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Design and Development of Copper Coil Leg Bending and Flatenning Hydraulic Machine

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ABSTRACT: *In various households and industries, the miniature circuit breaker (MCB) is used for preventing damage of equipments from excess current or abnormal conditions. For a particular requirement from a company, the coil leg is needed to be bent a flattened so as to fit in the MCB assembly. It is basically simultaneously bending and flattening the copper coil leg in the specific angle and dimension respectively resulting in the reduced spring back action. In the present investigation, the hydraulic press tool was designed and developed by various researchers for their respective applications. Using the concepts of mechanics and design of machines, a hydraulic bending and flattening machine is created according to the copper coil drawing. Also manufactured the auxiliary and supporting structures to help and absorb the impact of the load. Through various trials and discussions, the machine is made such that the bending and flattening process is within the tolerance limit calculated through the measuring instruments. It was observed that the simultaneous bending and flattening significantly reduces the processing time and increases productivity.*

Keywords*: Hydraulic Press Tool, Bending, Flattening, Copper Coil Leg, Miniature Circuit Breaker (MCB)*

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I. INTRODUCTION

Miniature circuit breaker (MCB) is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current from an overload or short circuit and represented in fig. 1.. Its basic function is to interrupt current flow after a fault is detected. This is where the solenoid coil also known as copper coil comes into the frame. It is also called as tripping coil as it breaks the contact when it detects any faulty current. It is key element in the tripping mechanism and thus it protects the cables and wires from the excessive temperature rise and destruction. [1]

During the industry survey, it was observed that different MCBs have different tripping coil. The survey reveals that, there is different design of tripping coil which needs modification and some processes for it to be assembled in the MCBs. As there is mass production of the MCBs in many industries, it is required to design and develop a press tool that modifies the coil leg and also reduces the spring back action. Further study indicates that the need of industry was to bend and flatten the copper coil legs simultaneously according to customer requirement. Also, the simultaneous action of the machine is a must as it reduces time and efficiency of the work, which with different machines for the two processes is not possible.

Also, because of the PLC controller the human element is minimal hence the errors are almost zero.

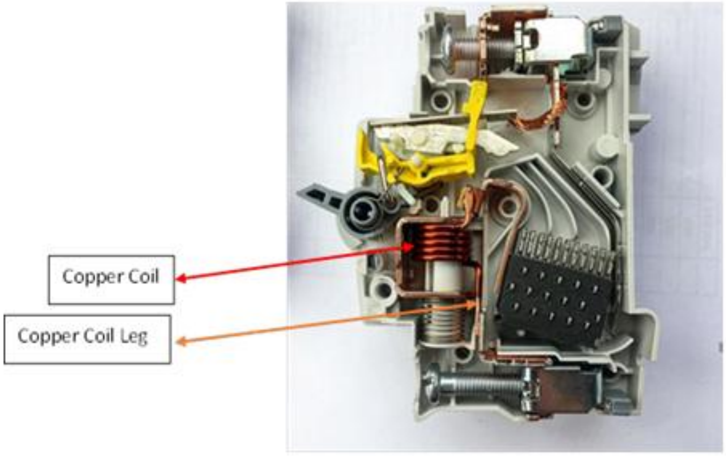

Fig. 1 Miniature Circuit Breaker (MCB) [1]

Considerable research has been carried out to design and development of hydraulic power press machines for various applications.Dong Yude [2] have done the research and implementation of parameters systems for small or medium sized four column hydraulic press design. Jason Gu [3] described the design and experimental implementation of a control system for hydraulic press machine for brick production lines. The overall operation and control was based on a programmable logic unit. ZHANG Merg [4] have proposed simulation based dynamic analysis method to analyse the response of forging press machine. The simulation results have shown that the flow of the hydraulic cylinder is affected by the back pressure value of the system. HUANG Changzheng [5] have established 300MN die forging hydraulic press, dynamics mechanical hydraulic coupling model of moving beams drive system and moving beam displacement with analytical method based on the composition of moving beams drive system. Juan Ruan [6] presented a new incremental bending process for manufacturing metal plate based on minimum energy principle and dieless forming. The results show that the desired shape can be obtained by appropriate punch path and support mode. Evegeny V. Vasilyev [7] explained the method of flattening of diamond wheels for processing of high precision hard alloy products.

The aim of this research work is to design and develop a hydraulic press machine which can perform bend and flattens the coil leg simultaneously without any breaking stresses induced.

