DESIGN AND FABRICATION OF FOOT PEDAL OPERATED BLACK SMITHY HAMMER

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Abstract— A hammer is one of the important tools used by the blacksmiths. It is a force multiplier that works by converting mechanical work into kinetic energy. It is a device that delivers a blow i.e. a sudden impact on object.

Most of the hammers are hand tools used for bending, hammering, forging, breaking a part, etc. This hand hammers require more effort, also may sometimes deviate from the target, where it is required to hit the object and cause injury to the operator.

In our device we made such an arrangement that the hammer can be operated with a foot. It works on a basic principle of four bar chain mechanism. It is a great tool for single blow with a fair bit of power for light swaging that we cannot do with a hand hammer. They are also great for the fact that it frees up your hand to hold the job. Hereby the operator can firmly handle the job which avoids falling of tools or hot workpiece on leg and avoids injury. It perfectly delivers the impact on the workpiece and at the target desired by the operator. It proves to be suitable and effective for making lot of stuff which does not require continuous blows but rather needs a striker to pound it. As compared to hand hammers it relatively takes less time to complete the jobs and hereby it improves the efficiency and increases productivity.

Keywords—Hammer, foot pedal, eco-friendly, innovations.

I. INTRODUCTION

A. BLACKSMITHING

Blacksmithing is the craft of heating iron and steel to a temperature where it is "workable" and then using various tools to work the metal into useful and decorative forms. A "blacksmith", fairly obviously is a person who blacksmiths.

The "Black" in black Smith refers to the black fire scale, a layer of oxides that forms on the surface of the metal during heating. The origin of "Smith" is debated it may come from the old English word "smythe" meaning "to strike" or it may have originated from the Proto-German "Smithaz" meaning "skilled worker".

Blacksmiths produce objects such as gates, grills, railings, light fixtures, furniture sculpture, tools, agricultural implements, decorative and religious items, cooking utensils and weapons. While there are many people who work with metal such as farriers, wheelwrights and armours, the blacksmith had a general knowledge of how to make and repair many things from the most complex of weapons and armour simple things like nails or lengths of chain.

At it's very simplest, blacksmithing requires 3 things:

1) Metal - typically steel anymore,
2) Some means of bringing the metal to working temperature,
3) Tools to handle and shape the heated metal. [5]

Simply Smiths put it as" something to get the metal hot, something to hit the hot metal on, and something to hit the hot a metal with". These three requirements have been commonly made with steel either from scrap or from the foundry; a forge using charcoal, coal, or gas as fuel; and with tongs, hammer, and anvil as tools.

Blacksmiths work by heating pieces of wrought iron or steel until the metal becomes soft enough for shaping. Heating generally takes place in a forge fuelled by propane, natural gas, coal, charcoal, coke or oil. Some modern blacksmiths also employee and oxy acetylene or similar blow torch for more localized heating. Induction heating methods are gaining popularity among modern blacksmiths. [6]

B. FORGING

The process which is use to shape metal by hammering defers from machining in that forging does not remove material. Instead, the smith hammers the iron into shape. Even punching and cutting operations (except when trimming waste) by Smith usually rearrange metal around the hole, rather than drilling it out as swarf.

Forging uses 6 basic operations or techniques

- Drawing down
- Shrinking (a type of upsetting)
- Bending
- Upsetting
- Swaging
- Punching

These operations generally required at least a hammer and anvil, but smiths also use other tools and techniques to accommodate odd sized or repetitive jobs. Unlike many other craftsmen, blacksmiths are able to make most of their own tools which includes a great number and variety of chisels, punches, tongs, and jaws of various shapes but the most common, important and principal tool used in black smithy is Hammer.[3]

C. FOOT PEDAL HAMMER

Our Foot Pedal Hammer is basically a treadle hammer which can be used by blacksmiths to pound heated metal into shapes.

A treadle is a type of lever or gear that uses an individual's stepping action to create mechanical motion. With the blacksmiths hammer these treadles are also used in variety of products such as sewing machine and water pumps. In case of a Foot Hammer, these treadle harnesses the kinetic energy or

motion from the movement of pedal. Usually, the foot pedal is pumped by the blacksmiths and the energy is transferred into mechanical energy that turns or forces a pound of hammer down on the anvil. Often, users can regulate the machine's speed simply by regulating the motion of their feet.

These machines typically do not use any electricity so they may be useful in developing nations around the world, or for environmentally conscious individuals who choose to not use fossil fuels.

