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Investigation of a fatigue-testing machine

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In the paper, diagnostic investigation of a fatigue-testing machine is presented. The most important sub-assembly of this fatigue-testing machine is the hydraulic intensifier, consisting of: a hydraulic cylinder, a plunger with sleeve, a plunger drive. The plunger drive - as power drive – consists of a disc cam and a cam roller with a ball slide.

During the operation of the fatigue-testing machine an accelerated wear of the disc cam was observed. The disc cam wear appeared as regular streaks on the active face of the cam. This kind of wear proofed that the wear of cam was a result of vibrations.

The diagnostic test of this fatigue-testing machine was focused on identifying the source of these harmful vibrations, and - as a next step - on minimizing these vibrations. As a result of identification of the vibration source it was found that the frequency of the harmful vibrations is equal to the harmonic frequency of the hydraulic system. To minimize these vibrations a modification of the hydraulic system (e.g. addition of hydraulic accumulator as -pressure vibration damper) is required. As modifications of the hydraulic system had an influence on the output parameters of the testing machine, the proposal of this modification was rejected. The problem of the accelerated wear of the cam was solved by modifying the design of the cam mechanism (a connecting-rod was added and - in effect - the cam mechanism changed into a slider-crank mechanism).

1. SPECIFICATION OF THE FATIGUE-TESTING MACHINE

The fatigue-testing machine consists of four sub-assemblies:

- the mechanical sub-assembly consisted (an electric asynchronous motor, a belt transmission, a shaft with a cam and a cam roller),
- the hydraulic sub-assembly (a plunger with sleeve, hydraulic cylinder and a necessary fittings Fig. 1),
- the hydraulic feeder,
- the counter-control electronic circuit.

The common feature of these sub-assemblies was their table shape. The mechanical sub-assembly realized a plunger driving with a stroke equals 12 mm and frequency equals 10 Hz. The hydraulic sub-assembly was in essence a hydraulic intensifier, which changed a plunger motion in a piston motion with the stroke equals 0,7 mm and 30 kN force. The electronic sub-assembly counted stress cycles and stopped the testing machine at the moment of destructure of the test specimen.

