Analysis of the Mechanism of the Drill Hammer

M. Konečný

Abstract This paper describes function of the mechanism of the hammer drill and solving the impact analysis and determining the contact pressure between the parts of the mechanism. The computational model was created by Creo Parametric 2.0., simulation of dynamic effect by the module Mechanism and stress simulation by the module Simulate.

Keywords Pneumatic hammer drill · Impact analysis · Contact pressure

1 Introduction

Use of compressed air is now widespread in many sectors. Pneumatic tools have a high degree of modernization. Manufacturers shall ensure competitiveness, superior technological performance, low price and especially functionality, which is closely related with high reliability. Pneumatic devices in these days widespread throughout the world. It has many advantages over hydraulic mechanisms, electric and solid mechanisms. The market has found a considerable number of companies that are engaged in the production of pneumatic mechanisms and machines.

2 The Drill Hammer

Work pneumatic hammers provides compressed air. It must be applied and regulated. The air supply is provided by a hose that connects to the machine by a thread. Lever built into the handle of the hammer is controlled airflow. The hammer inside air flows into the two chambers. This ensures the flow valve timing as shown in

M. Konečný (✉)
Technical University of Liberec, Liberec, Czech Republic
e-mail: martin.konecny@tul.cz

J. Beran et al. (eds.), *Advances in Mechanism Design II*,
Mechanisms and Machine Science 44, DOI 10.1007/978-3-319-44087-3_20

Fig. 1a, numerically labeled from 1 to 3 parts take care to ensure that the compressed air flow in the first phase of the movement in the chamber above the piston. In the second phase of movement the air flows into the chamber below the piston indicated in Fig. 1b. This cycle must be repeated continually. In the first case, when the compressed air flows into the chamber above the piston (red color component numbers 2), closes the holes in the green part indicated by 3. This process remains until the piston moving downwards opens the exhaust port. The air pressure suddenly in the chamber above the piston drops, part 2 releases closed openings in part 3 and air can flow into the chamber below the piston. To allow air to flow into the lower chamber, the cylinder of the linear motor drilled holes and recessed exhaust port, as can be seen in Fig. 1b. Operation of the distribution valve is provided decreases in pressure in the chamber above the piston and below the piston. The pressure in the chamber drops each time the shock worker is released and the air exhaust hole this hole can escape. A certain volume of the escaping gaps in the exhaust port of the shock worker flows through the tool and blowing debris from the drilled hole.

2.1 Determination of Dynamic Effects

The goal of this dynamics analysis is to determine the velocity of the shock worker before impact, the acceleration and kinetic energy. For the calculation of the dynamic effects used data, which the manufacturer says in the manual of the hammer. The stroke of the air motor has a size of 35 mm with frequency 3500 numbers of beats per minute. This value is set for the default position of the shock worker. Technical data was measured at a working pressure of the compressed air of 6.3 bar. The size of the force acting on the shock worker is determine with using analysis of the pneumatic motor. Given the size of this double-acting pneumatic motor and working conditions is the force $\boldsymbol{F_p}$ set at 580 N. Friction between the cylinder of the linear motor and the shock worker has been neglected.

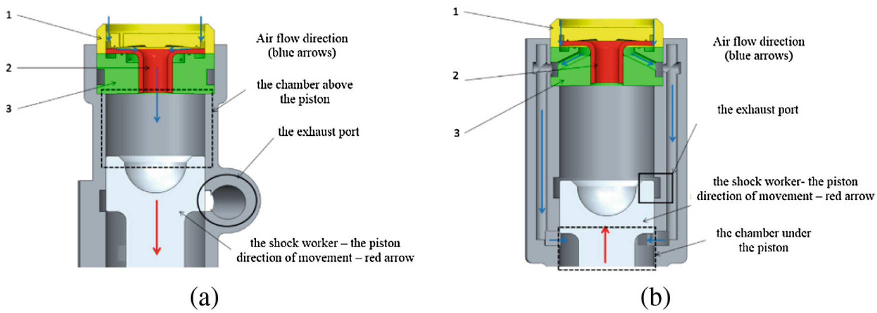

Fig. 1 Scheme of air distribution (Color figure online)

