ANALYSIS OF LOADINGS CARRIED BY JOINTS OF DIE HAMMER MPM 10000 B

Ludwik Majewski, Arkadiusz Trąbka

S u m m a r y

More and more modern and versatile computer programs give us an opportunity for modeling of many technological processes – especially of forging process. In the present work, die forging process was modeled by means of the finite element method. It allows for vast theoretical investigations aiming for checking of new as well as updated solutions of the designed appliances. Moreover the analogical experimental investigations are hard to perform due to a high cost of the experiments. Upon the taken considerations, the following characteristics were obtained: of loadings passing by screw-spring joints of columns with an anvil block and of columns with a cylinder obtained during a die forging process. The results of the computer simulation routines were presented in a form of adequate charts.

Keywords: die forging, calculation model, screw-spring joints, numerical simulations.

Analiza obciążeń przenoszonych przez złącza młota matrycowego MPM 10000 B

S t r e s z c z e n i e

Postęp w rozwoju programów komputerowych umożliwia modelowanie wielu procesów technologicznych, w tym procesu kucia. W pracy do modelowania kucia matrycowego zastosowano metodę elementów skończonych. Stanowi podstawy do rozważań teoretycznych oraz sprawdzenia nowych lub zmodernizowanych rozwiązań zaprojektowanych urządzeń, często niemożliwych do wykonania w warunkach rzeczywistych. Uzyskano charakterystyki obciążeń przenoszonych przez połączenia śrubowo-sprężynowe stojaków z szabotą i stojaków z cylindrem podczas procesu kucia matrycowego. Wyniki uzyskane z komputerowej symulacji kształtowania metalu przedstawiono na wykresach.

Słowa kluczowe: kucie matrycowe, model obliczeniowy, złącza śrubowo-sprężynowe, symulacje numeryczne.

1. Introduction

Investigations of machines performed by means of computer modeling allow for registration of versatile information – among others there are investigations of dynamical properties of machines. For example we can

Address: Ludwik MAJEWSKI, D.Sc., Eng., University of Bielsko-Biała, 2 Willowa St., 43-309 Bielsko-Biała, Phone: (+48) 0338279226, e-mail: lmajewski@ath.bielsko.pl, Arkadiusz TRĄBKA, D.Sc., Eng., University of Bielsko-Biała, 2 Willowa St., 43-309 Bielsko-Biała, Phone: (+48) 0338279226, e-mail: atrabka@ath.bielsko.pl

consider the investigations of dynamical properties of a die hammer which aim for minimization of propagation of its vibrations [1-5]. It is commonly known that in the die hammers dedicated to a hot forging process – the majority of the hit energy is converted during a forging process into the work of metal deformation and the rest of energy among others causes a reverse movement of the ram as well as it causes vibrations of the hammer body. Due to the excessive differences of masses of vibrating subsystems of a hammer and an existence of clearances in joints, therefore the joining elements have an essential role in a proper design and the work conditions of the die hammer.

In the paper, an analysis of an influence of the vibrations activated during the forging process on the loading passing by the screw-spring joints of the die hammer is performed. This problem is important because the steam-air hammer (having an anvil block and short ram) has a high hit energy for a low ram stroke. The time of one hit lasts approximately 0,7 s. The ram velocity in a moment of a hit reaches values from 5 to 6 m/s. The impulses arising during a hit of a medium hammer reach values 30-80 kNs, what indicates that it is a machine having excessive dynamic properties.

2. Model of die hammer

Modeling of technological processes, among other of the die forging process, is nowadays performed by means of more and more developed methods and computer programs [6-8]. They allow for consideration of an essential number of real factors. One of the methods which is especially useful for an analysis of a process of die forging is the finite element method (FEM). The method gives wide possibilities of theoretical investigations aiming for checking of new or changed solutions what in real conditions is difficult to perform due to high costs of experimental investigations.