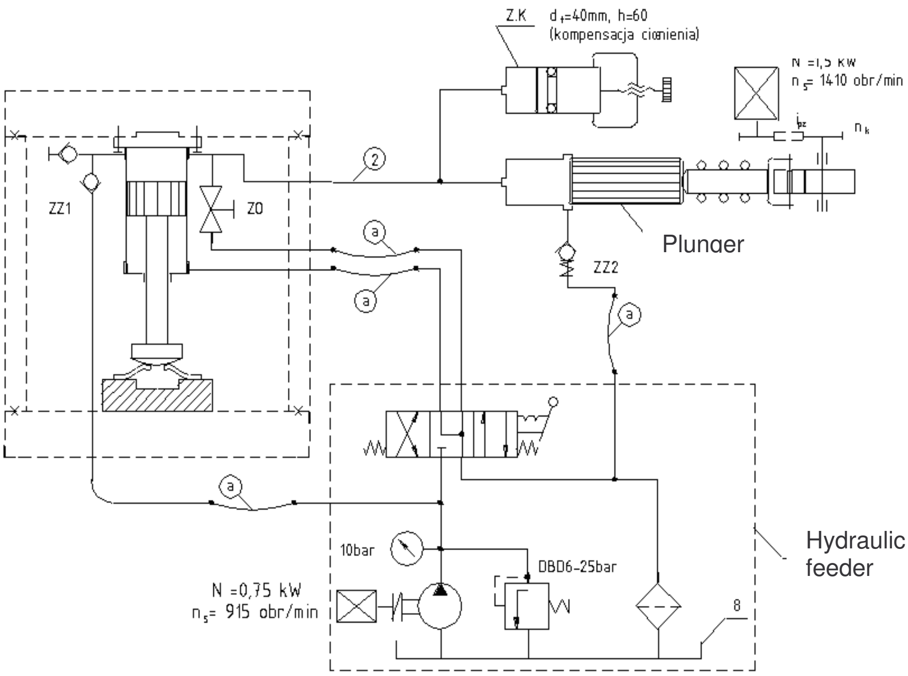

Figure 1. The hydraulic sub-assembly of the fatigue-testing machine

2. THE WEAR FORM

The real disc-cam life was very short, less than 1,5 million cycles (construction assumption was, that the cam life be longer that 100 millions stress cycles). The cam wear appeared as regular streaks on the active face of the cam (Fig. 2). Approximately 78 ÷ 80 streaks appeared on the cam circumference, rate of cam rotation was about 13 rev/s, hence the impact frequency of cam roller was estimated to be 1014 ÷ 1040 Hz.

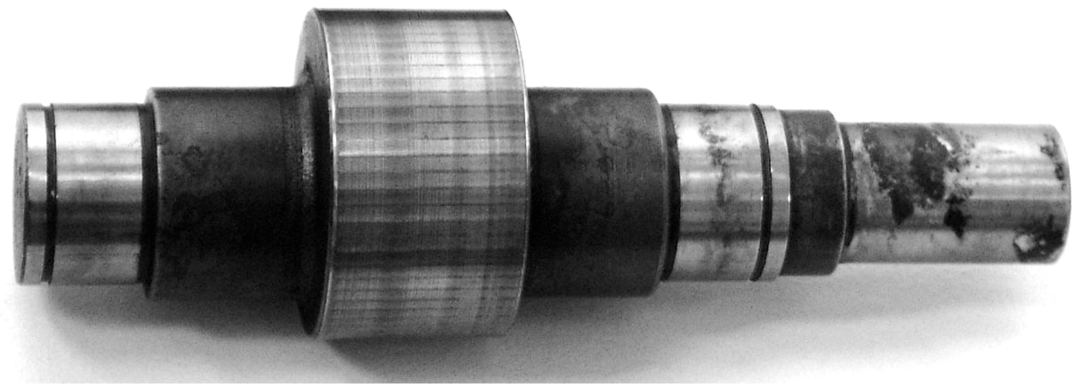
Figure 2. A photography of the disc cam

3. DIAGNOSTIC TESTS OF THE FATIGUE-TESTING MACHINE

3.1. Data measuring and acquisition

Following values were measured:

- the pressure in the hydraulic cylinder,
- the acceleration of the plunger,
- the acceleration of the piston.

The pressure was measured with a pressure gauge P8AP type (made by HBM), the accelerations were measured be means of piezoelectric sensors 4393 type (made by Brüel & Kjær). Signals of the piezoelectric sensors were conditioned and filtered with the charge conditioning amplifiers 2635 type (made by Brüel & Kjær). For the data acquisition a PC with a/d converter was used. The sampling frequency was 7,5 kHz, settings of the low-pass filters were 3 kHz.

3.2. Determining of natural frequencies of the fatigue-testing machine

Taking into consideration the wear form of the cam, were determined natural frequencies of the plunger. The test system is presented in Fig. 3, and the received spectrum of dynamic flexibility in Fig. 4.

