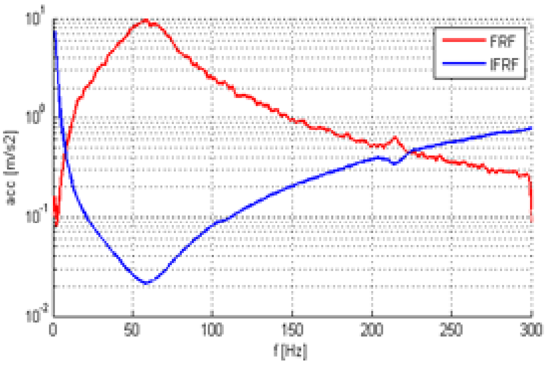
The harmonic excitation test is easy to control in time domain. The vibration motor controlled by the PID regulator uses the proportional component to fulfil the prescribed amplitude of the test harmonic signal. The modification of the desired value of the displacement, velocity or acceleration needs couple of periods of the harmonic signal to get the entered amplitude value.

3.2 Frequency Domain Iteration Control

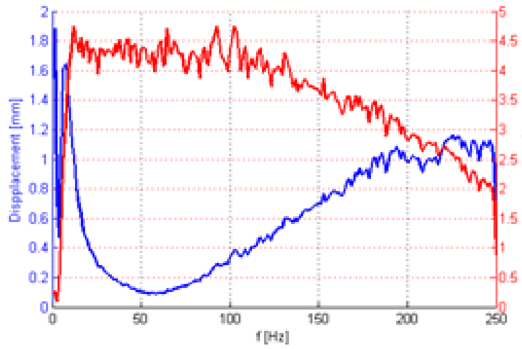
The input signal for the exciter is in most cases prescribed as the power spectral density spectrum of the pseudo stochastic noise in frequency range with normal distribution (in our case the railway standards [1]).

Frequency domain iteration is possible to divide in several parts. The model identification is the first step to get frequency response characteristics of the hydraulic exciter system. The frequency response is used for frequency response function evaluation (FRF) which is represented by internal model of the hydraulic system. The evaluation of the inverse frequency response function is necessary for iteration method. The information about the controlled system and FRF is known already in the first iteration step. It is very helpful to decrease the count of iteration steps. Inverse FRF (iFRF) is used for evaluation of the input signal (prescribed spectrum) response of the model. 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.

The test response described in following pictures shows that in couple of iteration is possible to fulfil the prescribed level of acceleration and the vibration motor is sufficient for this type of test.

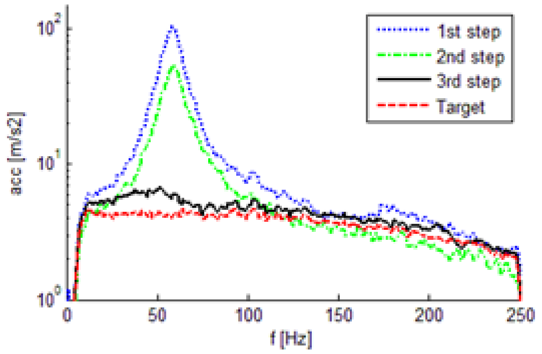


(a) fRF and iFRF function

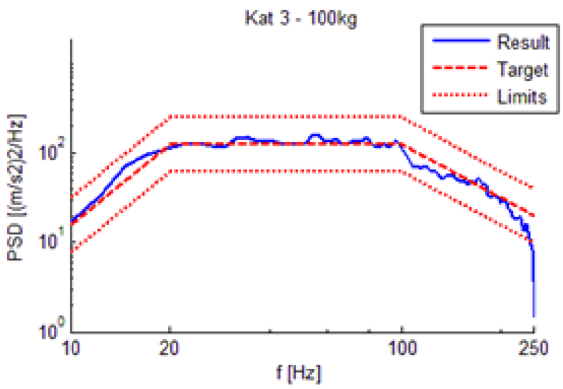


(b) input disp. signal and result acc. response

Fig. 2: Model identification and input signal with response.



(a) frequency domain iteration steps



(b) prescribed target PSD spectrum and test result

Fig. 3: Iteration steps in frequency domain and results with prescribed limits.