2.1.1 Calculation of Stiffness

In order to perform calculation of impact it is necessary to determine the overall stiffness of the system. The entire assembly is made up of tools and shock worker. Boundary conditions simulate the same deposit, as is in fact the deposit of these parts in real hammer. The end of the tool is used boundary condition fixed. The boundary condition for receiving the hexagonal part of the tool has been defined with clearance 0.1 mm in the direction perpendicular to the longitudinal axis and a permissible displacement of the axis of movement. For shock worker has been defined boundary condition for his large-diameter cylindrical surfaces, which enabled again only a shift in the axis of the tool motion. Boundary conditions for the shock worker is set up without prescribed. This was done due to the desire to get closer to real conditions. Material of the tool and shock worker has been set on hardened steel. Young's modulus for the hardened steel has a value $\boldsymbol{E} = 1.8 \times 10^5$ MPa. System is loaded with the general force $\boldsymbol{F_s}$. The maximal value of the displacement is $\boldsymbol{y} = 0.01145$ mm.

2.1.2 Calculation of Impact Force

After establishing the stiffness of the system of components which are in mutual contact during the impact, there was carried out the calculation of the impact force. For the purpose of this analysis is modified model from the previous analysis. The model is replenished with the subframe and the spring. The spring is inserting between the tool and the subframe. The stiffness of this spring is calculated in the previous stiffness analysis and Eq. (1). The value of stiffness is $\boldsymbol{k_s} = 43{,}626$ N mm. The model can be seen in Fig. 2.

$$\boldsymbol{F_s} = \boldsymbol{k_s} * \boldsymbol{y} \tag{1}$$

Insert the spring in the assembly of the calculated stiffness is one of the ways you can check the progress of the impact force by means of software. The tool weight was set to the minimum possible value. This was done because it is already known to the system overall stiffness and thus the weight of the tool is no longer necessary to calculate. The spring was supplemented by a shock absorber with low value of damping. The impact analysis is solved with parameters for the stroke of the pneumatic motor 35 mm, the force $\boldsymbol{F_p}$ 580N, the stiffness of the spring $\boldsymbol{k_s}$ which

Fig. 2 Assembly for the impact analysis, Creo mechanism

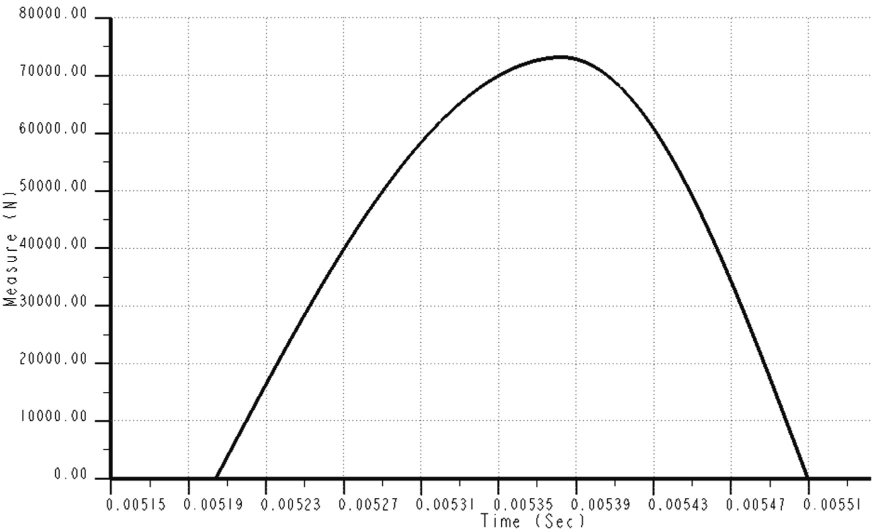

Fig. 3 Course of shock forces of the drill hammer, Creo mechanism

replaced the stiffness of the system and on the cam there has been set up the coefficient of restitution 0.75. The coefficient of restitution has been chosen according to the table for hardened steel.

