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# Design and Build Low-Cost Power Hammer Machine Based on Throttle Stomp

**Agus Sifa***, **Tito Endramawan, Dedi Suwandi, Ibnu Farhan dan Rivay Febrio Maulana**

Mechanical Engineering Department, Politeknik Negeri Indramayu
Jl. Raya Lohbener No.08 – Lohbener, Indramayu, Jawa Barat, Indonesia

**Corresponding author: agus.sifa@polindra.ac.id* Doi :https://doi.org/10.24036/invotek.v22i3.1065



## Abstract

Metal forming uses plastic deformation to change the shape of the workpiece. Deformation or change in shape results from the use of a tool which is usually called a die. The die provides stresses that exceed the yield strength of the material (plastic). The forging process is one of several types of metal forming. A power hammer machine is a machine used for the formation of a product in the manufacturing process, namely with a system of continuous forging/pressure on the specimen so that the deformed specimen becomes denser and stronger according to the desired shape. The forging process is superior to other processes such as casting and machining. The effectiveness of the forging process is characterized by low costs, high productivity, and high product quality. The cold forging process needs to be improved to reduce the occurrence of fine cracks and defects. The main factor is the quality of forging results by planning the design and production of the right die, improving product quality, and reducing the number of defective products to encourage industrial competitiveness. The method in this research is the process of making the design and calculation of the main components and making the power hammer machine. The results of the design and manufacture of the power hammer machine obtained that the impact force from the design was 58.3 Kg, the rotation of the drive shaft to drive the hammer was 206.5 rpm, the diameter of the driving shaft was 12.36 mm with the one made of 16 mm, the torque on the driving motor was 77.9 Nm, the minimum power designed is 2.2 hp with a rotation of 2800 rpm, and is selected for the manufacture of 3 hp, the electrical system is on / off using a throttle stomp.

**Keywords:** Power Hammer, Forging, Throttle Stomp, Design, Low-cost

## 1. Introduction

Metal forming belongs to a large group of manufacturing processes. Metal forming uses plastic deformation to change the shape of the workpiece. Deformation or change in shape results from the use of a tool which is usually called a die. The die provides stresses that exceed the yield strength of the metal (plastic). The metal is then deformed into a shape according to the die geometry [1]. Forging is one of the core manufacturing processes. forging products have superior mechanical properties. The forging process is superior compared to other processes such as casting. The effectiveness of the forging process is characterized by low costs, high productivity, and high product quality [2]. Forging operations are carried out with the help of hammers or forged dies. This technology is widely used in industry to produce well-defined material shapes [3]. Based on the working temperature, forging is divided into hot forging (warm forging), cold forging [4], and warm forging [3].

Forging operations are physically affected by the friction between the tool and the material, heat transfer during plastic flow, and the relationship between microstructure/properties and process conditions are difficult to predict and analyze during operation [5]. Several mechanical parameters occur during forging such as stress, strain, temperature, and force [6]. The cold forging process needs to be improved to reduce the occurrence of fine cracks and defects. Planning proper die design and production, improving product quality, and reducing the number of defective products encourage industrial competitiveness [7]. Operating temperature, contact pressure, sliding speed and contact time have a great effect on the wear depth of the die [8]. The types of molds in the forging process are open-die forging, closed-die forging, and impression-die forging [9].

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Defects that occur in the forging process such as surface cracks, imperfect penetration, residual stresses, and others, can be overcome by selecting the forging machine, the general characteristics and application of the given forging, as well as the characteristics of the mold [9]. Considering these problems, for a more economical and effective cold forging process, it is necessary to design and manufacture a power hammer machine to carry out the forging process, where the machine is designed for the cold forging process and can be used on a small scale and at low cost.

## 2. Research Methodology

Figure 1, the research flowchart of the stages of the process of making the design and calculation of the main components of the machine is the process of designing a power hammer machine, considering shape, geometry, strength, material, and function to support the level of engine performance [10]. The design is carried out by determining the main components to be calculated, namely: (a) determining the blow load, (b) the diameter of the drive shaft, (c) determining the transmission load, and (d) determining the power motor. Then do the manufacture of power hammer machine products.

