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EXPERIMENTAL INVESTIGATIONS OF DOUBLE MULTI-LEAF SPRING SUBJECTED TO IMPACT LOAD

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Abstract

The article deals with experimental investigations of a prototype double multi-leaf spring, compound of a four-leaf main spring and a double-leaf supporting spring subjected to an impact test. In real conditions of car movement (e.g. curb, bump), dynamic oscillating loads, which generate dynamic stress in a car suspension affecting other elements of the car, occur. Consequently, effects of coupled oscillations having a great impact on comfort of a driver and passengers can be observed. The research was conducted in the Laboratory of Material and Construction Strength Department of Mechanics and Applied Computer Science (DMACS) in the Faculty of Mechanical Engineering of Military University of Technology. The experiment was carried out on an original construction of a spring impact hammer developed in DMACS. Energy of the impact was set up by changing mass of a beam with beater and beam dropping height. The results were presented in the form of table summaries, time-dependent load and displacement graphs. The methodology of the research presented in the paper and a set of measuring equipment can be utilized to evaluate load and vibrations of any multi-leaf spring under impact load with given energy. The experimental results obtained from the test are supposed to be used to verify and develop FEM model describing a spring under impact load and oscillations.

Keywords: *double multi-leaf spring, suspension of a motor truck, impact load, experimental investigations*

1. Introduction

The object of the work, presented in Fig. 1, is a prototype of a double multi-leaf spring loaded dynamically. The spring is designed for truck (van) family cars with total mass up to 3.5 tons [1–3]. It consists of a four-leaf main spring (1), a double-leaf supporting spring (2) and has ability to move horizontally on a surface of a leading channel section (3) using four ball-bearings (4). This construction is characterised by a clearance between the main and the supporting spring (Fig. 1).

Experimental research presented in the paper is determined by analytical and experimental investigations of such kind of construction carried out by other authors from Military University of Technology (e.g. [1–3, 8]). A unique experimental method has been proposed for a double multi-leaf spring as well as for any other kind of a spring loaded dynamically and selected results has been presented. The main objective of the work is to evaluate the effects of impact load on dynamics of a double multi-leaf spring.

Fig. 1. Double spring prepared for impact tests: 1 – main spring, 2 – supporting spring, 3 – leading channel section, 4 – ball-bearings

2. Preparation of the spring for the investigations

In order to implement a research programme, with all necessary safety precautions, the double multi-leaf spring was supported on its ends (lugs of the spring) with four ball-bearings, two on each side (Fig. 2 a, b). This solution ensured free horizontal movement of the spring ends on the surface of the leading channel section under dynamic load. However, bolts were installed on axes of ball-bearings to restrain vertical movement of the spring ends. The bolts were mounted in fences milled on the sides of the leading channel section (Fig. 2 a, b).

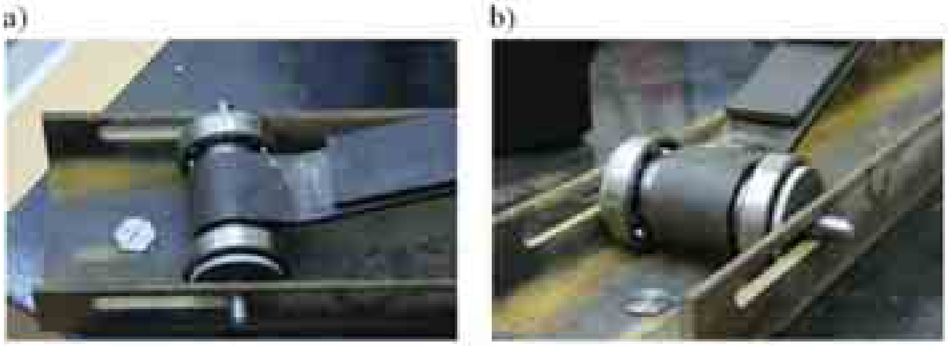

Fig 2. Mounting of the end of double spring: a) enabling horizontal movement; b) limiting vertical movement

A complete testing stand – a double spring with ball-bearings and a leading channel section were installed on the bottom support of the impact hammer. The leading channel section was fixed rigidly to the supporting plate. A testing bed installation method is presented in the photo in Fig. 3.

Fig. 3. Location of double spring on support plate of impact hammer

A piezoelectric force sensor, into which a hammer beater hit during investigations, was placed in the middle of the spring on the axis of a welding screw (Fig. 5 a). Installation of the construction imitates a real dependent suspension structure equipped with free suspension [5–8]. The testing bed with the object of investigation and the measuring equipment are presented in Fig. 4.