The calculation model was developed based upon the technical specification of the steam-air, die hammer MPM 10000 B type [9]. Taking into account the functional scheme of a real hammer, presented in Fig. 1, its geometrical model was made by means of the program INVENTOR.

In the next step, using the calculation system VISUAL NASTRAN DESKTOP (VND), the calculation FEM model was prepared (Fig. 2). In the calculation model, the surfaces of contact reactions between the hammer constructional elements were defined. Especially, joining elements between the columns and the anvil block as well as between the columns and cylinder were introduced (Fig. 3).

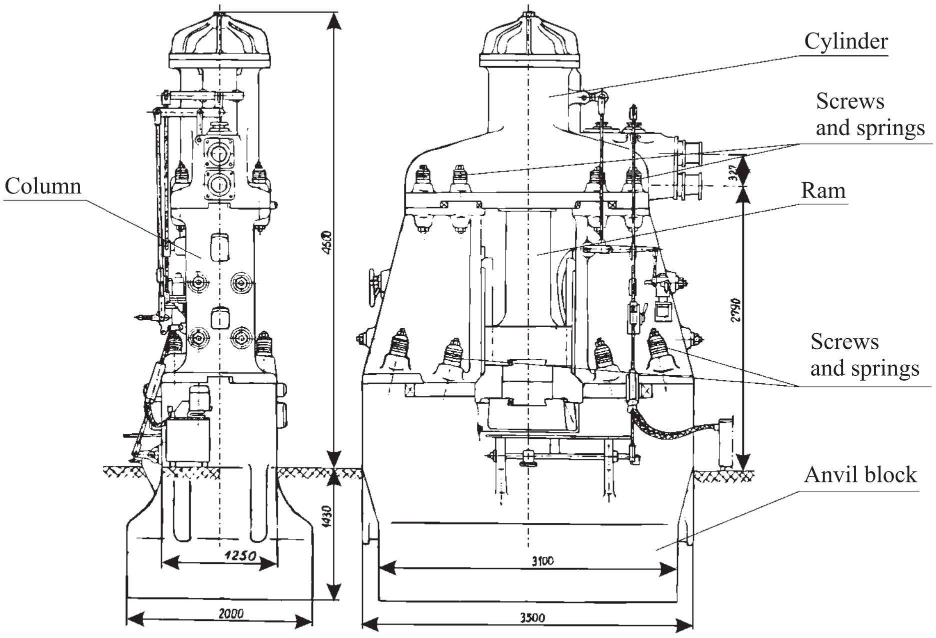


Fig. 1. The scheme of a die hammer 'MPM 10000 B' - type

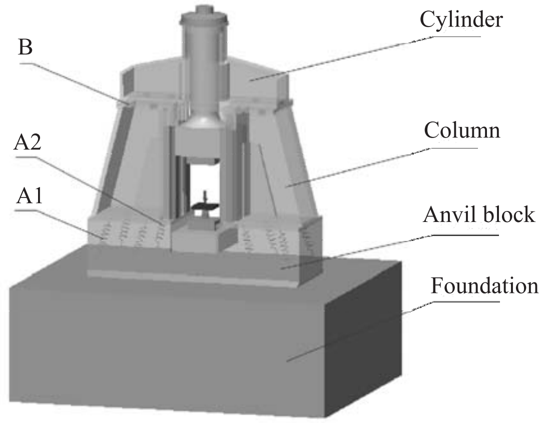


Fig. 2. Calculation model of a die hammer (A – screw-spring joint between the columns and the anvil block, B – screw-spring joint between the columns and the cylinder)

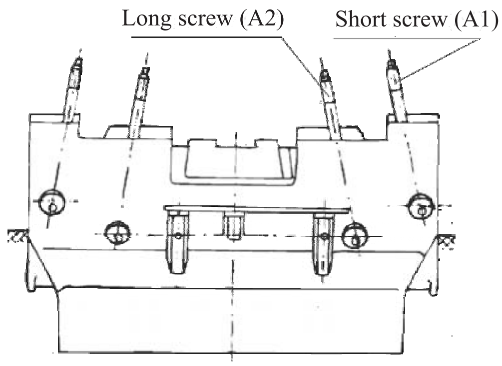


Fig. 3. The screws between columns and anvil block

3. Assumptions and parameters of the calculation model

Creating the model of the die hammer, the following assumptions have been made:

- forging is performed by means of closed dies;
- shaping of die forging proceed in conditions of plane state of strain;
- forged material is isotropic and perfectly plastic;
- a temperature of forged material is correct.