While performing the practical in the college workshop we came across some problems during hammering the jobs with hand hammer in black smithy section. The problem was regarding the safety, accidents, inaccuracy, requirement of more than one operator and more efforts required for blows.

The similar problems are also observed with blacksmith's working on the road sides. As a solution over these problems and to cover the aspects related to social need we decided to make such a machine with the mechanical components which would preferably operate without electricity.

It can be effectively used for controlled single blows at the target by sufficiently one operator.

D. LITERATURE REVIEW

The first use of hammers arguably dates back to 2.6 million BC when stones of various shapes were used to break and shape stone, bone and wood to create new tools. The simple stone tools lacked handles and were in essence simply heavy; fortunately shape rocks that were the right shape for gripping and banging. During this period, the ability for harder stones to break softer stones allowed some customization to the tools, depending on if they were to be used to crack nuts, or crush the marrow out of bones.

It took an estimated 2 million years for the release of hammer 2.0, when strips of leather and sinew where used to add wooden or bone handles to the stone heads. This innovation was in widespread used by 30000 BC. Aside from removing the users hand from the area of impact and avoiding the familiar purple thumb, handle remains the most important update to the hammer as it allows a huge amplification of force and speed to the head. Users familiar with the use of modern farming hammer and sledge hammers understand the multiplier in effect here. The longer the handle the more force can be delivered at the point of impact. The biggest problem with the new handles was the propensity for bindings to break or become loose, causing heads to literally "fly off the handle". The new magnification of force also allowed users to drive in a force to the stone head that the hammer stone itself would shatter and break.

Air hammer basically uses pneumatics to drive the hammer. The air driven hammers have a number of disadvantages including the requirement of expensive and bulky compressor equipment, clumsy air pressure lines communicating from compressor to the tool, and relatively lower efficiency since, in order to get an effective blow, compressed air tools must apply full air pressure through the entire stroke of the piston, discharging the only partially used air, still under pressure, at the end of stroke.

While working in workshops there are many causes which are leading to the small or big non-fatal accidents it can divided into following factors:-

Handling material 36%, Slip or fall of person 26%, Hand tools 13%, Powered haulage 10%, Machinery 8%, all others 7% So in order to reduce the accidents due to use of hand tools (13%) involving hand hammers and to improve safety of human we are working on this project.

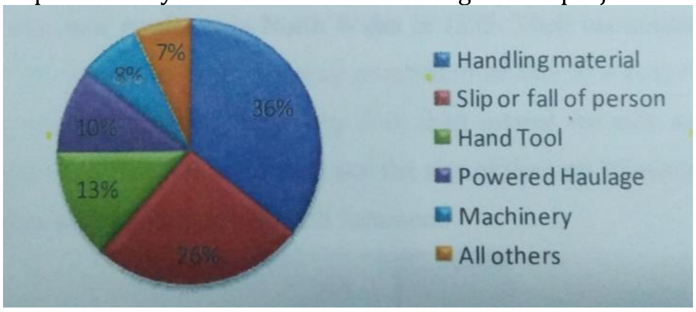

Fig. 1 Analysis of Accidents

Whenever the hot metal is to be hammered using the hand tools both the hands are engaged; one for holding the job and second for striking it with the hammer. These hammers are notorious for causing thumb and finger injuries. Many of the times they may not hit the target as per required by your operator and get deviated. These hammers may prove to be heavy to hold on to strike by the operator which sometimes may cause falling of hot job or hammer on the leg.

While using hand hammers the blacksmiths have to apply more effort and swag through a longer distance which causes the loss of stability and balance. Further when we consider the posture of an operator, it is observed that the worker has to sometimes hammer in an uncomfortable position for force required to strike. This ultimately causes problems such as backache, wrist pains, etc.

For 300 years after the Empire collapsed, very little historic records exist of any culture actively forging iron. In 1200 BC, however, iron forging exploded across the known world. Given iron strength compared to bronze, cultures that developed this technology were able to rapidly defeat their bronze clad opponents, as iron tools and weapons made quick work of bronze shields and armor.

During this time, iron hammers were developed to allow this shaping of iron tools. These early blacksmithing hammers began introducing new head shaping including features such as the peen.