4 Shock Test Control

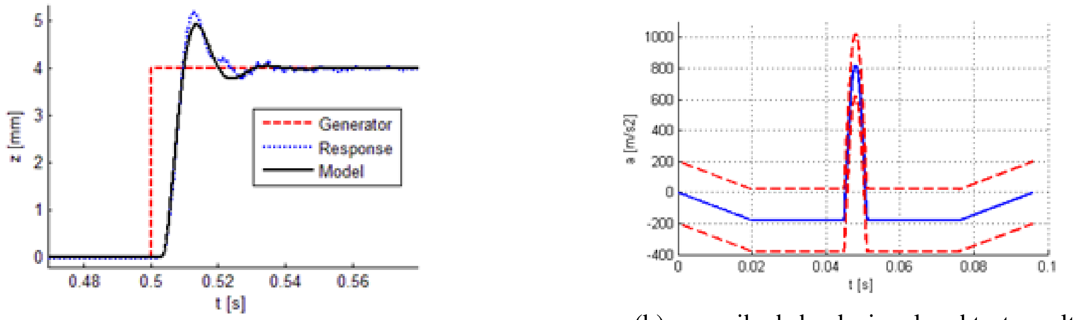
The aim of shock testing is to reproduce the prescribed pulse in acceleration. Test pulses are usually rectangular, triangular, or half-sine etc. Some shock signal can be defined also as response spectrum and are modeled in the frequency domain over the certain bandwidth. These types of test are necessary to use frequency domain iteration. In this article is described the shock control system for time domain methodology.

The prescribed shock test signal is defined as the function of acceleration in time [2]. The main acceleration growth is not possible to fulfil from the rest position. It is very helpful to include acceleration offset and the sharp increase is represented as the peak during the reversing of the displacement. The input signal is optimized for the displacement limits of the hydraulic motor. The initial estimate of the shock behavior under time domain control is useful and in the first step is necessary to identify the system. The response to rectangular signal represents the extreme behavior of the exciter and is used for identification. The Matlab Identification Tool helps to identify the model which is included to Simulink tool. The offset of the testing signal and also the time iteration is evaluated to decrease time requirements in real testing and save the energy of the hydraulic aggregate.

The real test showed the extremes of the valve opening during the main acceleration growth between -100 and 100 % (0.04 – 0.05 s) which is not steep enough (Fig. 5.). The maximum opened valve is not possible to control the system and causes the major decrease of the acceleration after 0.049 s. The next step might be to use by some sophisticated method like adaptive control methods [3].

5 Conclusion

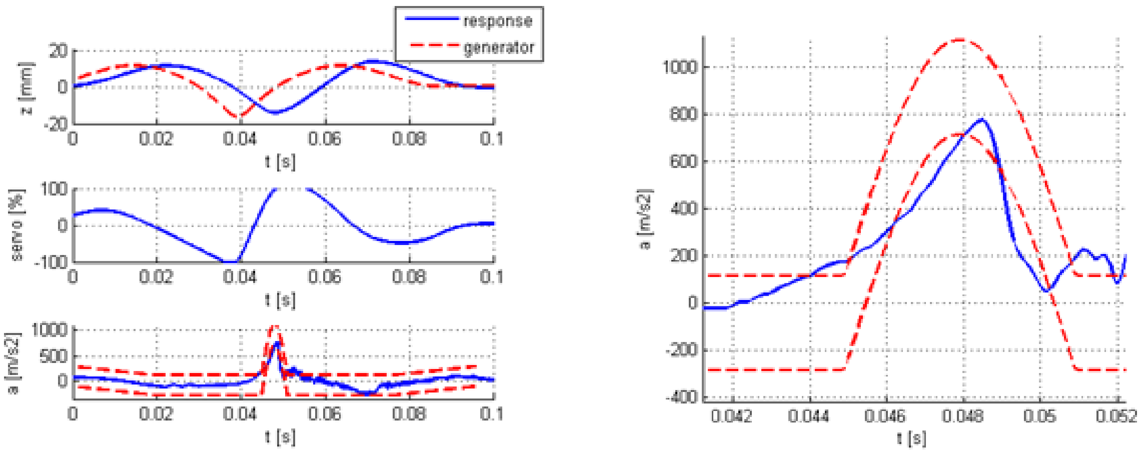
The using of identification and iteration methods supports the testing in term of fulfilling the prescribed standards in couple of iteration steps and optimization in simulation behavior. Each method is effective for each specific test. Frequency domain iteration is most useful for vibration with random signal and in couple



(a) identification of the model

(b) prescribed shock signal and test result

Fig. 4: Identification and acceleration shock test signal.



(a) displ. and acc. response, servo valve opening

(b) prescribed shock signal and test result

Fig. 5: Shock test control.

of step achieves the target spectral power density spectrum. The time domain iteration is effective for shock testing and by support of identification of the system is possible to predict and prepare the command signal for hydraulic valves. The current results of shock testing are not sufficient. The solution might be in using of additional volumes in hydraulic switchboards to increase the time limited oil flow and the control system will be extended by adaptive methodology.

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