II. Design And Development Of Hydraulic Machine

Based on the customer's prerequisite, a machine was to be designed that bends and flattens the coil leg according to the dimensions. So the process started with the detail study of the coil leg dimensions. Also material and mechanical properties like yield strength, ultimate tensile strength, density, etcetera to evaluate all the resistant forces that will need to tackle so that the required operation is performed in order to get proper dimensions of the coil leg.

2.1 Parts Description

The table 1 below consists the various parts which are included in the final assembly of the hydraulic machine.The three dimension cad model of hydraulic press machine is shown in the fig. 2

Table 1: Parts of assembly

Sr.No	Part	Material	Qty.
1	Base Plate	MS	2
2	Bend die	EN-31	1
3	Cam follower plate	D2	4
4	Coil Resting Plate	OHNS	2
5	Flattening Cam Plate	D2	4
6	L-Brackett	MS	1
7	Mounting Plate	EN-8	1
8	Vertical Mounting Plate	EN-8	2
9	Cylinder Resting Plate	EN-8	1
10	Dovetail Base Plate	EN-31	2
11	Dovetail Guide Plate	EN-31	4
12	Dovetail Moving Plate	EN-31	2
13	Slider	WPS	1
14	Slider Guide Blocks	WPS	2

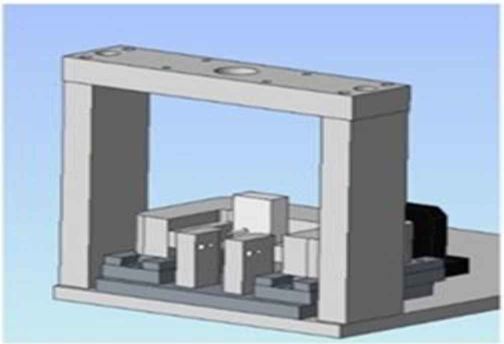

Figure 2: Complete Press Tool Assembly(3D)

2.2 Force Calculations

It is an important step as the coil leg needs precise force for the bending and flattening to avoid breakage or more deformation than required. So, it is important to know the exact bending and flattening force.
Firstly, we need to find the bending force,
But before that development length is to be calculated
Le = Development Length
a = Length of Leg = 17 mm, q= Correction Factor = 0.9, θ = Bend Angle = 45^o
S = Material Thickness = 3 mm

$L_e = a+(R+q\times s/2) \times (\pi \times \theta/180)$ [8]
$= 17 + (3 \times 8 \times 0.9/2) \times (\pi \times 45/180)$
$= 17 + (3 + 1.35) \times 0.785$
$= 17 + 4.35 \times 0.785$
$L_e = 17.3914 \approx 20$mm
Bending Force is to be calculated by P = Bending Force
C = Co-efficient = 2

B = Bending Line Length (mm) = 3 t = Plate thickness (mm) = 3
T_s = Tensile strength (N/mm^2) = $250N/mm^2$
$P=C\times B\times t\times T_s/L$ [8]
$=2\times 3 \times 3 \times 250/20=900$ N
Then, the flattening force needs to be calculated,
Volume is constant throughout the flattening process before flattening cylinder =
After Flattening Cuboid Volume of Cylinder = Volume of Cuboid
$\pi\times r^2\times h=l\times b\times h$ [8]
a) Where,
r=radius of cylinder=1mm, l= length of cuboid, = 17mm, h=height of cuboid = 3 mm
To find,b= Breadth of cuboid $\pi\times$ (1)2$\times$h= (l$\times$b) $\times$3
L= 17 mm, b= 2.35 mm
Force calculation for Flattening
σ_c= Fc/A
σ_c= Compression Stress
A = Cross-section area of the Compressed Wire = 40 mm^2, Fc = Flattening Force
$U=1/2\times\sigma \times \sigma$ = Stress
=Strain of the Wire =Change in Length/Original Length =2
U=Ultimate Tensile Strength = 220 Mpa
$\sigma_c= 2 \times 220/2$
=220 Mpa

As this is the maximum stress applied on the object Factor of Safety has to be considered. The factor of safety for the following operation can be considered as 2.5.

FOS= Maximum Stress / Applied Stress
$2.5 = 220 / \sigma_c$

$V\sigma_c$= 88Mpa
F_c = 88×40 = 3520N

As there is slider mechanism to be used. To compensate for the friction of the guideways and the slider, take the force 20% higher than the compression force.

F=1.2×3520= 4224 N

2.3 Selection of Power Pack:

While selecting the power pack there are many considerations like the cost, required force and pressure developed, wear and the overheating of oil. So through considering all the factors power pack was choose.