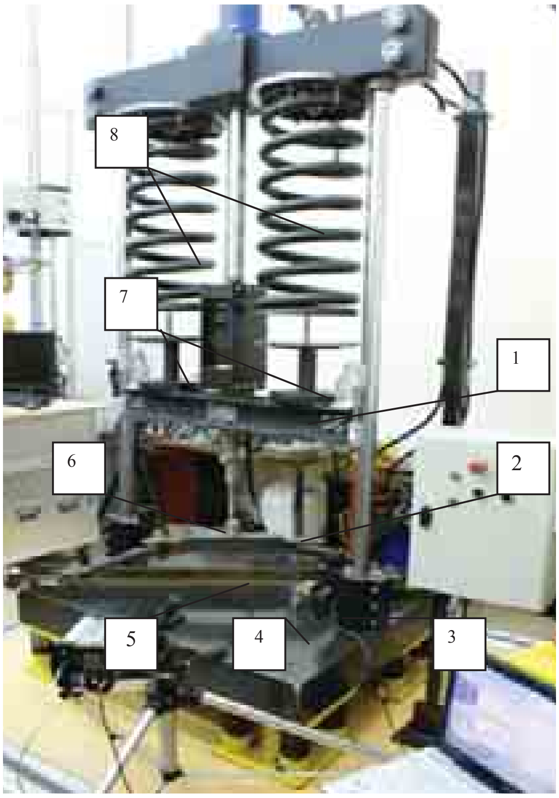

Fig. 4. Original testing stand for dynamic tests developed in DMACS – spring impact hammer: 1- moving beam with beater; 2 - double multi-leaf spring; 3 – laser triangular displacement sensor; 4 – bottom support plate; 5 - leading channel section; 6 – piezoelectric force sensor; 7 – additional weights; 8 – preliminary tension springs

3. Measurement equipment

PIEZOELECTRIC PCB 200C50 sensor conditioned and supplied by EC Electronics VibAMP PA-16000D measured the progress of force in time (Fig. 5 a). It was fixed rigidly with leafs of the spring with a weld screw. The displacement triangular laser sensor KEYENCE LKG-502 (Fig. 5 b) equipped with a supplier and a control panel recorded the position of the beater beam. Dynamic data acquisition system TRAVELLER PLUS synchronised and recorded digital data in computer files with sampling frequency 50 kHz.

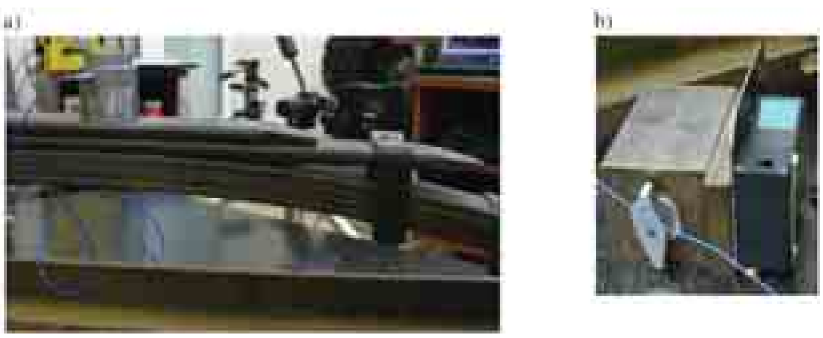

Fig 5. Mounting of measurement devices on impact hammer construction: a) force sensor on multi leaf spring; b) laser displacement sensor on hammer support plate

4. Experiment conditions

Weight of the testing bed components required to evaluate load conditions was obtained before the experiment (Fig. 4) and gathered in Tab. 1. Load energy and velocity were controlled by mounting additional weights on the hammer beam and changing of beam drop height. The springs of the hammer were not tensioned during the experiment.

Tab. 1. Weight of testing bed components

Part, component name	Unit	Quantity
Complete double multi-leaf spring	kg	29.5
Double multi-leaf spring (without ball-bearings)	kg	24.3
Additional weights	kg	44.8
Moving hammer beam with beater	kg	65.7
Leading channel section	kg	27.5

Accuracy ± 0.1 kg

Table 2 presents main parameters of the impact load conditions established for the experiment implementation.

Tab. 2. Dynamic load conditions of double multi-leaf spring on impact hammer

Value	Unit	Quantity
Weight of moving beam with beater	kg	65.7
Beater beam drop height	mm	174.6
Impact velocity of beam beater	m/s	1.7
Maximum load of spring	kN	4.38
Kinetic energy of impact	kJ	94.9
Maximum displacement of beater beam	mm	275.8
Maximum spring deflection	mm	101.15

5. Conditions and results of the experiment

Dynamic load tests of the multi-leaf double spring were performed on the impact hammer (Fig. 4). A free moving beam with a beater, weighing 65.7 kg, was raised 174.6 mm above a top surface of the spring and then dropped after realising the hook of the hammer. The beam accelerated in the gravity field (with little friction in beam slides). Impact of the beater, with vertical velocity 1.7 m/s, into the centre of the spring (directly into the force sensor) occurred 202.9 ms after hook unlocking (see Tab. 2). Kinetic energy of the beam impact was equal to 94.9 kJ. The spring absorbed total energy of the impact enlarged by potential energy of a free drop of the beam on the way of the spring deflection, in total: 95.6 kJ.