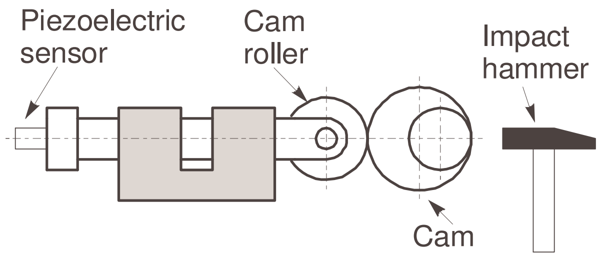

Figure 3. Test system for determining of natural frequencies of the machine

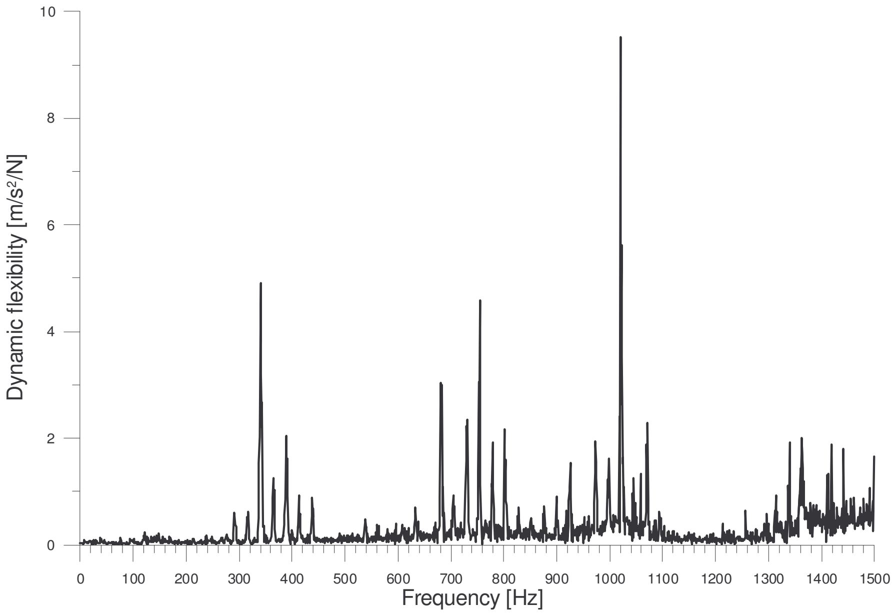

Figure 4. Spectrum of dynamic flexibility of the plunger

The frequency of the maximum of the dynamic flexibility of the plunger equals 1020 Hz this was a good relation to the impact frequency, which was determined from streaks value and speed of rotation.

3.3. Measurement results

The measurements were realized for three values of the compensator volume Z.K of the stroke (Fig. 1). The courses of the measured quantities are presented in Fig. 3 ÷ 5.

