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Modal Analysis of Multi-Purpose Hydraulic Die Spotting Press

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Abstract:

Multi-purpose hydraulic die spotting presses can be used for both die spotting and mass production. Due to the reducing cycle time of hydraulic presses in mass manufacturing, dynamic analysis can be used to determine the oscillations caused by the structural design of the hydraulic press. Oscillations are generated during loading and unloading cycle of press operation and can affect product quality, energy consumption, product life of press etc. Resonance which is related to natural frequency and damping ratio, must be avoided in order to increase the quality of press. There must be a necessary interval between operation (cycle) frequency and the natural frequency of the hydraulic press. Thus, the resonance can be prevented. In this work, the natural frequencies of the 2000 tone multi-purpose hydraulic die spotting press is firstly calculated by modal analysis by using finite element model (FEM) and secondly measured during operation.

Key words: Hydraulic Press, Modal Analysis, Die Spotting

1. Introduction

Multi-purpose hydraulic die spotting presses can be used for both die spotting and mass production. Due to the reducing cycle time of hydraulic presses in mass manufacturing, dynamic analysis can be used to determine the oscillations caused by the structural design of the hydraulic press [1]. Oscillations are generated during loading and unloading cycle of press operation and can affect product quality, energy consumption, product life of press etc. Resonance which is related to natural frequency and damping ratio, must be avoided in order to increase the quality of press [2-4]. There must be a necessary interval between operation (cycle) frequency and the natural frequency of the hydraulic press. Thus, the resonance can be prevented [5-6]. In this work, the natural frequencies of the 2000 tone multi-purpose hydraulic die spotting press is firstly calculated by modal analysis by using finite element model (FEM) and secondly measured during operation. The paper is organized as follows; section 2 covers materials and method, section 3 introduces results of FEM model and experiments, section 4 presents discussion and in section 5 conclusion is given.

2. Materials and Method

2.1. FEM Model

The drawings of the 2000 tone multi-purpose hydraulic die spotting press are simplified to be used in finite element analysis (FEA) program. Figure 1 shows the solid model used in FEA. During FEA, model is meshed firstly then the supports are defined. In Figure 2, the meshed model is shown

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with support locations.

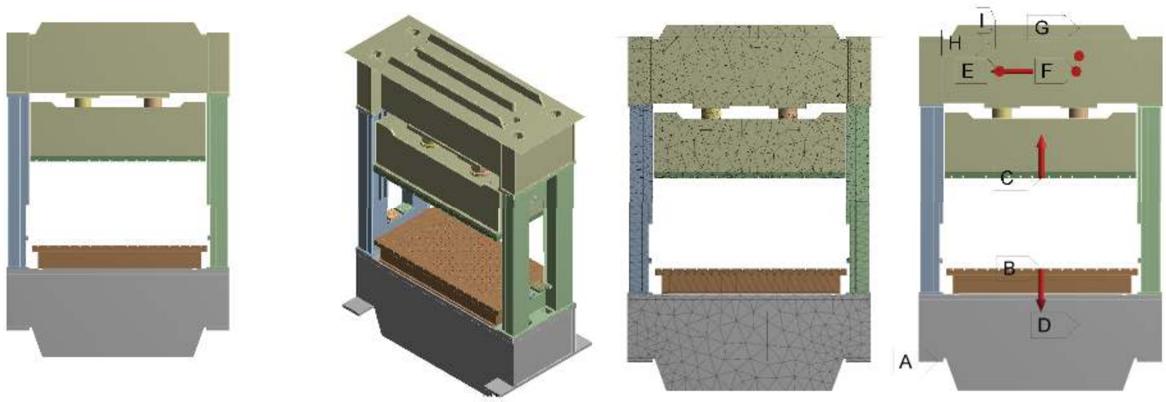

Figure 1. Simplified solid model used in finite element analysis.

Structural steel is considered as body material of the press. Fixed support is defined from base of the press. Linear support is defined between press body and slide (ram) [7-8]. Within the scope of modal analysis, natural frequencies and the mode shapes of the press are calculated between the range of 0.1 and 100 Hz. The model is assumed to be undamped which eases the calculation and increases the safety margin.