Time dependences of spring load and displacement of the beam during a 3.0 second drop after the hook release were recorded and are presented in Fig. 6. The effects of the influence between the spring and the hammer (couplings) beam were observed during the process. It was concluded that during impact there were four characteristics points where actions and reactions between the beater and the spring occurred. They are marked in Fig. 6 as „Contact I-IV“.

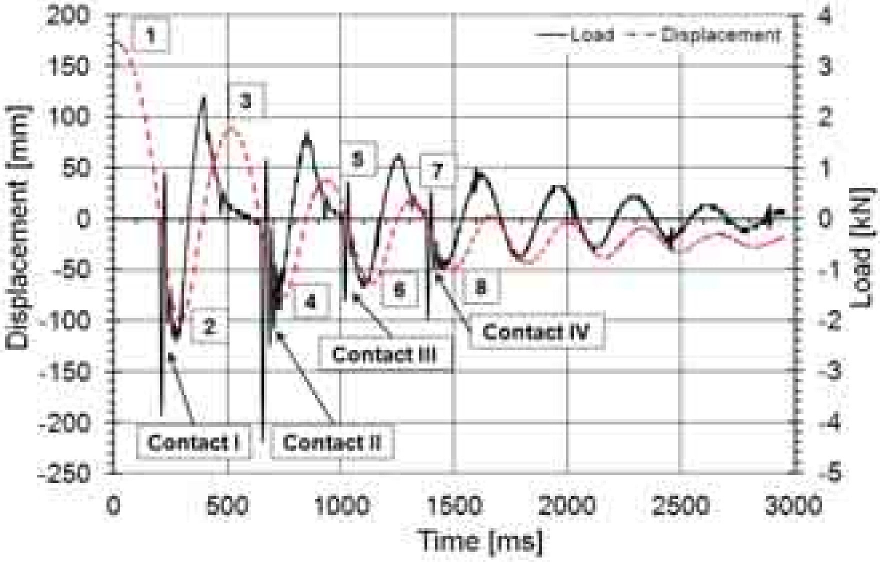

Fig. 6. Load of spring superimposed on displacement of beam in time. Time t=0 ms corresponds to moment of hammer hook realise

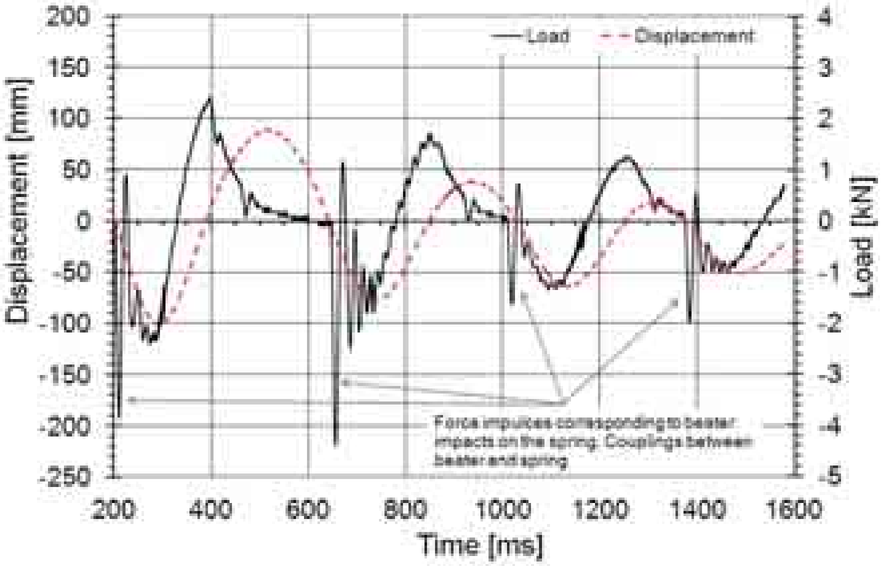

Fig. 7. Zoom of the graph from Fig. 6 presenting contact characters between spring and hammer beater. Time dependence are measured from time t = 202.9 ms (Contact I in Fig. 6)

Coupled oscillations were manifested by the effect of multiple reflects (impact and detaches) of the beater from the spring (Fig. 6-8). This phenomenon was clearly illustrated in zoom in Fig. 7. The arrows mark local extremums (minimums) – local impulses of force. When the first contact occurred, the impulse of spring load reached 3.9 kN. The highest spring load was equal to 4.4 kN and this force was recorded during the second contact, where the beam and the spring were moving in opposite directions. Maximum deflection of the spring was noticed in the first contact of the beater of the hammer beam with the spring. It was preceded by multiple hits and detaches (Fig. 7).

