Design & Development of Tractor Trolley Hook Bending Machine
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Abstract:
Tractor-trolley hook is main part for joining trolley with tractor. It acts as joining media in between them. This project is to bend the bar at specified dimensions which will be used as a hook of tractor trolley. Presently bars are bent manually to make hook which suffers from many drawbacks like lack of accuracy, low productivity, irregular shape formation, more stresses formation due to manual hammering which results in reduced life span of hook. This manual process of manufacturing results in severe fatigue in operator. Operators not only subject their hands to hours of repetitive motion, but many occasions it results into several musculoskeletal disorders. The project is designed based on principal of hydraulic system. The hydraulic load has more power compared to other manual loading types as well as pneumatics and electric. The system that we proposed is that bending of hook bar. The bar is bent with the help of hydraulic force, because the hydraulic force is very large. The aim of our project is to increase the productivity so with the help of hydraulic force we can able to bend the bar. The drawbacks in older methods are rectified. If we place a bar for bending in the existing manual mode, we have to reposition the bar for six to eight times for every bend, but in our system we need to reposition it for four steps only.

Index Terms: Tractor Trolley Hook, Hydraulic Press, Punch, Jig, Rack and pinion,

I. INTRODUCTION
TRACTOR trolley hook is the connecting part in between trolley and tractor which connects them both. It is fitted between the connecting components of both with the help of bolt and locking pin. In tractor trolley transportation it is the most important component as it connects tractor with loaded trolley. So the large load comes on the hook which results in stress formation. Presently these hooks are manufactured manually by hitting and hammering method. This method is not appropriate as impact load is acting on heated bar which causes non uniform stress formation, which results in reduction of its life. In manual hook bending there is less accuracy. It causes musculoskeletal disorder and causes fatigue in workers. So to avoid this problem we came up with the solution of hydraulic hook bending machine. We have implemented a hydraulic press and one rack and pinion mechanism in this machine to bend the bar. In hydraulic hook bending machine, the hydraulic fluid power will be utilized for bending of the hook. In this machine the force will be gradually applied on the heated bar, which will eliminate the problem of non-uniform stress formation. As hydraulic force is used there is no need of labor to apply impact load on the bar. So the problems we face in manual hook bending are eliminated. Due to the use of the hydraulic hook bending machine, the mass production of hooks will be possible with reduced cycle time and increased profit.

II. LITERATURE REVIEW
Thermo mechanically treated bars are preferred over conventional mild steel bars because of their superior tensile properties. But increased strength and toughness of thermos mechanically treated bars create problem during subsequent manual bending operation. Hence, there felt a need of adoption of machine bending operation. In this paper problems associated with the manual bending operation and subsequent adoption of machine bending are discussed. A systematic study reveals that there is a substantial improvement in the quality of the bending. More uniform bend products are produced. Productivity is also improved because of reduction in time of bending. Along with the quality of the bending there are saving in terms of the floor space area and labour cost. [1] Metal forming is one of the manufacturing processes which are almost chip less. These operations are mainly carried out by the help of presses and press tools. A mechanical power press is a machine used to supply force to a die that is used to blank, form, or shape metal or non-metallic material. Thus, a press is a component of a manufacturing system that combines the press, a die, material and feeding method to produce a part. A mechanical power press is a machine used to supply force to a die that is used to blank, form, or shape metal or non-metallic material. Thus, a press is a component of a manufacturing system that combines the press, a die, material and feeding method to produce a part. Economy of construction and unhindered access to the die area. Inclined models and those with moveable beds or tables also offer a great deal of versatility, making them particularly useful for short run production or job shop applications. The drawback of the open frame design is the fact that such presses are generally limited in practice to the use of single dies. This is a result of several factors including the lack of stiffness and the typically small force capacity and die area of open frame presses. [2] The hydraulic press is one of the oldest of the basic machine tools. In its modern form, is well adapted to presswork ranging from coining jewellery to forging aircraft parts. Modern hydraulic presses are, in some cases, better suited to applications where the mechanical press has been traditionally more popular.
Advantages of Hydraulic Presses The mechanical press has been the first choice of many press users for years. The training of tool and die makers and manufacturing engineers in North America has been oriented toward applying mechanical presses to sheetmetal press working. Modern hydraulic presses offer good performance and reliability. Widespread application of other types of hydraulic power equipment in manufacturing requires maintenance technicians who know how to service hydraulic components. New fast acting valves, electrical components, and more efficient hydraulic circuits have enhanced the performance capability of hydraulic presses. [3] The design optimization & structure frame analysis of a heavy duty metal forming hydraulic press has been proposed. In this paper the structural analysis & design optimization of hydraulic press has been done and a comparative study of results of finite element analysis of a press with 300 ton capacity has been conducted. It is not possible for the real experimental studies to take into consideration the influence of the connections between the main beams and the rest parts of the construction, the influence of the longitudinal and transverse ribs as well as the influence of the supports on the overall stressed state of the construction.[4]