2.2. Vibration Measurement

In this study, column and mold vibration amplitudes are measured in die spotting process. In these measurements, the natural frequencies of the bolster and the press column are determined. Vibration measurement are made with accelerometers placed on mold on the bolster and press column. Using signal analyzer, data from the accelerometers were processed and saved to the computer. Figure 1 shows the measurement methodology of the system.

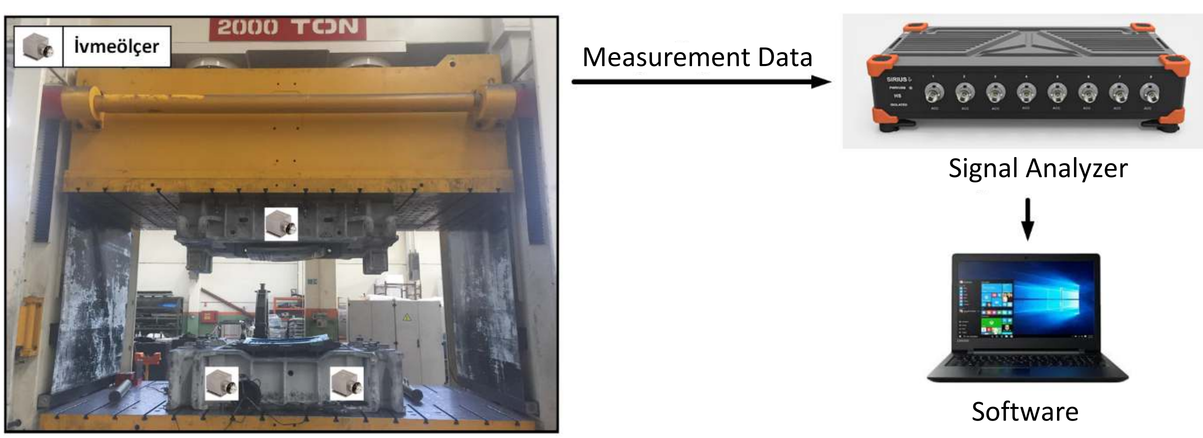

Figure 2. Measurement methodology.

Location of the accelerometers placed on the press in order to measure the vibration amplitudes and in which direction the vibration amplitude is measured is shown in Fig. 2.