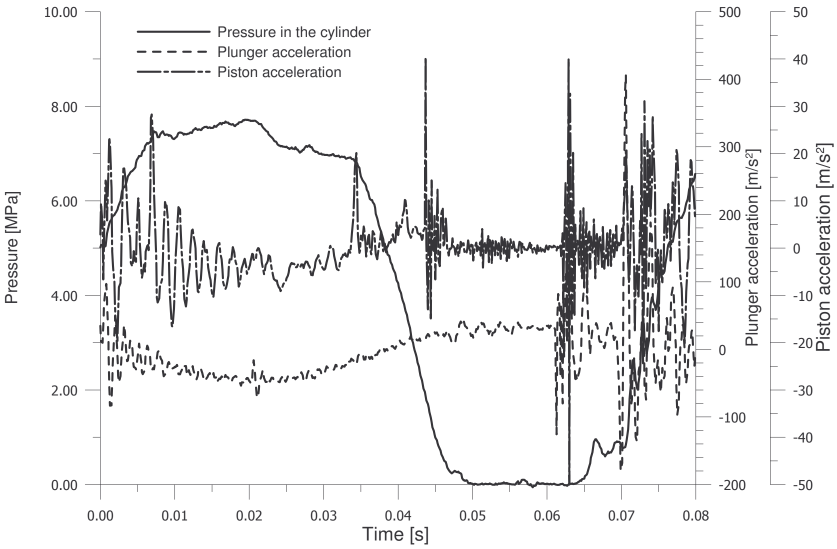

Figure 3. Oscillograms received for the minimum compensator volume

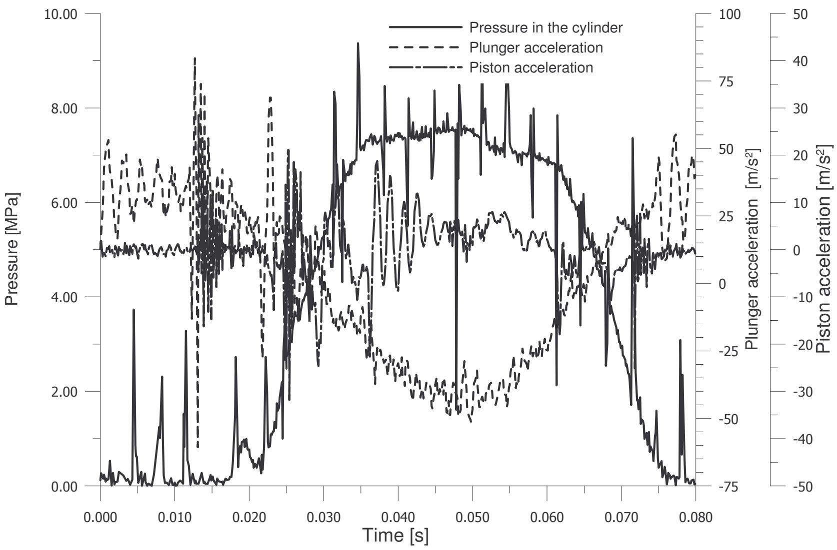

Figure 4. Oscillograms received for the nominal compensator volume

The accelerated wear of the cam is a result of high peak values of the plunger accelerations. In order to test the influence of the compensator volume on the plunger acceleration Figure 6 was drawn. The characteristic numerical values of acceleration are described in tab. 1. High values of plunger acceleration result from cam-roller rebounding and impacting. This effect was presented for a low pressure (while the hydraulic system was flushed).

The average values of accelerations testify to the measuring errors (theoretical average values equal zero).

Table 1
Characteristic values of measured accelerations

Value of the compensator volume	Numerical values of accelerations [m/s^2]			
	Minimum	Maximum	Peak to peak	Average
Minimal	-222,83	454,09	676,92	-0,93
Nominal	-108,15	127,47	235,62	0,09
Maximal	-131,80	125,69	257,49	0,49