E. Experimental Set up

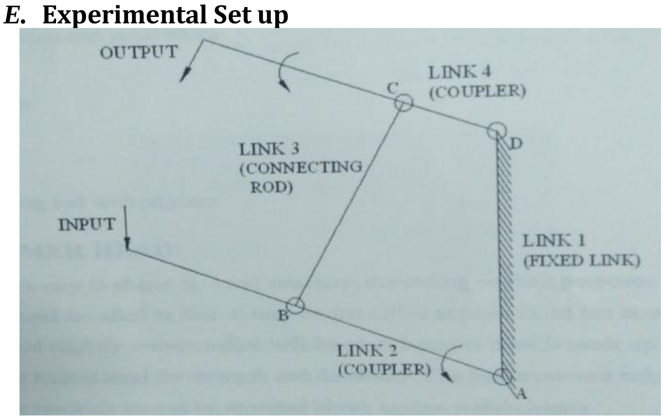

Fig. 2 Four bar Chain Mechanism

Input= Link 2- Oscillating Motion

Output= Link 4- Oscillating Motion.
It works on the principle of Four Bar Chain mechanism.[1] The figure shows the mechanism used for Foot Pedal Hammer, which is a four bar chain consisting of the 4 links each of them forming turning pairs at A, B, C & D. Link AD is fixed, whenever the input is given at link 2, it will oscillate about point A. This oscillating motion will be transmitted to the link 4 via the connecting rod (link 3).

Constructional details
The main components of this device are as follows:
1. Hammer head and anvil block
2. Spring
3. Foot Pedal
4. Lever
5. Bearing
6. Connecting rod with adjuster

1. Hammer head & anvil Block

Fig. 3 Hammer Head

Hammers vary in shape, size and structure, depending in their purposes. Striking surface of head is called as face. It may be flat called as plain faced but in this project we have used slightly convex called bell faced. A hammer head is made up of high carbon heat treated steel for strength and durability. The heat treatment helps prevent chipping or cracking caused by repeated blows against metal objects.
The weight of the hammer used in our project is 10lbs (5 kg approx.)

Fig. 4 Anvil Block

Anvils are of two general grades: cast iron and steel. Steel anvils are much better and should be used if they can be afforded. Two kinks can be distinguished by striking with hammer. A cast anvil has a dead sound while a steel one has a clear ring. In this project we have used a round anvil block made up of surface hardened EN8 Steel material (weighing approx. 28 lbs.) and having a diameter of 150mm and height 80mm.

2. Spring

Fig. 5 Spring

Spring is an elastic body, whose primary function is to deflect or distort under the application of load. When the load is removed the spring restores it original shape. Spring is made up of hard drawn and oil tempered spring steel.
The wire diameter of the spring used in this project is 3 mm and the mean diameter of the spring is 20 mm. the spring is of helical tension spring. These springs take axial tensile load. The coils of such springs are held close to each other. This type of spring is provided with hooks at the ends. The hook may be made by turning whole coil or half of the coil. This type of spring is primarily subjected to torsional shear stresses. They are used where constant spring rate is required.[2]
Function: - In this project the spring functions as a return spring, which is able to quickly lift hammer back to its initial position away from the job and anvil block.

3. Foot Pedal

Fig. 6 Foot Pedal

Foot Pedal is a kind of manual prime mover which when operated with the foot, operates the hammer head through the connecting rod. The moment of pedal is completely depend on the force applied on it by the foot.

4. Lever

Fig. 7 Lever

In its most basic form the lever consists of rigid bar supported at one point known as fulcrum which of two bearings on either side supporting the pin with a bush fitted in the boss of lever. At another end of the lever the hammer head is connected.

5. Bearing

Fig. 8 Bearing

The fulcrum of a lever is a pivot and often a bearing is used to allow the beam to pivot. The bearing for the lever serves as the rest, ensures the controlled position and provides a means of holding the lever in place. In this project we have used two pedestal ball bearings on either side of lever.

6. Connecting rod with adjuster

Fig. 9 Connecting Rod

A connecting rod is a rigid connecter which connects the pedal and the arm of the hammer with each other. When the pedal is operated the hammer is lower and raised as per the moment of pedal through this connecting rod.

Fig. 10 Adjuster

In this device we have made use of this adjuster connected to connecting rod in order to allow the variations in job heights and accordingly adjust the hammer stroke. It can be simply tightened on lever with the help of nut and bolts.