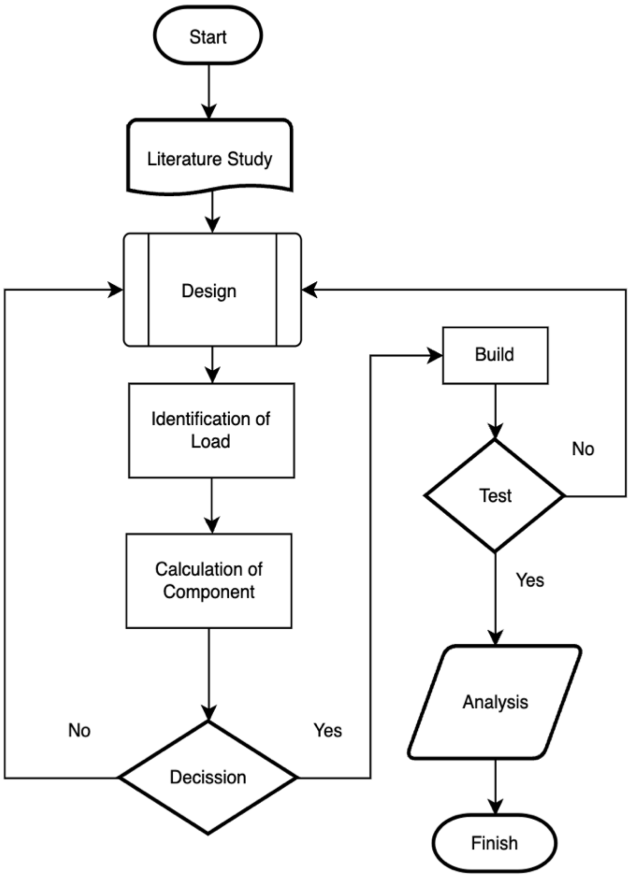


Figure 1. Flowchart of Methodology

## 3. Results and Discussion

### 3.1 Design

Figure 2, design of a power hammer machine with the main components: hammer (open die), crank system, drive shaft, v-belt transmission, frame gearbox and drive motor with throttle stomp system.

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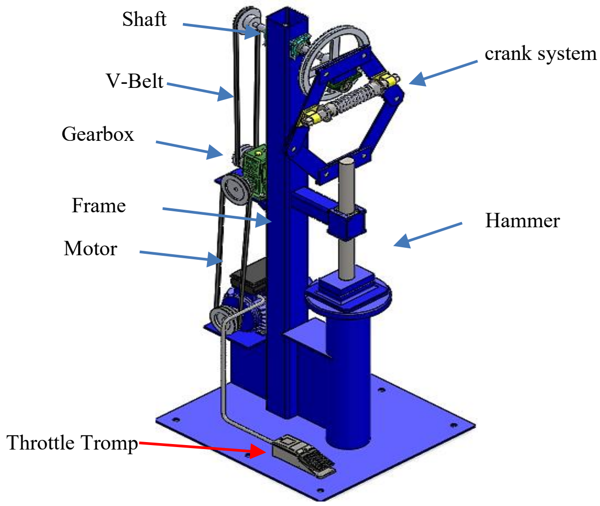
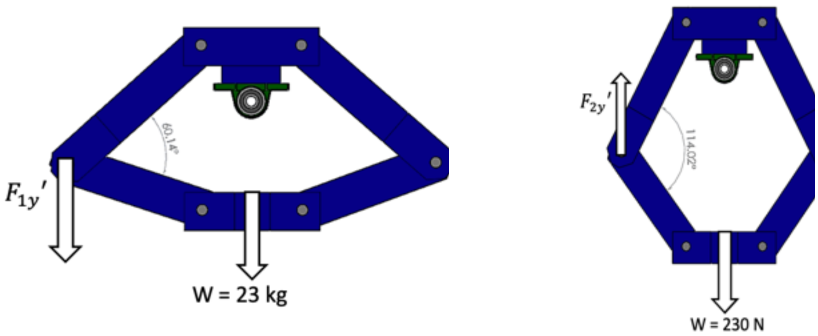



Figure 2. Design of Power Hammer Machine

### 3.2 Impact Load

The power hammer machine design, the main component of the hammer has a mass of 23 kg, and the hammer force moves vertically in the direction of gravity, according to Figure 3.