III. RELEVANCE OF WORK

- Reduced requirement of manpower.
- Increased productivity.
- Reduced total cost of manufacturing.
- Reduced risk of operator’s musculoskeletal disorder.
- Improved reliability: As gradual load is applied for bending, stress formation is uniform throughout the bend.

IV. MATERIAL SELECTION

Mild steel (Low Carbon Steel) is used for manufacturing the press and EN31 for punch.

Mild steel
Ultimate tensile strength = 440 MPa
Yield strength = 370 MPa
Hardness = 131 (Vicker)
Modulus of elasticity is 205*103 MPa

Chemical composition:
Carbon 0.1 to 0.20%
Iron 98.81 to 99.26%
Manganese 0.6 to 0.9%
Phosphorous 0.04%
Sulphur 0.05%
It has good machining properties with good weld-ability.

EN 31
Ultimate tensile strength = 1100MPa
Yield strength = 750 MPa

Composition:
Carbon 0.95 to 1.20%
Silicon 0.10 to 0.35%
Manganese 0.30 to 0.35%
Chromium 1 to 1.65%

V. PRODUCT SPECIFICATION

Hook:
There are three different sizes of hook which has to be manufactured on the machine.

There specifications are as follows
1. 2" hook – It has 20 inch length with 8.75” OD and 1.57 inch ID
2. 1.75" hook – It has 19.5 inch length with 8.5” OD and 1.57 inch ID
3. 1.5" hook – It has 18.5 inch length with 8” OD and 1.57 inch ID

The current manufacturing cost by manual hook bending is Rs.550 per piece. So the machine should produce the same with less cost.

VI. CALCULATIONS

Load Diagram

Calculate the Bending moment i.e.,
\[ M = \frac{w*l}{4} \]
\[ M = F*\frac{L}{4} \]
\[ M = \frac{981*103*1524}{4} \]
\[ M = 44.85*107 \text{ N-mm} \]

Now the bending moment equation can be written as,
\[ M/I = \frac{6b}{Y} \]
\[ I/Y = M/6b \]
\[ Z_{xx} = M/6b \]
\[ = 44.85*107/250 \]
\[ = 1794052.8 \text{ mm}^3 \]

This value is less than the std section modulus.

Therefore our final beam size will be 305*25 mm2

Final plate size will be 1524*305*25

No of columns = 4

Columns are for support hence same crosssection plates are used for it.

Working pressure (from machine) = 40 MPa
Pressure = \( F/A \)
\[ A = \frac{F}{P} = \frac{1177200}{40} = 29430 \text{ mm}^2 \]
\[ A = (\frac{P}{4})*d^2 \]
\[39240 = \left(\frac{P}{4}\right)d^2\]
\[d = 193.57 \text{ mm}\]

Thickness of cylinder for design pressure of 40 MPa
\[t = \frac{P*R}{(2*S*E-0.6*P)}\]
\[= \frac{40*193.57}{2*120.663*1-0.6*40}\]
Therefore \(t = 17.81 \text{ mm}\)

Outside diameter of cylinder = 193.57 + 2*17.81 = 229.19 mm

Design of end cap of cylinder
Internal pressure = 40 MPa
Material used is mild steel, yield strength = 250 MPa, allowable stress = 6a = 165 MPa
\[F = 120 \text{ tonnes} = 1177200 \text{ N}\]

Thickness of end plate \((t_{cap}) = \sqrt{\frac{k*P*d}{ft}}\)
\[= \sqrt{\frac{0.162*40*193.57}{165}}\]
Therefore \(t_{cap} = 38.36 \text{ mm} = 40 \text{ mm}\)

Design of gland
\[t_2 = \frac{C*W}{6a}\]
\[\text{C= imperial constant}\]
\[R/r \quad 1.25 \quad 1.5 \quad 2 \quad 3 \quad 4 \quad 5\]
\[C \quad 0.592 \quad 0.976 \quad 1.44 \quad 1.88 \quad 2.08 \quad 2.196\]

\[R = 230+30+30 = 290 \text{ mm}\]
\[r = 120 \text{ mm}\]
\[R/r = 290/120 = 2.41\]
Therefore \(C = 1.62\) (by linear interpolation)
\[t_2 = 1.62*1177200/165\]
Therefore \(t = 107.50 \text{ mm}\)