F. Equations

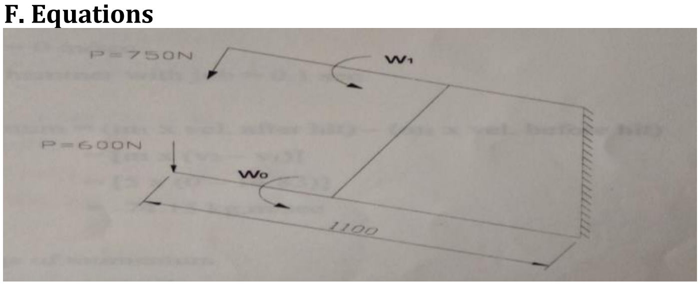

Fig. 11 Force Calculations

Let,

1. $F = 600N$
   $r = 1.1m$
   Mass of pedal = 3kg
   So, $F = m \times a$
   $F = m \times \omega^2 r$
   $\omega = \sqrt{(F/mr)}$
   $= \sqrt{(600/3 \times 1.1)}$
   $\omega = 13.48$ rad/sec

$V = \omega \times r$
$= 13.48 \times 1.1$
$V = 14.83$ m/sec

2. at hammer,

$v = v_1 = 14.83$ m/sec (before hit)
m_1 = mass of hammer = 5kg
v_2 = velocity after hit = 0 m/sec
t = time of contact of hammer with job = 0.1sec
So,
The change in momentum = (m_1 x vel. after hit) – (m_1 x vel. before hit)
$= [m \times (v_2 - v_1)]$
$= [5 \times (0 - 14.83)]$
$= -74.15$ kg.m/sec
Force = rate of change of momentum
F = change in momentum / time
$= -74.15 / 0.1$
$F = -741.5$ N……. (Impact force of hammer in the direction of velocity)
OR
$F = 741.5 \approx 750$ N in opposite direction of velocity of hammer.

1. SPRING CALCULATIONS

Total force by foot, say = 600 N
$\delta = \delta_1 = \delta_2 = 180$ mm
Also, $W = W_1 + W_2$
Let,
$W_1 = W_2 = 300$ N
Type of spring: Tension Spring
Use: - it is used as a return spring to bring the hammer back to its position.
Material used: Spring Steel.
$\zeta = 680$ N/mm^2

$G = 80\ kN/mm^2$

K = Wahl's concentration factor

$= [(4C - 1) / (4C - 4)] + (0.615 / C)$

$= [(4 \times 6 - 1) / (4 \times 6 - 4)] + (0.615 / C)$

$K = 1.2525$

The max. Torsional shear stress is,

$\zeta = K \times (8\ WD / \pi d^3)$

$= K \times (8\ WC / \pi d^2)$………$[C = (D/d)]$

$680 = 1.2525 \times (8 \times 300 \times 6 / \pi d^2)$

$d = 2.90$ mm

Mean dia. = D = 6d

= 6 x 2.90

= 17.4 mm

Taking, **D ≈ 20 mm** and **d ≈ 3 mm**

No. of active turns

Deflection $= \delta_1 = (8WD^3n) / Gd^4$

$n = (180 \times 80 \times 10^3 \times 3^4) / (8 \times 300 \times 20^3)$

n ≈ 62

2. LEVER CALCULATIONS

Taking moment about fulcrum,

$W \times l_1 = P \times l_2$

W x 500 = 750 x 900

W = 1350 N

Reaction at fulcrum

$R_f = W - P$

= 1350 – 750

R_f= 600 N

Design of fulcrum pin,

$R_f = d \times 1 \times P_b$

$600 = 1.25d^2 \times 5$

d = 9.79 mm

d≈ 10mm

l = 12.5 mm

But practically as per the standard available shaft (pin) fitting in bearings on both sides we took

d ≈ 180mm and **l = 180 mm**

Diameter of hole (outside diameter of bush) = d + 2 x 3

= 18 + 6

D_h= 24 mm

Diameter of boss = 2d

= 2 x 18

D_h = 36 mm

Designing c/s of lever

Moment @ point B,

$M = P \times (l_2 - r_b)$

= 750 x (900 - 18)

M = 661500 N.mm

Hollow square cross-section

Let, b = 0.5B

Now, s_b= M/Z

$= 661500 / \{[(TB^3 / 12) – (tb^3 / 12)]\ [B/2]\}$

$80 = 661500 / [(B^4 – b^4) / (6B)]$

$80 = (661.5 \times 10^3) / [(B^4 – 0.5B^4) / (6B)]$

$B^3 = (661.500 \times 10^3 \times 6) / (0.9375 \times 80)$

B = 37.54 mm ≈ 38 mm

And b = 18.77 mm ≈ 20 mm

But as per the standard available we took **b≈ 35 mm and B ≈ 38 mm**

t = (B – b) / 2

= 38-35 / 2

t = 1.5 mm

Acknowledgment

All the members of our project group have taken lot of efforts to complete this project. However it would not have been possible without the kind of help and support of many individuals and organizations. Many say that success is going from failure to failure without losing zest. Regardless of many hurdles and hardships we have successfully completed our project.

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