The course of impact force approximately corresponded to the theoretical course of impact force. As the size and course of the impact force cannot determine exactly is the calculation of certain parts only theoretical. The value of the maximum resultant forces came 73° 192N (Fig. 3).

2.1.3 The Impact Theory

This phenomenon we associate with the emergence of large forces and sharp changes in speed. The impact in technical practice we encounter very often. For example, impact drill, jackhammer, and the like. From a mechanical standpoint it is a complicated phenomenon, which is influenced by many factors [1]. Shock plot spreads in waves and its duration is extremely short. It is a time of about 10^{-4} s. In this short period of time there are changes in speed almost immediately and forces acting in the contact area are enormous. For this reason we can be neglected under the influence of buckling on the long tool. When comparing the course of the force depending on the time when a theoretical calculation nature can observe a great resemblance to a graph obtained from the module Creo Mechanism when the maximal value of the shock force is 73° 192N (Fig. 3).

3 Theoretical Analysis of Contact

For resolving the task was chosen a modified equation for the contact of two balls. The maximum value of the contact pressure was obtained from Eq. (2):

$$p_o = \frac{\sqrt[3]{6}}{\pi}\left(\frac{E_{red}}{R_e}\right)^{\frac{2}{3}} F^{\frac{1}{3}} \tag{2}$$

The size of the force $\boldsymbol{F}$ has been selected 73192N. $\boldsymbol{E_{red}}$ value for two steel balls of the same material is $\boldsymbol{E_{red}}$ = 1.153846 10^5 MPa (E = 2.1 × 10^5 MPa and μ = 0.3). Furthermore simplification $\boldsymbol{R_e = R_1}$. Size $\boldsymbol{R_1}$ was chosen 75 mm, the value rounding shock worker (3). The tool was considered plane.

$$p_o = \frac{\sqrt[3]{6}}{\pi}\left(\frac{E_{red}}{R_e}\right)^{\frac{2}{3}} F^{\frac{1}{3}} = \frac{\sqrt[3]{6}}{\pi}\left(\frac{1.153846 \times 10^5}{75}\right)^{\frac{2}{3}} (73192)^{\frac{1}{3}} = 3224.4 \text{ MPa} \tag{3}$$

The value of the resulting pressure is approximately 1.5 times greater than the figure recorded in the impact analysis. This value would be correct, assuming that the area of the shock worker is completely straight. Calculated pressure went higher than a contact pressure in the analysis. The formula for calculating the contact of two spheres also does not exactly correspond to the real situation. Due to the fact that the tool is a hole diameter $\boldsymbol{d_d}$ = 7 mm, there is a concentration of the largest voltage at the border of the hole. It is possible to say that the result of the contact is approximately analysis results counted according to the formulas. To check whether the counted value analysis is correct, we were made more simplified calculation for contact with the cylinder surface and the planar surface according to the formula (4).

$$p_o^2 = 0.175E\frac{F}{l}\frac{1}{R_e} = 1{,}630{,}185.46 \text{ MPa} \Rightarrow p_o = 1277 \text{ MPa} \tag{4}$$

Again, we consider that the value of $\boldsymbol{R_e = R_1}$, is 75 mm. The length $\boldsymbol{l}$ was considered as a circuit holes $l = \pi \cdot d_d$. As seen, this value of the contact pressure according to the formula 4 is closer to values that can be seen from Fig. 4.