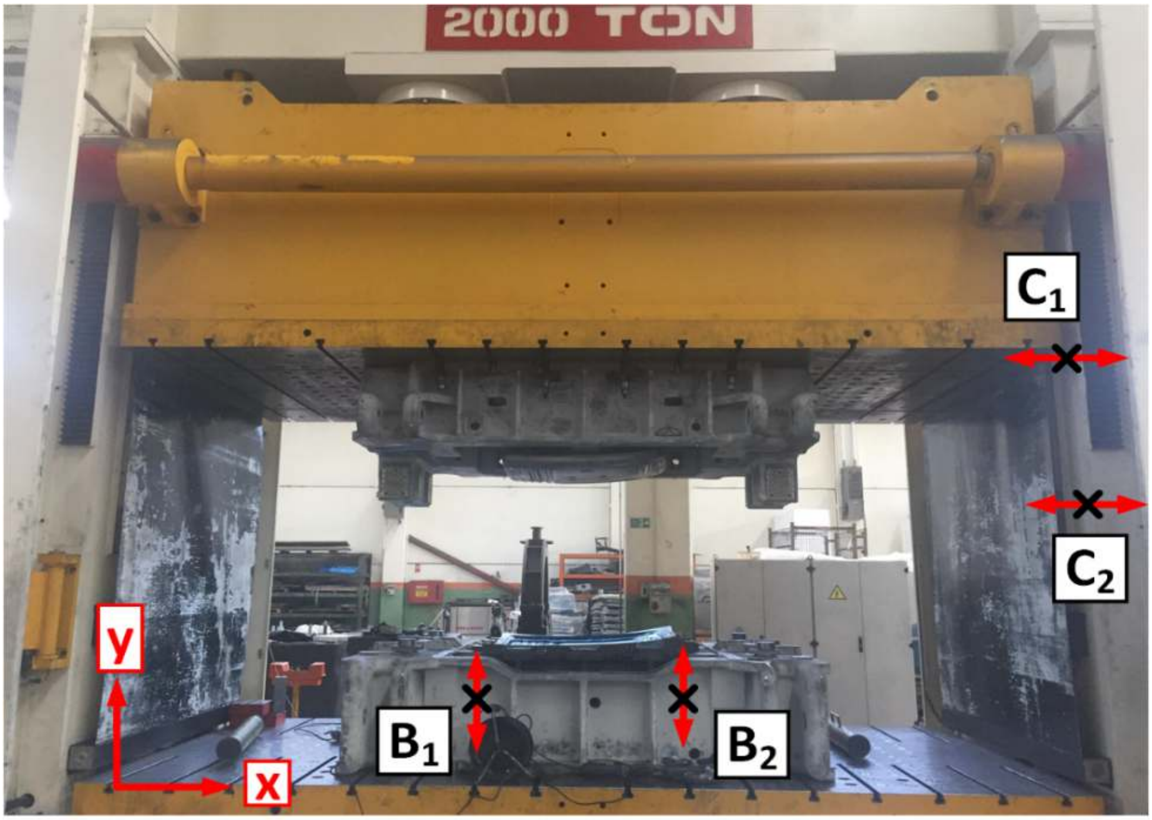

Figure 2. Accelerometer locations and measurement axis.

It is aimed to find the natural frequencies of the press from the vibration data received from the points B_1, B_2, C_1 and C_2. Vibration amplitudes are measured at points B_1 and B_2 on the y-axis, and at points C_1 and C_2 on the x-axis. Since the press is symmetric with respect to the y axis, it is sufficient to measure the vibration amplitudes of a single column

Vibrations of the column in the y-axis direction are less than x-axis direction. The reason for this is that the upper part of the press has a large mass. The large mass in the upper part creates a bending moment with respect to the x axis instead of the shortening/elongation movement in the y axis of the columns. Vibration measurement are made while press operates. Repeatability and correctness of the measurements were also checked by performing the measurements three times.

The measurement of the oscillation amplitudes was carried out in two stages. At the first stage, accelerometers are connected to points B_1 and B_2. The vibratory amplitudes at the points B_1 and B_2 were obtained during the pressing motion of ram in the direction of - y axis and the retraction movement in the direction of + y axis. Fig. 3 shows the time chart of the vibration measurement results taken from points B_1 and B_2. At the second stage, the accelerometers used at points B_1 and B_2 are now placed at points C_1 and C_2. The bending vibration amplitude of the column is measured during operation cycle.