Amplitudes of forced oscillations of the spring and the hammer beam were changed during the experiment (Figs. 6-8). Tab. 3 presents coordinates of local extreme positions of the beam (maximums and minimums) – time and height. Numbers of extremums are described in Fig. 6. First extreme beam location is before the hook realise and drop of the beam.

Tab. 3. Coordinates of time and high of local extremes of hammer beam

No of extremum (Fig. 6)	Description	Time	Displacement of beater beam
		[ms]	[mm]
1	Local maximums	0.0	174.6
3		515.0	88.7
5		936.0	37.9
7		1310.0	17.6
2	Local minimums	293.7	-101.15
4		740.7	-77.72
6		1134.3	-64.04
8		1489.6	-51.17

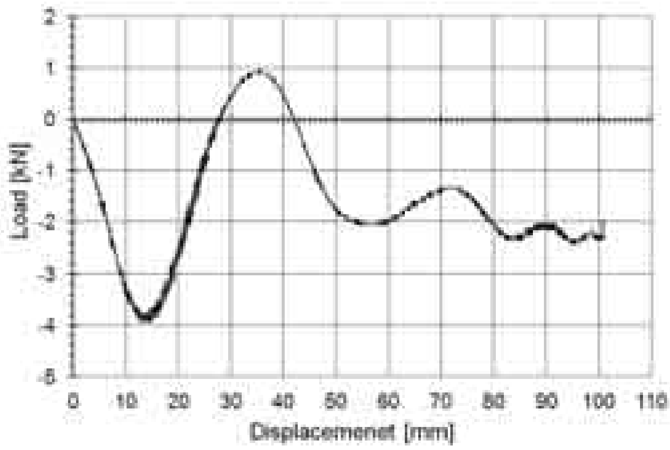

Fig. 8. Dependence of spring load on beam displacement

Figure 8 illustrates load of the spring vs. displacement of the beam, until the moment of the minimum high of the beam (corresponding to maximum deflection of the spring) is obtained. The displacement value sign was changed to positive.

The progress of beam deflection in time was presented in Fig. 9. The maximum displacement of the beam was equal to 101.15 mm, while a total beam movement range was equal to 275.8 mm (Tab. 2).

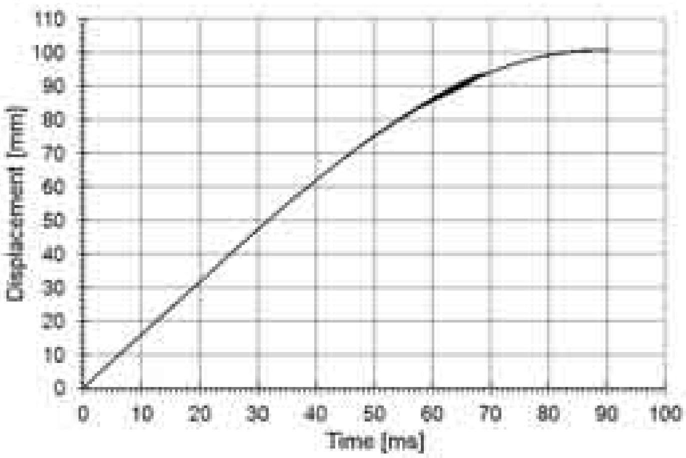

Fig. 9. Displacement of hammer beam loading spring

6. Conclusions

The experimental method presented in the paper and the equipment used for the investigations allow the evaluation of the character of spring response to dynamic impulse force with specified energy. In real conditions of car movement, during passage of wheels of the rear (front) suspension on the road bumps, constrains in the form of dynamic force from the road side occur. These constrains generate dynamic stress in the suspension affecting other elements of the car [5, 6]. Consequently, effects of oscillations influences (couplings), which have an impact on comfort of both the driver and passengers, can be observed. [7].

Based on the experimental results, the following conclusions were derived:

- parameters of dynamic force (quantity and velocity of mass movement, force duration, energy absorbed by spring),
- force (as reaction of the spring on specified impact load conditions) progress in time and its maximum value,
- spring deflection equal with good estimation to beam displacement from the moment of the first contact with the spring to the nearest position,
- oscillations of constraint in time caused by multiple contact beam mass with the evaluated spring (nonlinear elastic element),
- mutual influence (coupled oscillations) between dynamic constraint (constraint mass) and a double multi-leaf spring.

The experimental results obtained in the test are supposed to be utilised to verify and develop FEM model describing effects of spring load and oscillations.

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