Research on damping parameter identification of elastomer buffer

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Abstract. The object of this paper is the changing process of damping force as the falling weight impacting the elastomer buffer. The whole mechanical system is built up through practical test and simulation. According to the type of elastomer buffer and the experimental process in shock environment, velocity damping force identification model was established. Wavelet denoising and least square method were used for parameter identification of damping force. Considering the data saturation problem in the traditional least square method, the limited memory least square method was obtained to improve the identification method. The results of parameter identification of damping force based on limited memory method proved that the limited memory method was superior to least square method. The numerical results demonstrate the effectiveness of the identification model.

Keywords: elastomer buffer, damping force, limited memory method, parameter identification.

1. Introduction

Elastomer buffer has great application in various fields, which has the advantages of large capacity, stability, and simple structure. Over the years, the analysis and exploration of the damping process of elastomer buffer has been a hot research. For different application fields of elastomer buffer, accurate modeling of damping process is very meaningful to the study of mechanical system and noise reduction.

When the types of elastomer buffer and experimental environment are different, the damping parameter identification model is different. Accurate experimental subjects and establishing a right identification model directly determine the feasibility of damping parameter identification. The experimental object in this paper is a vertical impact process. According to the experiment, velocity-damping identification model was established. In the simulation phase, the wavelet denoising was used to filtering the experimental data. Aiming at the defects of the traditional least square method, the limited memory method was used to solve the problem of data saturation, which ensured that the algorithm has better precision of fitting.

2. Identification model

2.1. Elastomer buffer

At present, the most widely used elastomer buffer for practical application is shown in Fig. 1. It is a single rod elastomer buffer. This kind of damper has a closed chamber, which is filled with viscoelastic fluid damping materials. When elastomer is impacted by external load, the buffer piston rod is pressed into the cavity. The damping material flows through the annular gap formed by piston and cylinder wall. The damping medium in cavity is compressed and the internal pressure increases, that caused the elastic force to the piston rod. At the same time, the piston head and damping structure produce great friction with the viscous damping medium. When the speed is higher, more viscous resistance will be produced. The impact kinetic energy can be turned into heat energy and elastic potential energy, which can be released in a very short time to achieve the

effect of energy absorption. The elastomer also has good elasticity, that means, the volume will shrink under great external force. When the external pressure is up to 500 MPa, the compression ratio is not less than 17 % of the initial volume. When the external force is removed, the elastomers will automatic reset and release energy storage. And from Fig. 1, the numbers 1 to 5 represent piston rod, cylinder head, piston, resilient rubber and cylinder block.
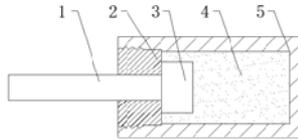

Fig. 1. Schematic diagram of elastomer buffer structure

2.2. Identification model

Energy buffer device can be manufactured according to different materials, energy dissipation mechanisms and structures. The experiment in this paper was performed in the shock environment. Speed-damping model is widely used for elastomer buffer in shock environment, which is shown as Eq. (1):

$$F = Cv^n, \tag{1}$$

where F is damping force, C is damping coefficient, v is the relative velocity of the piston and cylinder body and n is velocity correlation coefficient (the larger its value, the smaller buffer's nonlinear degree).

The model Eq. (1) shows is nonlinear. The complexity of nonlinear model is higher than that of linear model in the process of fitting. If it can be transformed into linear model, the fitting effect will be better. In order to linear fitting, logarithm was used on both sides of the formula which is shown as Eq. (2):

$$\ln F = \ln C + n \cdot \ln v. \tag{2}$$

After the transformation above, the parameters need to be identified are linear parameters $\ln C$ and n. The data $\ln F$ and $\ln v$ can be obtained by the calculation of the damping force and velocity.

3. Identification algorithms

3.1. Least square method (LSM)

The least square method is a relatively mature algorithm. It has been widely used in scientific experiments and engineering technology. With the development and popularization of modern computer, LSM shows more powerful vitality. LSM is used for solving the problem of how to find reliable value from a set of measurements. Its basic principle is: a group of data (x_i, y_i, $i = 1, 2,…, n$) are obtained, and try to find a best fitting curve in which the difference quadratic sum of the value of each point on the curve and measured value is minimum.