(a) (b)

Figure 3. Hammer Arm Force (a) Up Condition, (b) Down Condition

The hammer arm in the down position moves vertically down, with the hammer moving vertically in the direction of gravity, then the hammer arm force when it goes down and up can use the following equation [11]:

$$F_{1,2y}' = F.\ \mathrm{Cos}\ \vartheta \tag{1}$$

The angle of the hammer arm when going down is 60.14°, then $F_{1y}'$= 115 N, and the force of the hammer arm when going down is 115 N. The angle of the hammer arm when going up is 114.02° which moves vertically upwards, with the mass of the hammer moving vertically in the direction of the earth's gravitational force of 230 N, then the magnitude of the hammer arm force when it rises is $F_{2y}'$ = F. Cos ϑ, then $F_{2y}'$ = 1242 N, the magnitude of the hammer arm force when it rises is 1242 N. From the calculation of the magnitude of the hammer arm force when it goes down and when it goes up, the impact force can be calculated by the equation:

$$F_{tumbukan} = F_{1y}' + F_{2y}', \tag{2}$$

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The results obtained from the calculation of the impact force of 1357 N. On the hammer shaft there is a linear bearing so there is a frictional force with a coefficient of friction of steel with steel of 0.57 then the magnitude of the frictional force [11][12]:

$$F_s = \mu_k \cdot F_{tumbukan} \tag{3}$$

The magnitude of the frictional force obtained is 773.5 N, the total distribution of forces resulting from the magnitude of the collision force minus the magnitude of the frictional force, $F_{total} = F_{tumbukan} - F_s$, then the total collision is $F_{total}$ = 583.5 N.

### 3.3 Drive Shaft

The load of the large pully (P1) of 819.1 N and the load of the small pully (P2) of 585.2 N, the magnitude of the moment that occurs on the shaft can be found, with the length of the shaft on the large pully of 220 mm, and the length of the shaft on the small pully of 190 mm, then the magnitude of the moment that occurs at the frame point of the two loadings is 69000 N.mm. The torque on a large pulley with a radius of 75 mm is 61400 N.mm.

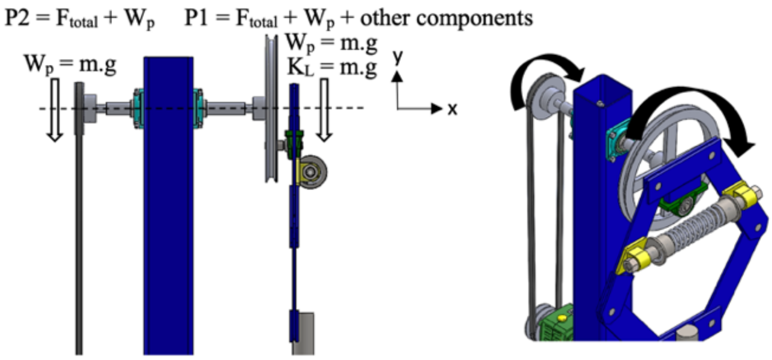


Figure 4. Force on the Horizontal Shaft

Calculation of the diameter of the shaft determined by the combined torsional and moment loading, using the following equation [13]:

$$d^3 = \frac{16}{\pi \, x \, \tau_{max}} \sqrt{M^2 + T^2} \tag{4}$$

Where shaft diameter (d), $\tau_{max}$ = Maximum shear stress (Mpa) on ST 37 material of 230 MPa [14-15], M = Moment (Nmm), T = Torque (Nmm), then a shaft diameter of obtained is 12.36 mm.