Given

Bore Diameter (D) = 50 mm Rod Diameter (d) = 36 mm
Assume, Pressure (P) = 70 bar, Velocity of Stroke (V) = 0.05 m/s

To Find

(i) Force at Extension Stroke(F), To Select Auxiliary Components

To find the auxiliary components required, Pressure during extension stroke (P_e) Discharge during extension stroke (Q_e) Discharge during retraction stroke (Q_r)

Solution

(i) Fe =P×A
$= P \times \pi/4 \times D^2 = 70 \times 105 \times \pi/4 \times (0.05)^2$
= 13.75KN ≈ 14KN
Fr = P × (A−a) [9]
$= P \times \pi/4 \times (D^2 - d^2) = 70 \times 105 \times \pi/4 \times (0.052 - 0.0362)$
= 6.61KN ≈ 7KN

(ii) P_e=F/A= 14 × 103 × 4/π × (0.05)=71.30bar
Q = A ×V
$= \pi/4 \times D^2 \times V = \pi/4 \times (0.05)^2 \times 0.05 \times 60000$
= 5.89lpm
Q_r= (A −a) ×V [9]
$= \pi/4 \times (D^2 - d^2) \times V = \pi/4 \times (0.05 - 0.036)^2 \times 0.05 \times 60000$
= 3.612lpm
Vane Pump P2 is selected, Maximum discharge at 0 bar=12.9 lpm[9]
Selection of tank= MaximumDischarge×3= 3 × 12.9= 38.9lpm
Tank T1 is Selected.
All components which are selected are shown in table 2.2.

Table 2: Cylinder components and model

Component	Model
Pressure Gauge	PG1
Relief Valve	R3
Flow Control Valve	F4
Direction Control valve	D1
Check Valve	C1

Now, after the selection of the power pack, the important step is to set the pressure of the cylinder as per the required force. If not done the force exerted on the coil will be more or less and the proper dimension will not be achievable.

To calculate the Pressure of Hydraulic Cylinder that needs to be set for the Bending Operation.
P = F/A
$=F\times4/\pi \times (D)^2 = 900\times4/\pi \times (0.05)^2$
=4.583 bar ≈ 5 bar

The Pressure that needs to be set for the Bending operation is 5 bar.

To calculate the Pressure of Hydraulic Cylinder that needs to be set for the Flattening Operation.
$P = F/A$
$=F\times4/\pi \times (D)^2=4224\times4/\pi \times (0.05)^2$
$=21.51$ bar ≈ 22 bar.
The Pressure that needs to be set for the Flattening operation is 22 bar.
Photograph of assembly of hydraulic press machine is shown in the fig. 3

Fig 3: Photographs of Assembly of Manufactured Machine.

III. Trials And Discussions

The process of bending and flattening begins with mounting the coil on base plate and after that there is a simultaneous operation takes place which bends and flatten the coil. While these operations are running there are certain tolerances which have to be considered, such as for bending of the leg the allowable tolerance should be ±1 degree and for flattening there is a tolerance of 0.05mm. With the help of the simultaneous operation, the process time is 14 seconds as opposed to the 28 seconds needed for the operation when the bending and flattening is done separately in the 2 machines.

Inspection of the coil was carried out to check the quality of the product obtain. This inspection is carried through Rapid I Profile Projector Software foe bending angle. Flatten leg is checked through the Vernier caliper. Random product is selected to inspect the quality. In this way, the quality of the product is checked.

A press tool operated on a power press is subjected to continuous reciprocating motion which causes compressive and tensile forces on the tool. For this, the alignment and for carrying capacity must be proper. For checking these parameters, it is necessary that press tool should be tested to give the required productivity. Tool Trial Run and Production Trial Run are the types of tool testing.
The bending and flattening of the coil is shown in the fig. 4

Fig. 4: Coil before and after operations

IV. CONCLUSIONS

Following are the generic conclusions have been drawn from the present work are given below.

1. The industrial survey reveals that the different design of tripping coil which needs modification and some processes for it to be assembled in the MCBs. The industry required a machine which performs simultaneous process of flattening and bending of copper coil leg.
2. The literature review indicated that considerable research has been carried out to design and development of hydraulic power press machines for various applications.
3. Hydraulic press machine for bending and flattening of copper coil leg is designed and developed.
4. From the trials it was observed that, the tolerances for bending and flattening operations are within limits as per the customer's requirement.
5. It is also observed that the process time required for the operation is now reduced up to half of the previous process in which bending and flattening was carried out separately.

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