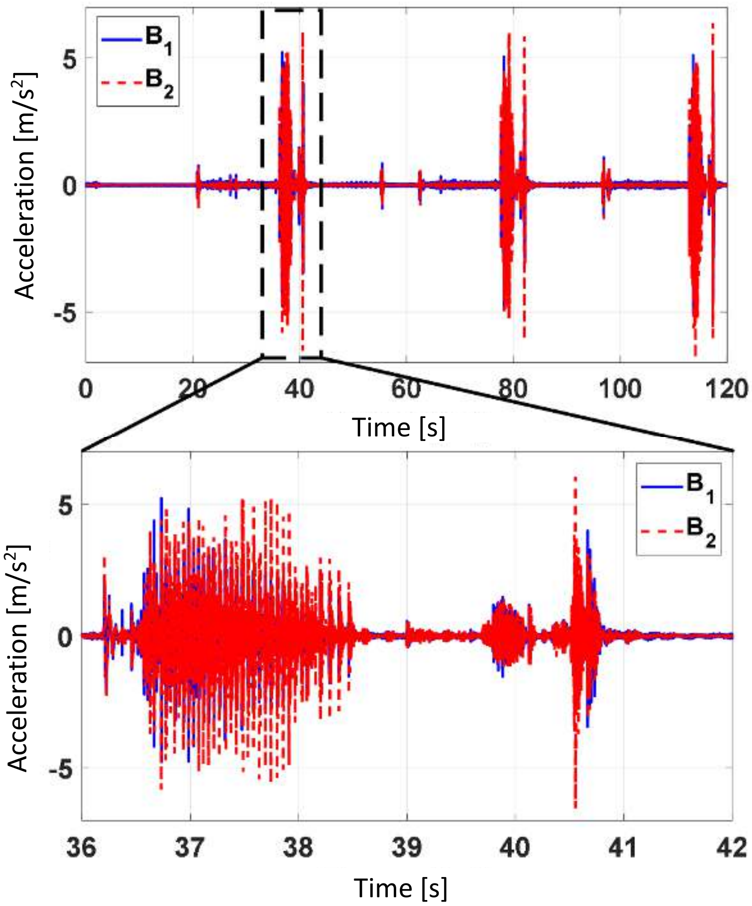

Figure 3. Comparison of acceleration data picked up from B_1 and B_2 points.

3. Results

3.1. FEM Model

In this section, the results of modal analysis by using FEM is given. Vibration amplitudes are given in time and frequency domain. Natural frequencies are identified by frequency response of hydraulic press. The natural frequencies (0-100 Hz) calculated by the press finite element method are given in the following table.

Table 1. Natural frequencies of the first 6 mode of the press calculated by using FEM.

Modes	Natural Frequencies (Hz)
1	10,80
2	11,00
3	25,82
4	53,17
5	60,77
6	84,91

Hydraulic press natural frequencies are well below the operating frequency (0.05 Hz). The highest frequency of the working components in the hydraulic press is the electric motor. The electric motor is operating at 24 Hz. The natural mode shapes of the first six modes of press are given below. In the first vibration mode, the press body is tilted in such a manner that the pressing base remains constant. In the second mode, the press body is bended so that the base of press remains fixed. First mode to second mode bending axes are perpendicular to each other. In third mode, press is in torsion motion. In fourth mode, press is in second bending mode. In fifth mode, press is in second bending mode. Bending axes between fourth and fifth mode are perpendicular. In sixth mode, press body is making a shortening-elongation motion [9].

