Investigation of Hot Piercing method for manufacturing of conveyor chain link of bagasse carrier of the sugar industry to enhance the breaking load

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Abstract. A chain is the most crucial element of sugar industry required for transmitting power and conveying of sugar cane, sugar & bagasse, etc. As these chains operate under various forces, failure of chain assembly is the major problem. The main cause of this failure is ineffective manufacturing processes like cold piercing method. The bearing length of the conveyor link hole is lesser (approx 33% straight and the remaining 67% taper). The breaking strength is directly proportional to the bearing length of the conveyor chain link hole. Therefore, the bearing length is always desired higher. Only a few studies report in the literature related to the effect of bearing length on braking load. Thus, there is scope for work. This work is focused on hot piercing of the conveyor chain link of bagasse carrier to enhance the breaking load by increasing the bearing length of the pierced hole. It is carried out by varying heating temperature of chain link from 650°C to 850°C with an interval of 100°C, by keeping variable clearance between punch and die. The bearing length is measured by using a Coordinate Measuring Machine (CMM). The comparative analysis is carried out for bearing lengths obtained at the cold condition and three hot conditions at temperatures 650°C, 750°C, 850°C, respectively. The higher bearing length required for enhancing the breaking strength of the conveyor chain is predicted as an outcome of the study. This study is useful in Conveyor Manufacturing Industry.

1. Introduction
Failure of the conveyor chain can occur because of varieties of reasons. Still, majority of them can ultimately be attributed to defects of various stages of manufacturing the conveyor chain component [1]. Conveyor chain having several joint each joint subjected to tensile loading under working conditions. Each joint is an assembly of inner plate, outer plate, bush, pin and rollers. Breaking load of the conveyor chain usually is 8 times of working load. This braking load depends upon shear and bending stresses of the pin in the conveyor joint and minimum cross-section of the inner link plate of the conveyor. Pin in the joint has been fitted in outer link plate having holes which are pierced by press tool. So as per the basic principle of the piercing hole by press tool, the penetration of the punch 1/3 thickness of the conveyor link plate and after that remaining portion of the plates will get a
fracture. This fracture length is depending upon clearance between punch and die. It is expected to make a straight fracture in the link plate to increase the bearing length of the hole. More bearing length more accurate pin can fit in the link plate. Because of this, there is less bending stress, and hence it will help to increase the breaking load of the conveyor chain. In cold working piercing, there is the optimum clearance between punch and die. If this clearance is reduced, then either punch or die will get cracks. In mass production, it is not affordable. So, it is expected with minimum clearance between punch and die. To get more bearing areas in the holes, it is only possible in hot piercing [2-5]. Various researchers have reported studies related to conveyor chain link. Sujata et al [1] reported a case study for failure analysis of conveyor chain link. The cause of the was determined as material processing.

From the above-reported literature, it is noted that very less work has been reported on the piercing process for carrier conveyor chain. So, there is a scope for employing a hot piercing method for fabrication of carrier conveyor chain. This work presents manufacturing of bagasse carrier conveyor chain for sugar industry application. The analysis of bearing length and breaking load is also performed.

2. Experimental Setup

2.1. Mechanical Power press for piercing operation
Need of mechanical power press, for piercing conveyor link plate by using press tools. This press machines having capacity 60 tons, 25 mm stroke length and 300 mm shut height. With proper table face for fitting press tools on the machine table.

2.2. Design and manufacturing of press tool
As per table 1, various sizes of press tool elements have been calculated, which are dependent upon cutting force required for piercing holes of conveyor chain link plate.

| Parameter                  | Value/Size   |
|----------------------------|--------------|
| Cutting force              | 59.66 tons   |
| Clearance                  | 0.6 mm       |
| Punch Size                 | 25 mm        |
| Die Size                   | 25.6 mm      |
| Stripping Force            | 29.83 tons   |
| Clamping bolt              | M14x2 (4 no.)|
| Die thickness              | 40mm         |
| Die Length                 | 262 mm       |
| Die Width                  | 90mm         |
| Punch Holder size          | 20x90x262    |
| Stripper size              | 20x90x262    |
| Backplate                  | 10x90x262(2no.)|
| Bottom plate               | 60x190x362   |
| top plate                  | 60x190x362   |
| Punch                      | Dia34x70     |

2.3. Material required for press tool
While selecting the press tool materials, there is a need to consider properties like dimensional stability, damping, wear-resistance and suitability of heat treatments [2-5]. Accordingly, suitable material has been selected, and details of the same have been shown in Table 2.
Table 2. Selected Material and Hardness for press tool

| Sr. No. | Particular   | Material | HRC  |
|---------|--------------|----------|------|
| 1.      | Die          | HCHCR    | 58-60|
| 2.      | Punch        | HCHCR    | 58-60|
| 3.      | Stripper     | OHNS     | 35-40|
| 4.      | Punch Holder | EN 31    | 35-40|
| 5.      | Back Plate   | OHNS     | 30-35|
| 6.      | Top and bottom plate | M.S | Nil  |

2.4. Material selection for conveyor link plate.
While selecting the material for the conveyor link plate, there is a need to consider Mechanical Properties like tensile strength, excellent wear resistance, good shock-absorbing capacity [4]. By considering these properties, the material has been selected as per B. S. 970 which is shown in table 3.