As loading, the rectangle type force impulse was assumed (Fig. 4) [4]. It was applied to the upper surface of the forging element.

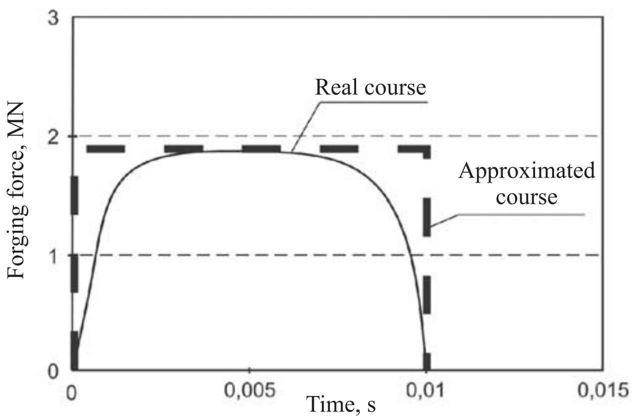


Fig. 4. Time history of the current forging force in case of steel

Stiffnesses, substitute damping coefficients in joints, and masses of elements were determined as follows:

- stiffnesses of the screws mounting the cylinder to the columns and the columns to the anvil block were determined building their geometrical models by means of the program INVENTOR, whereas the calculations of stiffnesses were performed using the program ANSYS. The values are as follows:
  - stiffness of the shorter screw mounting the columns to the anvil block $k_{A1} = 6{,}991*10^8$ N/m;
  - stiffness of the longer screw mounting the columns to the anvil block $k_{A2} = 6{,}0576*10^8$ N/m;
  - stiffness of the screw mounting the cylinder to the columns $k_B = 3{,}5132*10^8$ N/m;
- stiffnesses of the springs co-operating with the above mentioned screws are equal (respectively): $k_{As} = 40000$ N/m, $k_{Bs} = 28571$ N/m;
- initial tensions in the above mentioned springs are equal to (respectively): $F_{Ai} = 560$ N, $F_{Bi} = 286$ N;
- stiffness of placing the anvil block on the reinforced foundation (via oak beams) was determined analytically [2] $k_f = 5{,}83*10^9$ N/m;
- stiffness of placing the reinforced foundation directly on the ground was determined analytically [2] $k_g = 1{,}98*10^9$ N/m;
- damping coefficients determined analytically for particular joints:
  - columns with anvil block $c_a = 67734$ kg/s;
  - cylinder with columns $c_b = 26750$ kg/s;
  - anvil block with foundation $c_c = 643750$ kg/s;
  - foundation with ground $c_d = 3806250$ kg/s;
- masses of particular elements of the hammer are equal to [9]:
  - foundation $m_f = 100000$ kg;
  - ram with top die $m_r = 4000$ kg;
  - anvil block with bottom die $m_a = 77500$ kg;
  - columns (frame) $m_k = 13100$ kg;
  - cylinder $m_c = 4600$ kg.

The applied in calculation model characteristics of the screw-spring joints between the columns and the anvil block as well as between the columns and the cylinder are presented in Fig. 5.

NUMERICAL SIMULATIONS

The numerical simulations were performed for determination of several relations between parameters of forging process e.g.: time courses of forces acting in screw-spring joints (i.e. columns-anvil block and columns-cylinder).