3.1 The FEM Analysis of Contact Pressure

After determining the size of the impact force could be created contact analysis in the module Creo Simulate. The objective of this analysis was to determine the pressures at the contact point with the shock worker and the tool. The analysis used the same model as for the calculation of the overall stiffness. In the report were made slight adjustments. The size of the force has been set at 73° 192N. Defining

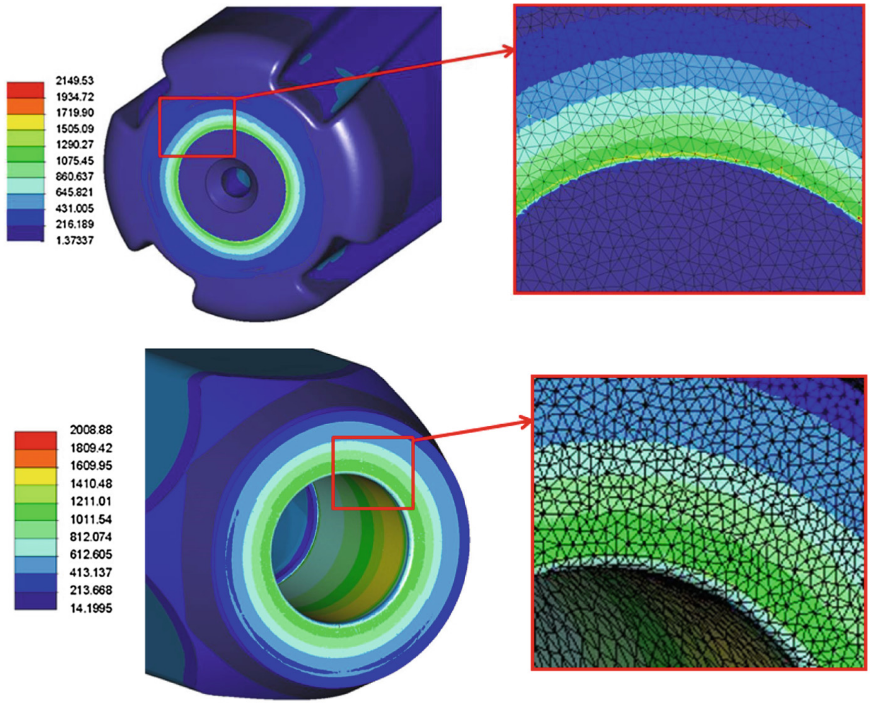

Fig. 4 Detailed distribution of pressures on the shock worker and the tool

Fig. 5 Detailed of the real wear

the contact surface between the tool and the shock worker maintained as the analysis stiffness. The contact area was been awarded on the tool and the shock worker 0.2 mm. The size of elements of concentrated mesh can be seen in Fig. 4.

The result of the contact analysis is visualized in Fig. 4. The critical point of reaching pressure values of almost 2150 MPa in the area of the hole's edge. In other locations the pressure is at lower levels and corresponds to the value of the contact pressure obtained from the formula according to the Hertz theory of contact a ball with the planar surface (4). The measured results were compared with the actual wear part (Fig. 5).

4 Conclusions

Because of limited extent of the article, it is impossible to describe the concerned analysis in detail. Owing to high values of contact pressures acting on a relatively small area, the wear and tear will be fast in the beginning. However, it will result in an enlargement of contact areas consequently, the force will be distributed to a larger area, and the contact pressure will drop down. The wear will also result in toughening of the material, too. The higher will be the wear of the components, the more slowly it will continue subsequently. It is known character of the distribution of the contact pressure. On the difference between the theoretical calculation and the value that are obtained by contact analysis of Creo Simulate probably contributes simplifying assumptions solution that is between the two general surfaces and not exactly correspond to reality. Hertz theory is accurate in case of contact tasks such as spheres with planar surface. The resulting value of the distribution of the contact pressure also affects the by the mesh quality in the contact area and its surroundings. We can see (Fig. 5) that the results come close to the real thing, even if maybe not concerning the value of the pressure, but concerning the proportion of distribution of operating pressures instead of greatest wear suit incidence of the biggest pressure identified in the analysis.

Acknowledgments This publication was written at the Technical University of Liberec, Faculty of Mechanical Engineering with the support of the Institutional Endowment for the Long Term Conceptual Development of Research Institutes, as provided by the Ministry of Education, Youth and Sports of the Czech Republic.

Reference

1. Medvec, A., Stradiot, J., Záhorec, O., Caban, S.: Mechanics III Dynamic, Bratislava SNTL (1988)