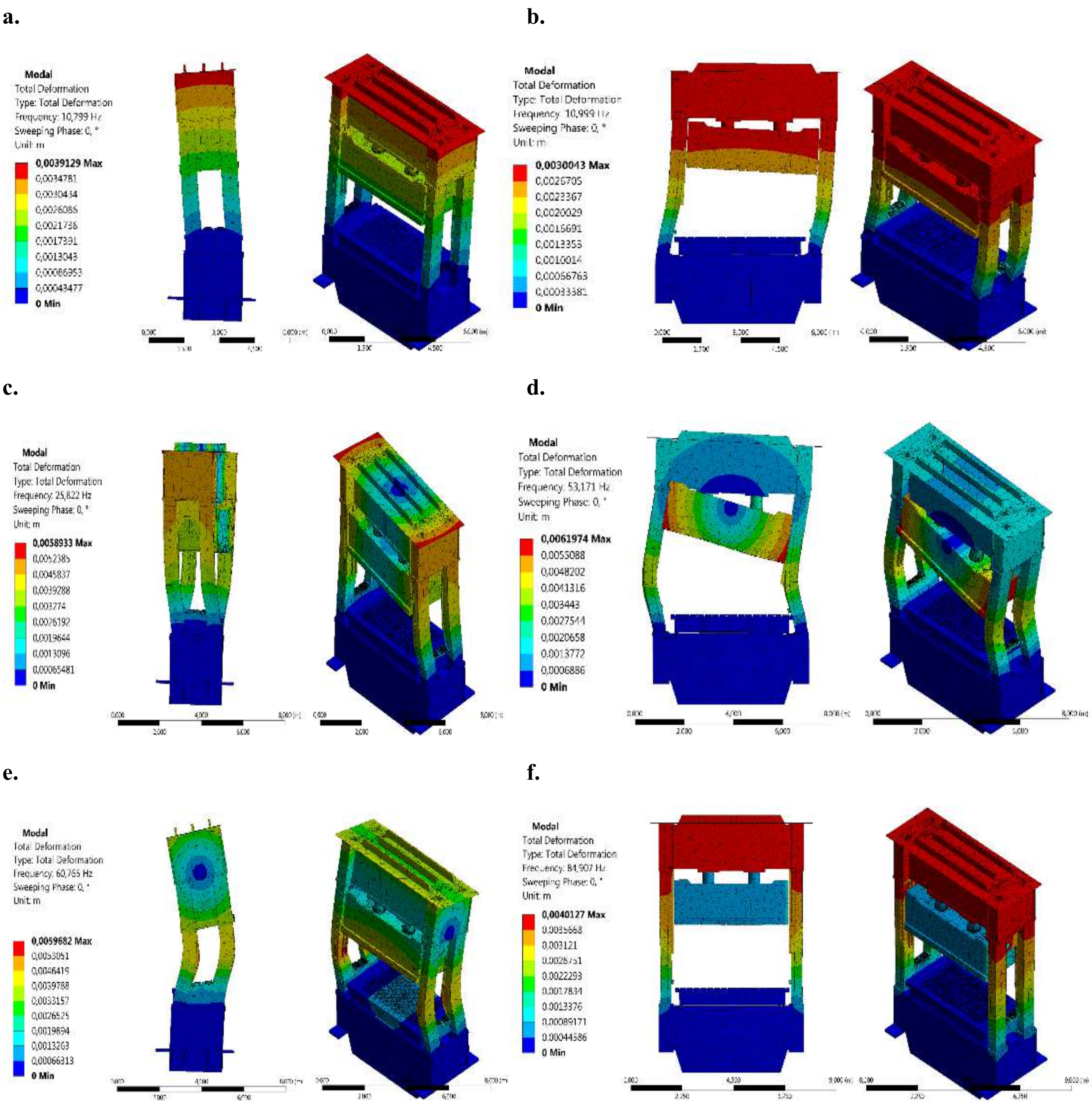

Figure 4. First 6 mode shapes of the hydraulic press.

3.1. Vibration Measurements

Firstly, results of the vibration measurements taken from mold is given in time and frequency domain. Secondly, Measurements taken from press column is given in time and frequency domain. Acceleration-time response of vibration measurements taken from mold during pressing is given in Fig 5.

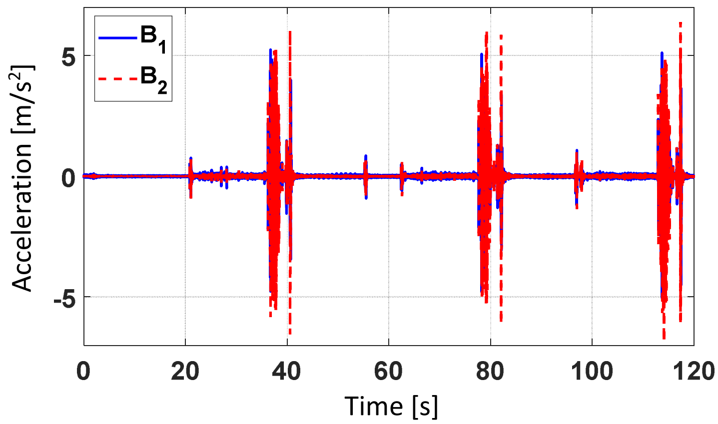

Figure 5. Acceleration-time response of the mold.

During pressing, the maximum vibration amplitude reaches ~ 6 m / s2 while it also has a minimum value of 1 m/s^2. In the frequency spectrum of press, it is peaking at 18.5, 30, 51, 65, 87, 102, 114.5 and 222 Hz.