In the design of experiments, in order to reduce the error, multiple point measurement is performed. The number of the equations is far more than that of undetermined parameters. These equations are called inconsistent equation group. The equations transformed by LSM are called the normal equations (here the number of equations is equal to the number of undetermined parameters). The undetermined parameters can be calculated by the normal equations.

3.2. Limited memory method (LMM)

The LSM is simple and practical, and its recursive algorithm is convergence and reliable.

When the noise is white noise, the estimates can be unbiased, consistent and efficient. But with the growth of data, LSM will show the phenomenon of data saturation so that the recursive algorithm loses correction ability slowly. In that case, limited memory was introduced to LSM and the recursive algorithm called limited memory method was obtained. LMM can solve the problem of data saturation caused by LSM.

4. Study case

4.1. Experimental installation

Before the experiment, the buffer is arranged on the base. The impact hammer with quality of 30 kg was put in a suitable height. Then let the hammer fall free along the rail and impact the piston rod of buffer. The variation rule of displacement during the impact process was recorded by laser displacement sensor and data acquisition system. The actual installation of measuring equipment and buffer is shown in Fig. 2. And from Fig. 2, the numbers 1 to 5 represent impact hammer, acceleration sensor, laser displacement sensor, elastomer buffer and data acquisition equipment.
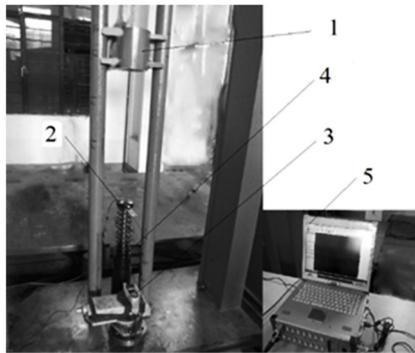

Fig. 2. Schematic diagram of equipment

4.2. Data processing
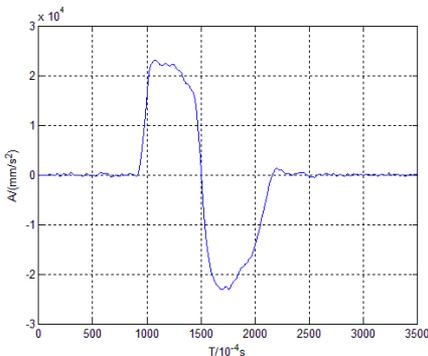
**Fig. 3.** Acceleration-time curve of low speed
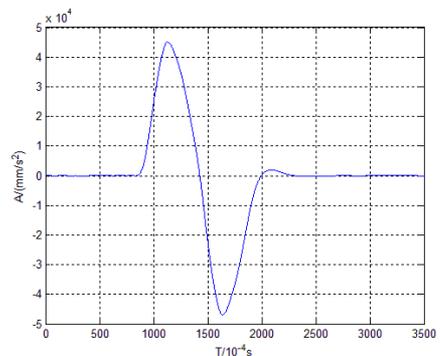
Fig. 4. Acceleration-time curve of high speed

During the falling process, displacement information of the hammer was collected by laser displacement sensor with sampling frequency of 10 KHz. After the displacement information was collected, acceleration information could be obtained by two differential operation of displacement. Combined with the quality of the hammer, the damping force time curve could be obtained. During the falling process, there would be noise and vibration interference. Therefore, the data need to filter so that the accuracy of data can be ensured. By adjusting the initial height

of the hammer, displacement-time curves of different initial velocity can be obtained. Thus the damping force time curves of different initial velocity can also be gained. Two different initial heights, 300 mm and 700 mm were used to perform the low speed test and high speed test in this paper. The parameter identification of two sets of data was used to verify the validity of the identification model.

The acceleration-time diagrams of low speed and high speed are shown in Fig. 3 and Fig. 4.

Through the calculation, the damping force curves during the hammer impacting the buffer are shown in Fig. 5 and Fig. 6.
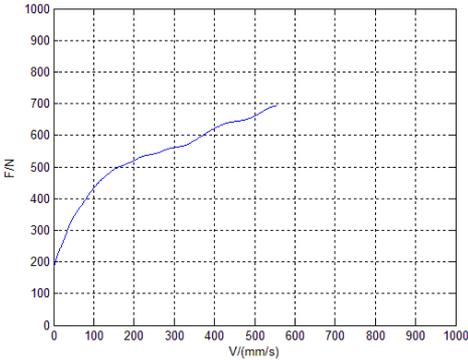