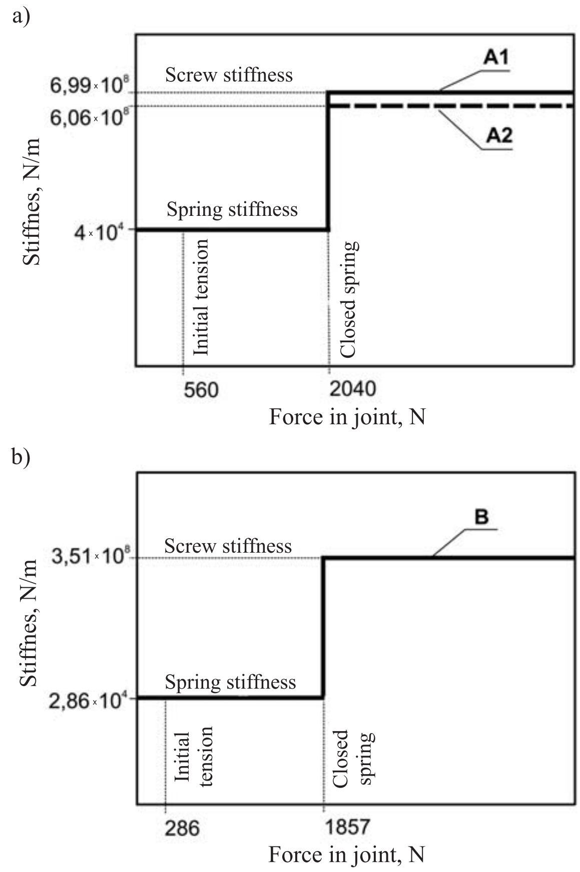
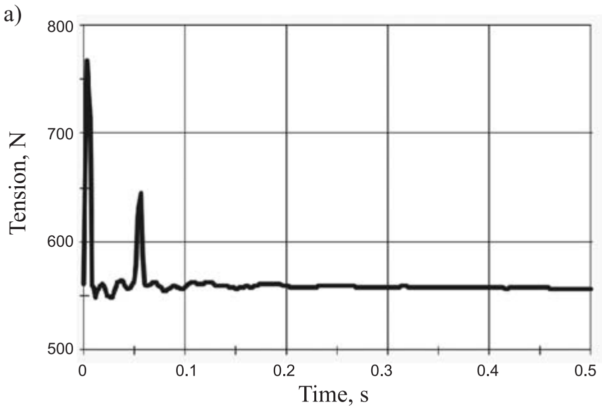


Fig. 5. Characteristics of screw-spring joints:
a) columns-anvil block, b) columns-cylinder

The results of calculation (taking into account the assumed symmetry of the system) are connected with two screws chosen among 8 existed in the joint of the columns with the anvil block (A1 – shorter screw, A2 – longer screw) as well as one screw chosen among 8 screws in the joint of the columns with the cylinder. The joints chosen for analysis are shown in Fig. 2. The registered courses of loading are presented in Figs. 6 and 7.

Based upon the loading courses it can be stated that the maximal value of short-lasting (impulse) force acting in the joint of the columns with the anvil block is two and half higher then the maximal value of impulse force acting in the joint of the columns with cylinder. In the joints columns-cylinder course of loading reaches 310 N. After termination of the shaping process of metal the impulse force declines. However, force – which is connected with the initial tension of springs – remains on the constant level, i.e. 286 N.

a)



b)

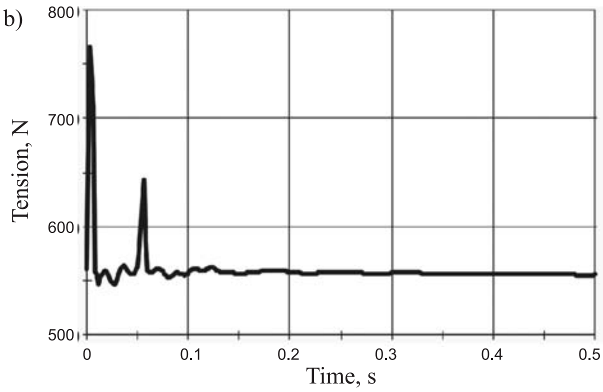


Fig. 6. Characteristics of loadings of screw-spring joints connecting the columns with the anvil block: a) A1, b) A2