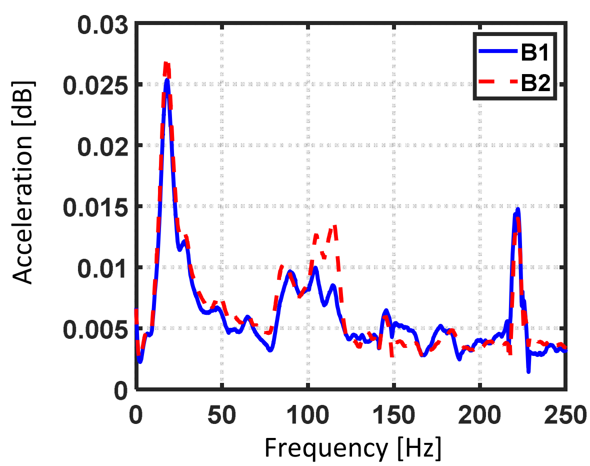

Figure 6. Acceleration-frequency response of the mold.

The natural frequencies found in this measurement in the range of 0-100 Hz are given in the Table 2 below.

Table 2. Natural frequencies picked up the measurements from the mold.

Modes	Natural Frequencies (Hz)
1	18.5
2	30
3	51
4	65
5	87

Acceleration-time response of vibration measurements taken from press column during pressing is given in Fig. 7. During pressing, the maximum vibration amplitude reaches ~ 18 m / s2 while it also has a minimum value of 5 m/s^2. In the frequency spectrum of press, it is peaking at 6, 21, 31, 51, 66, 81 and 92 Hz. The natural frequencies found in this measurement in the range of 0-100 Hz are given in the Table 3 below.

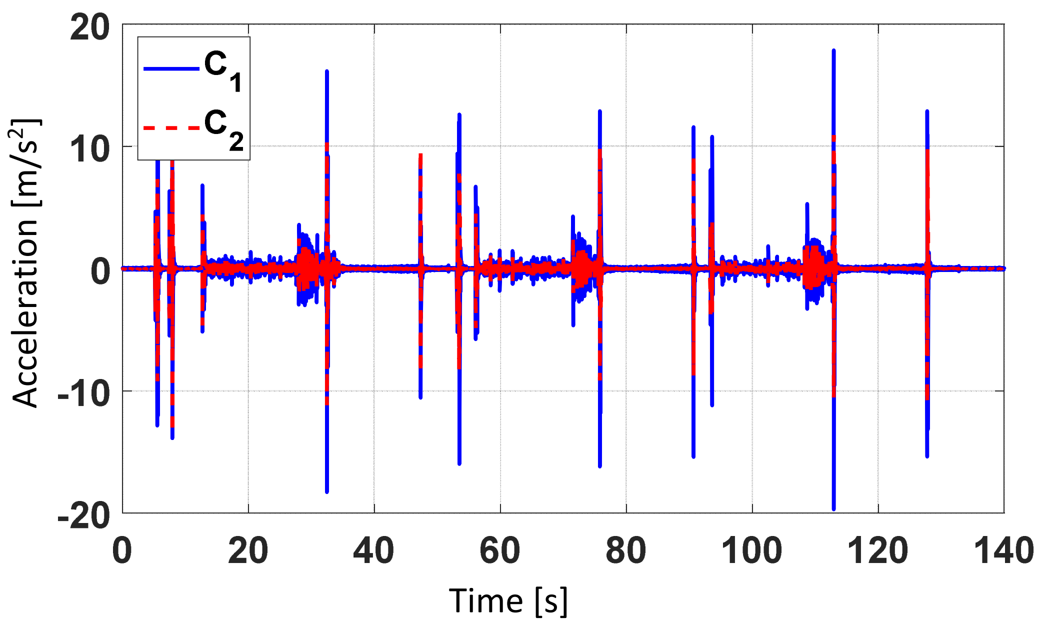

Figure 7. Acceleration-time response of the press column.