### 3.4 Transmission

Figure 5, loading on the transmission, the gearbox pulley mass is 1.6 N, pulley 3 (output) on the gearbox is obtained at the combined loading (P3) that occurs on the gearbox pulley P3 = P1 + P2 + Wpulley3, then a loading of 1406 N is obtained. The mass on pulley 2 (input) of 0.26 Kg or 2.6 N, pulley 2 on the gearbox obtained a combined load (P4) on pulley 2 (input) gearbox of P4 = P3 + Wpulley2, then the load on P4 = 1408.6 N. Loading of pulley 1 on the electric motor with a mass on pulley 1 of 8 N, the load on pulley 1 (P1) of the driving motor is P5 = P4 + Wpulley1, then the amount of loading that occurs on pulley 1 on the electric motor is 1416.6 N.

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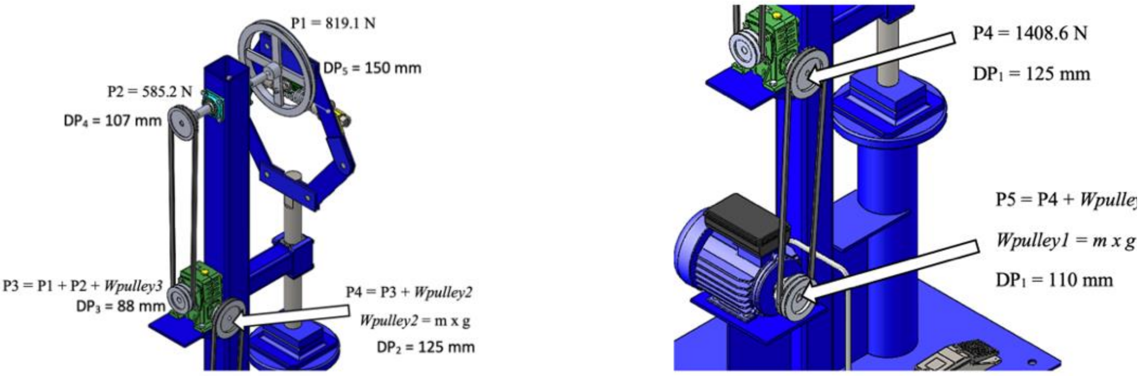
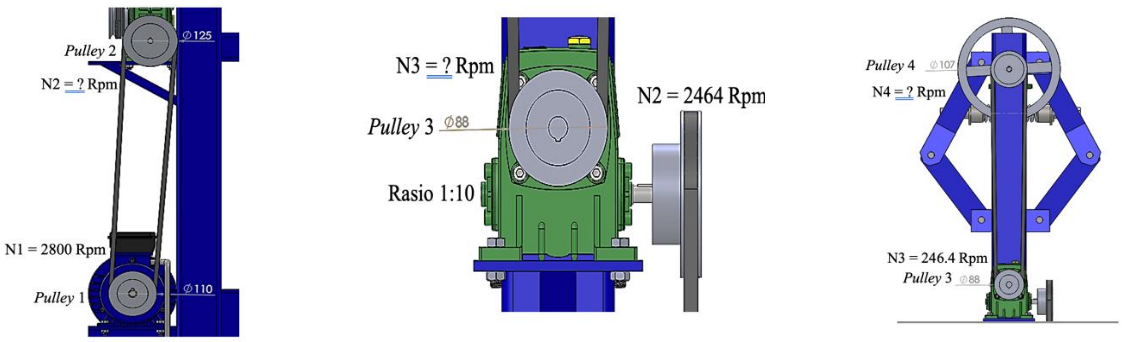



(a) (b)

Figure 5. Loading Conditions on the Transmission (a) Gear Box Transmission Load, (b) Motor Transmission Load

The power hammer machine is selected by a motor that has a rotation of 2800 rpm with a gearbox with a ratio of 1:10, then the reduced rotation of the gearbox is $N2$ = (N1 · P1)/P2, obtained $N2$ = 2464 rpm, $N3 = N2 \cdot rasiogea$rbox. The output of the gearbox is $N3 = 246.4\ rpm$, a gearbox output is produced from 2464 rpm with a gearbox ratio of 1/10 to 246.4 rpm, referring to the following description:




(a) (b) (c)

Figure 6. The number of revolutions (a) the number of revolutions on the motor pulley, (b) the number of revolutions on the gearbox, (c) the number of revolutions on the drive shaft

Figure 6, the number of revolutions of the gearbox to the main pulley $N3$ = 246.4 R , $P3$ = 88 mm , $P4$ = 107 mm, then $N4$ = (N3 · P3)/P4, obtained by 206.5 R$pm$, so the transmission on the main pulley of the drive shaft for driving the hammer is known to be 206.5 rpm, the rotation that is planned to be able to move the hammer, where the rotation of the hammer will have an impact on hammer wear [8].

### 3.5 Calculating Electric Power Motor

The force on pulley 1 (P) is 1416.6 N which rotates on pulley 1 with a radius of 0.055 m, the torque is 77.9 Nm, and the transmission is 206.5 rpm, it is known that the power to drive the die hammer with a force of 1416.6 N, to determine the magnitude motor power using the following equation [13]:

$$P = T \times w \tag{5}$$

Where P = Power (hp), T = Torque (Nm), W = angular velocity (rad/s), the angular velocity is unknown, the angular velocity formula is as follows [13]:

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$$W = \frac{2\pi \; x \; N}{60} \quad (6)$$

The angular speed obtained is 21.6 rad/s, then the power generated is P = 1683 watts or P = 2.2 hp, the power on the electric motor required is at least 2.2 hp.

### 3.6 Build

Figure 7 shows a Power Hammer Machine Product that has been made in accordance with the design analysis that has been carried out in the previous discussion.

Figure 7. Power Hammer Machine Product

The throttle stomp functions as the driving force for the power hammer machine, in addition to the automatic throttle stomp, the author also adds a dimmer as a rotation control for the electric motor. Figure 8 is a schematic of the automatic throttle stomp installation.

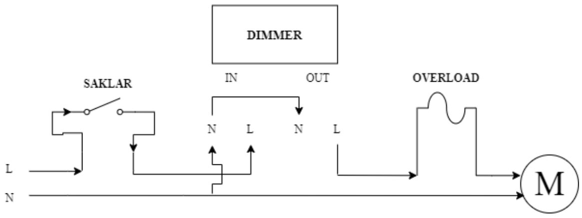


Figure 8. Schematic of the automatic throttle tromp circuit

The power supply of the driving motor is sourced from single phase AC, through the on/off switch and speed regulation via a dimmer and enters the on/off throttle stomp system to activate the driving motor.

(a) (b)

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Figure 9. (a) Thickness and (b) wide measurements of speciments after beating the power hammer machine

Figure 9, measuring the thickness (Figure 9a) and width (Figure 9b) of the test object after being impacted using a power hammer machine with time variations, the test object using steel plate material, was carried out with three test objects for each time parameter. Obtained the difference in thickness and width after beating, is presented in Table 1.

Table 1. The results of beating the power hammer machine.

| No. | Difference of Thickness | Difference of wide | Time (Minute) |
|---|---|---|---|
| 1 | 8% | 2% | 5 |
| 2 | 13% | 1% | 10 |
| 3 | 13% | 1% | 15 |

Table 1 presents the difference in the results of measurements of thickness and width in the test specimens, at 5 minutes there was a change in thickness of 8% and a change in thickness of 2%, while at 10 minutes and 15 minutes the changes were the same, the thickness underwent a change of 13% and the width experienced a change of 1%, this indicates the existence of plastic deformation and displacement that occurs [16].

## 4. Conclusion

The design and manufacture of a power hammer machine with an impact force of 58.3 kg, the rotation of the driving shaft to drive the hammer is 206.5 rpm, the diameter of the drive shaft is 12.36 mm with the one made of 16 mm, the torque on the driving motor is 77.9 Nm, the system electricity on/off by using the throttle, the minimum power obtained from the design is 2.2 hp with a rotation of 2800 rpm and is selected for manufacture of 3 hp. The results of the power hammer test show that there is a change in the thickness and width of the steel plate, this indicates plastic deformation and displacement.

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