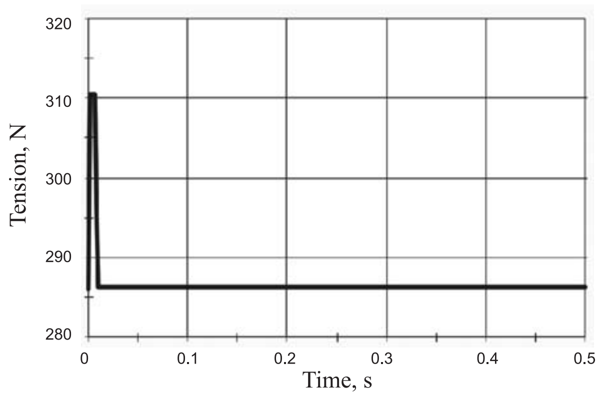


Fig. 7. Characteristic of loading of the screw-spring joint connecting the columns with the cylinder: B

In the joints columns-anvil block, the impulse loading forces reach the maximal values 770 N. After termination of the shaping process of metal, the impulse forces do not decline and after a period of 0,04 second they appear again and their values do not exceed 650 N. Then the force value diminish down to the value of the initial tension, i.e. 560 N.

Summary and conclusions

Choice of screw-spring joints joining the columns with the cylinder as well as the columns with the anvil block has an essential meaning for proper work conditions of a die hammer. These joints plays a role of dampers (shock absorbers) which reduce the vibrations passing onto the anvil block and the foundation [1, 3].

The courses of dynamical loads in the screw-spring joints of the columns with the cylinder for the analyzed die hammer are correct. During the process of die forging shaping (lasting 0.01 s), some relatively low forces appear, which disappear immediately after stopping of the process. Such a course of loading in joints is caused by a small difference of masses of columns and cylinder as well as low difference of accelerations of these elements.

Existence of an effect of dual impulses of dynamic forces acting in the screw-spring joints of the columns with the anvil block results from the difference of the acceleration of the columns and the acceleration of the anvil block [8] as well as low ratio of the columns mass to the mass of the anvil block together with the bottom die (this ratio equals to 0,23) and additionally due to too low initial tension of springs. The most simple method of minimization of the effect of dual impulse is increasing of the initial tension of springs.

References

[1] R. GRYBOŚ: Theory of impact for discrete mechanical systems. PWN, Warszawa 1969 (in Polish).
[2] I. KISIEL: Dynamics of foundations for machines. PWN, Warszawa 1957 (in Polish).
[3] A. MAJOR: Dynamics in civil engineering. Vol. II. Foundations for hammers. Budapest 1980.
[4] I. WASIUNYK: Die forging. WNT, Warszawa 1987 (in Polish).
[5] L. MAJEWSKI, A. TRĄBKA: Numerical simulation of die forging process. *Advances in Manufacturing Science and Technology*, **30**(2006)4.
[6] D. SZELIGA, S. WĘGLARCZYK, J. SIŃCZAK, M. PIETRZYK: The problem of essentialness of rheological parameters for simulation of hot forging. Polska Metalurgia. Wydawnictwo Naukowe „Akapit", 2006 (in Polish).

[7] A. ŻMUDZKI, P. SKUBISZ, J. SIŃCZAK, M. PIETRZYK: Application of simulation method in analysis of die forging processes (in Polish). *Obróbka Plastyczna Metali*, **17**(2006)3.

[8] Paper in a proceedings: L. MAJEWSKI, A. TRĄBKA: Assessment of dynamical properties of die hammer MPM 10000 B considering deformations of working material. Proc. 3rd Inter. Conf. Mechatronic Systems and Materials (MSM 2007). Kaunas 2007.

[9] Technical-service specification of the die hammer MPM 10000 B - type (in Polish).

Received in April 2008