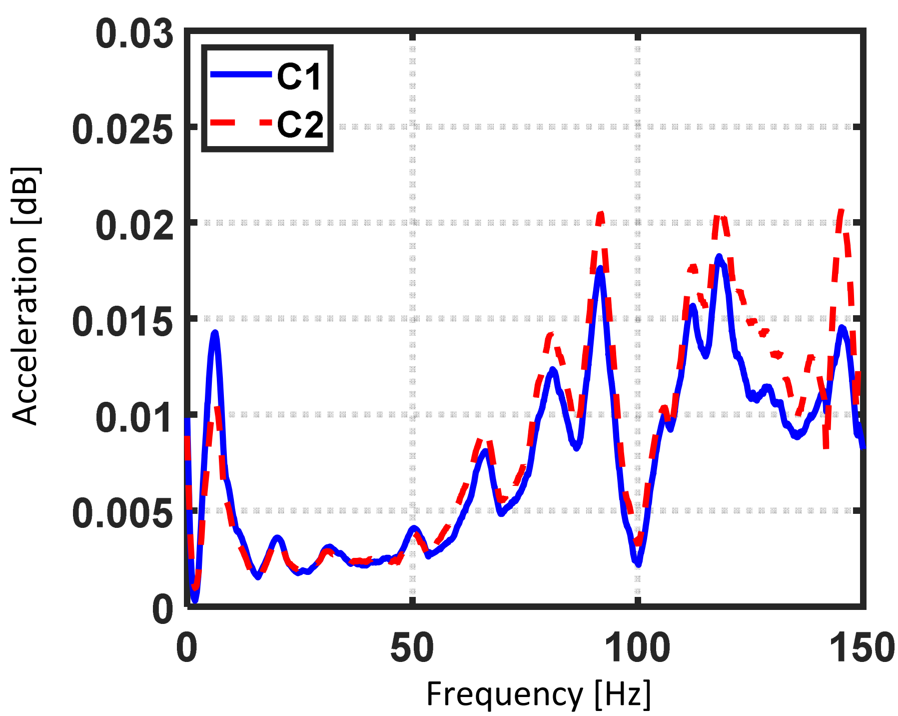

Figure 8. Acceleration-frequency response of the press column.

Table 3. Natural frequencies picked up the measurements from the press column.

Modes	Natural Frequencies (Hz)
1	6
2	21
3	31
4	51
5	66
6	81

4. Discussion

The measured natural frequencies are close to the natural frequency values calculated in the numerical modal analysis operation. A comparison of natural frequencies of measured and calculated is given in Table 4.

Table 4. Measured and calculated natural frequencies.

Modes	Calculated Natural Frequencies (Hz)	Natural Frequencies (Hz) (Picking up the measurements from the mold)	Natural Frequencies (Hz) (Picking up the measurements from the column)
1	10,80	-	6
2	11,00	18.5	21
3	25,82	30	31
4	53,17	51	51
5	60,77	65	66
6	84,91	87	81

The differences between the measured and calculated natural frequencies can be summarized as following:

• In numerical modal analysis, guides and bearings between body and ram are assumed to be rigid and frictionless.

• In numerical modal analysis, the system is assumed to be undamped.

As a result, the system in the modal analysis is defined as undamped and more rigid than normal system due to the given assumptions. The real system is more flexible and damped.

Conclusions

In this work, the natural frequencies of the 2000 tone multi-purpose hydraulic die spotting press is calculated by modal analysis by using finite element model (FEM) and measured during operation. Within the scope of modal analysis, natural frequencies and the mode shapes of the press are calculated between the range of 0.1 and 100 Hz. Column and mold vibration amplitudes are measured in die spotting process in order to determine the natural frequencies of the bolster and the press column. Natural frequencies of the hydraulic press are higher than the operating frequency (0.05 Hz). The highest frequency of the working component in hydraulic press is the electric motor which is operating at 24 Hz. The measured natural frequencies are close to the natural frequency values calculated in the numerical modal analysis operation. The differences between the measured and calculated natural frequencies are due to assumption of the rigid supports and connections in the undamped system which makes real system more flexible and damped.

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