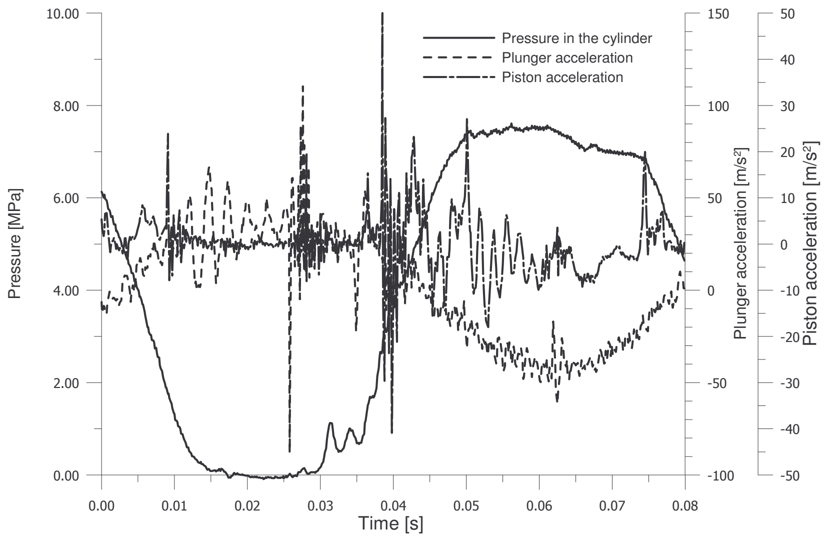

Figure 5. Oscillograms received for the maximum compensator volume

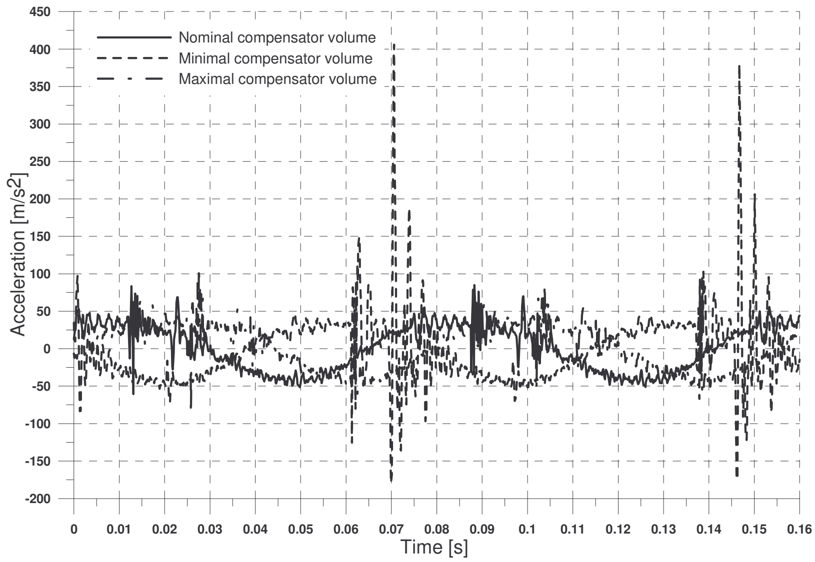

Figure 6. Oscillograms of plunger accelerations

The acceleration courses from Fig. 6 and their numerical values from Tab. 1 testified, that the value of the compensator volume had a considerably influence on the plunger accelerations. A distinct difference (acceleration course had distinct impact character) was received especially for the minimum compensator volume.

The accelerations were compared in the frequency domain too. The frequency spectrums of the acceleration courses are presented on Fig. 7. For low frequencies the received spectrums were similar, distinct differences appeared for medium and high frequencies.

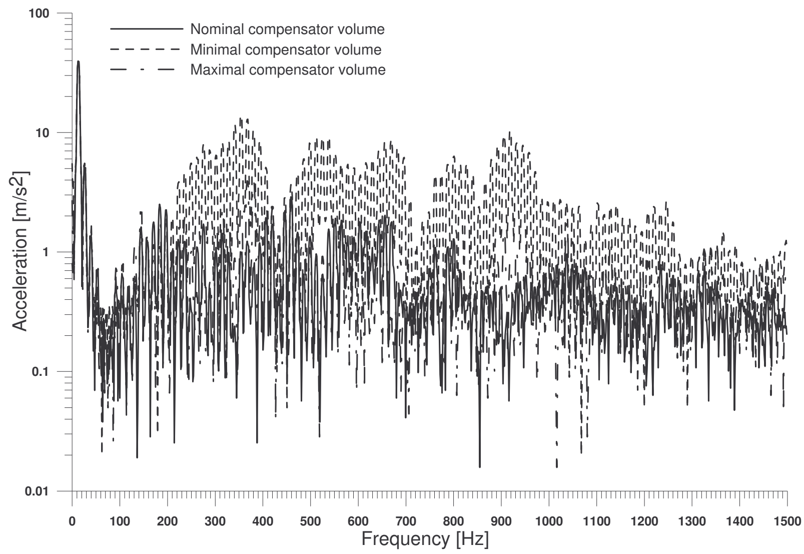

Figure 7. Spectrums of plunger accelerations

4. CONCLUSIONS

Accelerated wear of the cam is a result of vibrations of the plunger with the cam roller. The working frequency of the testing machine has a lot of generated nearly-harmonic frequencies. In effect, many eigenfrequencies of the fatigue-testing machine were excited. As modifications of the hydraulic sub-assembly were impossible, it was decided, that the cam mechanism has to be changed into the slider-crank mechanism. The exclusion of the possibility of rebounding in this mechanism, results in the decrease of the impact loads. Additionally, the rigidity of the slider-crank mechanism is higher than it of the cam mechanism. This constructional modification resulted in a considerable increase of the service life of the fatigue-testing machine.

REFERENCES

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