Fig. 5. Damping force curve of low speed
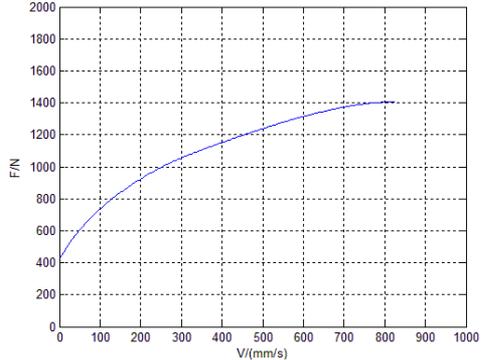
Fig. 6. Damping force curve of high speed

4.3. LSM for parameter identification

According to Eq. (2), parameter identification was performed with LSM respectively in low speed group and high speed group. The identification results were shown in Fig. 7, Fig. 8 and Table 1.
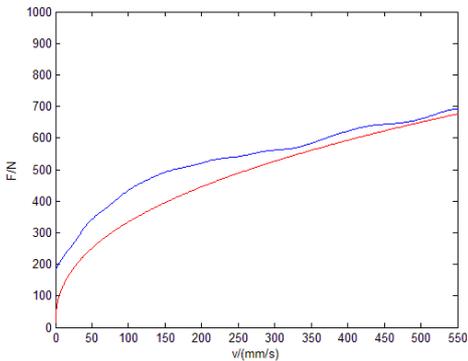

Fig. 7. LSM result of low speed group
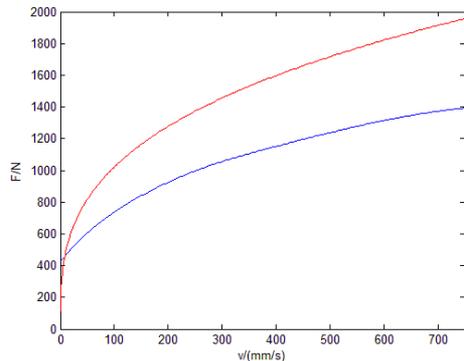
Fig. 8. LSM result of high speed group

Table 1. Identification result of LSM

Speed type	$C/N\cdot(m/s)^{-1}$	n
Low speed group	263.34	0.4225
High speed group	314.45	0.3965

Table 2. Identification result of LMM

Speed type	$C/N\cdot(m/s)^{-1}$	n
Low speed group	272.46	0.4352
High speed group	282.56	0.4410

4.4. LMM for parameter identification

According to Eq. (2), parameter identification was performed with LMM respectively in low speed group and high speed group. The identification results were shown in Fig. 9, Fig. 10 and Table 2.
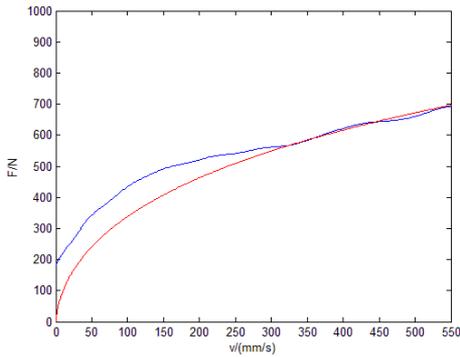
Fig. 9. LMM result of low speed group
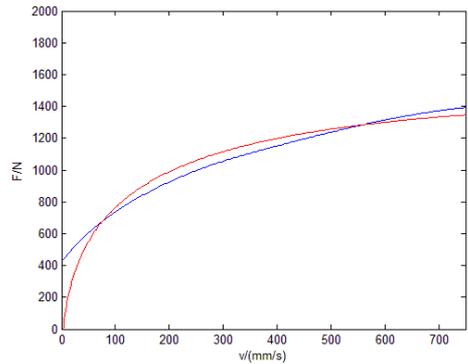
Fig. 10. LMM result of high speed group

5. Conclusions

The damping force model of elastomer buffer in shock environment is nonlinear. Through linearizing the nonlinear equation, the original parameters will be obtained by inverse logarithmic operation. This method can guarantee the accuracy of the premise and greatly improve the efficiency of the algorithm. By identifying the model parameters with LSM and LMM, the correctness of the model is confirmed.

The traditional LSM has defects of data saturation. In the fitting process, the accurate parameter identification cannot be guaranteed with the growth of initial velocity. LMM can solve this problem and identification parameters can be also obtained accurately at high speed.

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