Cylinder mounting plate area = 406.4*304.8
\[= 123870.72 \text{ mm}^2\]

\[F/A = 1177200/123870.72 = 9.50 \text{ MPa}\]

Design Calculations:
Design of Rack:
Rack - Cast iron
Pinion - Cast iron
\[\text{\(6u < 390 \text{ N/mm}^2\)}\]
\[\text{\(6b = 30 \text{ N/ mm}^2\)}\]

Calculation of Centre Distance
Corresponding Number of Starts:
\[Z = 3\]
\[Z = \frac{1}{2}Z\]
\[24*3=72\]

Check Whether Z Lies Between 25 and 85
Choose \(q=11\)
Assume \((6c) = 159 \text{ N/mm}\)
Assume initially \(kkd=1\)
Wheel torque = power \(\times 60\div2\pi \times \text{rpm of the pinion}\)

\[= 50\times60\div2\pi \times (50\div24)\]
\[= 229 \text{ Nm}\]

\[\text{[Mt]} = k.kd.Mt\]
\[= 1\times1\times229\times10^6\]
\[= 229\times10^6 \text{ Nm}\]

\[a = \{[z\div q]+1\}v\left[\frac{(540-(z\div q)\{6c\}^2)}{\text{[Mt]}}\right]^{10}\]
\[= \left(\frac{72\div11+1}{v}\left[\frac{540-(72\div11)\times159}{(229\times10^6)}\right]\right)^{10}\]

\[= 7.56^v\left(0.518867\right)^x \times (229\times10^6)^{10}\]

\[= 7.56\times18.336\]
\[= 139\text{ mm}\]

Calculation of Axial Module
\[M_x = 2a\div(q+z)\]
\[= 2\times139\div(11+72)\]
\[= 3.3 \text{ mm}\]

Take \(m=5 \text{ mm}(\text{standard})\)
REVISE \(a\) and \(obtain\) \(d_1\)
\[a = 0.5 \text{ mm} (q+z)\]
\[a = 0.5\times5(11+72)\]
\[= 207\text{ mm}\]

Pitch circle diameter of rack\(=d_1=q.mx\)
\[=11\times5\]
\[=55\text{ mm}\]

5. \(V_s = V_1\cos\gamma \tan\gamma = z^q\)
\[= 0.14\times\cos15.25^\circ =3\div11\]
\[=0.145\text{ m/s lead}\]

Angle \(\gamma = 15.25^\circ\)

\(V_1 = \text{pitch line velocity of rack}\)
\[= \pi d_1 n_1\div(60\times1000)\]
\[= \pi \times 55 \times 50 \div(60\times1000)\]
\[= 0.1439\text{ m/s}\]

\(V_2 = \text{rack speed(rpm)}\times\text{lead} \div(60\times1000)\)
\[= 50\times(2\pi \text{ mx})\text{ or } zpa \div(60\times1000)\]
\[= \text{0.03 m/s}\]

Since \(V_2 = 0.03 \text{ m/s} < 3 \text{ m/s}, \text{kd}=1\)
\([Mt]= k.kd.Mt\]
\[= 1\times1\times229\times10^6\]
\[= 229\times10^6 \text{ Nm}\]

Determination of Induced Stress:
\(\text{Bc} = 540\times(z\div q)v\left[\frac{(z\div q)+1}{a}\right]^2\times[\text{Mt}]\times10\]
\[= 540\times v\left(\frac{72\div11+1}{207}\right)\times 229\times10^6\]
\[= 82.5\times 1.03512\]
\[= 86.9 \text{ N/mm}^2 < \{6c\} = 159\text{ N/mm}^2\]

\(\text{Bb} = 1.9[\text{Mt}]\times m^3\text{xqyxv}\)
\[= 1.9\times 229\times10^6 \div (5\times 11\times 72\times 0.499)\]
\[= 8.808 \text{ N/mm}^2 < \{6b\} = 30\text{ N/mm}^2\]

\(Z_{eq} = z\cos^3\gamma\)
\[= 72\times \cos^315.25^\circ\]
\[= 80\]

\(y_v = 0.499\text{(for 80 teeth)}\)
Basic Dimensions:

Rack:
\[ L = (12.5 + 0.09 Z) MX \]
\[ = (12.5 + (0.09 \times 72)) \times 15 \]
\[ = 284 \text{mm} \]

\[ L = L + 35(\text{grinding allowance}) \]
\[ = 284 + 38 \]
\[ = 319 \]

Number of Threads on Rack
\[ = \frac{L1}{\pi \times 5} \]
\[ = \frac{319}{\pi \times 5} \]
\[ = 21 \]

Actual Length of Rack
\[ = 21 \times \pi \times 5 \]
\[ = 330 \text{mm} \]

Pitch diameter of the rack = 55 mm

Tip diameter \( da = d1 + 2mx \)
\[ = 55 + (2 \times 5) = 65 \]

Root diameter \( df1 = d1 - 2mx - 2c \)
\[ = 55 - (2 \times 5) - 2 \times (0.3 \times 5) \]
\[ = 42 \]

Design of Pinion

Face Width of the Pinion
\[ b = 0.75 \times d1 \]
\[ = 0.75 \times 55 \]
\[ = 42 \]

Pitch circle diameter of pinion, \( d2 = zmx \)
\[ = 72 \times 5 \]
\[ = 360 \text{mm} \]

Tip diameter of the wheel, \( da2 = (z+2) \times 5 \)
\[ = (72 + 2) \times 5 \]
\[ = 370 \text{mm} \]

Maximum pinion diameter \( de2 = da2 + 1.5mx \)
\[ = 370 + (1.5 \times 5) \]
\[ = 378 \text{mm} \]

Root diameter of the pinion
\[ df2 = (z-2) \times 5 \times 2 \times 0.3 \times 5 \]
\[ = 347 \text{mm} \]

Specification of Rack:
- Material: Cast iron
- Module: 1.5 mm
- Cross section: 58x25 mm
- Teeth on the rack is adjusted for
  86 mm

Specification of Pinion:
- Material: Cast iron
- Outside diameter: 58 mm
- Pitch circle diameter: 55 mm
- Circular pitch: 4.7 mm
- Module: 1.5 mm
- Pressure angle: 21°

Addendum = 1.5 mm
Dedendum = 1.8 mm
Circular tooth thickness = 2.35 mm
Fillet radius = 0.45 mm
Clearance = 0.375

VII. CONSTRUCTION

The hydraulic hook bending machine consists of the following parts:

7.1.1 Cylinder
Cylinder holds the hydraulic fluid inside it. It has a piston which in turn is connected to the piston rod. This moves up and down as hydraulic force is applied on the piston. The piston rod holds the punch which bends the hook.

7.1.2 Jigs
There are two jigs used in the machine. The first jig is used to hold the bar properly. It has a hole bigger than the size of rod. The red hot bar from the furnace is properly inserted in this jig. Here it is bent slightly. The second jig is of the shape of the hook. A small curvature of the hook is given to this jig, so when the hydraulic force is applied the hook gets the required shape.

7.1.3 Frame
The frame holds all the components of the hydraulic press. It is rigid enough to withstand the hydraulic force on the hook. It consists of columns and horizontal bars to support the structure. It is made of mild steel material.

7.1.4 Punch
It is conical and rectangular in shape, joint together to exert a uniform load on hook. It is made of material En 31.

7.1.5 Rack and pinion mechanism
The half part of the hook is bend on the rack and pinion arrangement provided separately. Hydraulic force moves the rack to and fro which in turn rotates the pinion. As the pinion rotates a circular plate which bends the hook.

Figure 1. Press Assembly
WORKING

The bar of the required length will be heated in furnace up to 800 to 900 degree Celsius at which it gets into red hot state. Such bar is then taken on the jig manually with the help of holding device. Then on press the punch will get pressure from the cylinder so the resulting force will directly act on the bar which is placed on the jig exactly below the punch. The bar is kept over the curved shape on which it gets curved through required dimensions as a result of force through punch. This half curve bar will be moved to the next step of machine i.e. on rack and pinion bending mechanism on which it is placed over a circular plate jigs. The twisting force will act on that bar through the rotation of round plates due to movement of pinion. As a result of which bar will get full curve. Then that hook will be cooled by natural air flow. By this way hook manufacturing will take place.

CONCLUSION

By use of hydraulic hook bending machine the hook can be manufactured with more accuracy and has uniform stress distribution with increased life. All the problems we face in manual hook bending are completely eliminated. This enables mass production and increased profit.

REFERENCES


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