Table 3. Selected Material for conveyor link

| Material | Tensile (kg/mm²) | Yield (kg/mm²) | Elongation (mm) | BHN | Composition                          |
|----------|------------------|----------------|-----------------|-----|-------------------------------------|
| EN 24    | 75               | 57             | 20              | 270 | C- 0.35-0.45, Si- 0.1-0.35 Si, Mn- 0.45-0.70, Ni- 1.32-1.8, Cr- 0.9-1.4, Mo- 0.2-0.35 |

2.5. Conveyor link data
Based on conveyor capacity and required breaking load of the conveyor chain, various specifications have been indicated in Table 4.

Table 4. Specifications of bagasse carrier chainplate

| Sr. No. | Particular   | Value           |
|---------|--------------|-----------------|
| 1       | Plate size   | 225 x 65 x12 mm|
| 2       | Hole Size    | Dia 25 mm       |
| 3       | Pitch        | 150 mm          |
| 4       | Material     | EN24            |
| 5       | Hardness     | 30-35 HRC       |

2.6. The cold piercing operation for conveyor chain link.
After design and manufacturing of press tool assembly, it has been fitted on mechanical power press having capacity 60 tons and stroke length 25 mm. And operation of piercing started on the conveyor link plate. As shown in figure. 1 (a, b) pierced plate holes has been inspected by the coordinate measuring machine. It has been observed that one side of the hole that is called punch entry the hole inside edge is straight up to 4 mm and after that remaining portion of the link plate is fractured that means one side hole size is diameter 25 mm, and the opposite side is 25.7 mm. so it is expected to reduce the size 25.7 mm and make it as possible as close to diameter 25 mm by decreasing the clearance between punch and die and optimum temperature for hot piercing.
2.7. The hot piercing operation for conveyor chain link.

It is carried on the same mechanical power press with the same press tool by changing clearance between punch and die. For hot piercing, we have selected clearance between punch and die half of the cold piercing, i.e. 0.35 mm. That means punch size diameter 25 mm and die size is 25.35 mm. as shown in below Figure 2 (a, b). Like this way, it has been pierced 4 plates, and its hole sizes have been measured with different temperatures, and it will lead to the results.

| Cycle Stages     | Temperature (Degree) | Time (Min) |
|------------------|----------------------|------------|
| Preheating       | 650                  | 60         |
| Heating          | 850                  | Starting   |
| Soaking          | 850                  | 90         |
| Oil quenching    | 20                   | 30         |
| Tempering        | 550                  | Starting   |
| Soaking          | 550                  | 90         |
| Cooling          | At Room Temp.        | 30         |
2.8. Heat treatment of the conveyor chain.
After piercing all samples, plates have been heat-treated by through hardening process. And pin bush rollers have been heat-treated by case hardening process [6]. Related brief data of heat treatment has been given in Table 05.

3. Testing and measurements.

3.1. Estimation of bearing length of the hole.
This is performed by Coordinate measuring machine (CMM) as shown in below Figure 3 and the result has been noted in Table 6.

![Figure 3. Testing of bearing length of link plate hole by using CMM](image)

3.2. Checking of the breaking load of the conveyor chain.
Checking of the breaking load of conveyor chain assembly is done by ultimate tensile testing machine with special fixtures mounted on the two machine jaws as shown in figure 4(a) having UTM Control unit as presented in figure 4(b) and reading has been noted in Table 6.

4. Result

![Figure 4. (a) UTM setup (b) UTM control unit](image)

4.1 Comparison between Cold Piercing and Hot Piercing:
It is observed in Table 06, for cold piercing breaking load is lesser as compared to hot piercing.
Figure 5 and 6 depict the breaking load for the average length of bearing area for cold and hot piercing, respectively. The trend of the breaking load increase for cold piercing is in good agreement with that for hot piercing. Also, the length of the bearing area is observed to be lesser for cold piercing as compared to hot piercing.

By using Coordinate Measuring Machine (CMM), bearing length of the hole of the chain link plate has been measured. And after assembly of conveyor, the breaking load has been tested on UTM for the chain links manufactured by cold piercing and hot piercing.

Table 6. Breaking load and Average length of bearing area for cold and hot piercing

| Operation          | Conveyor link plate temperature (°C) | Breaking Load (KN) | Average Length of Bearing Area (mm) |
|--------------------|--------------------------------------|--------------------|-------------------------------------|
| Cold Piercing      | Room Temp.                           | 650                | 3                                   |
| Hot Piercing       | 650                                  | 687                | 3.5                                 |
| Hot Piercing       | 750                                  | 689                | 3.7                                 |
| Hot Piercing       | 850                                  | 686                | 3.6                                 |

Figure 5. Average Length of Bearing Area (mm) Vs Breaking Load (KN) [Cold Piercing]

Figure 6. Average Length of Bearing Area (mm) Vs Breaking Load (KN) [Hot Piercing]
4.2 Effect of temperature in Hot Piercing:
From Table 6, it is observed that the breaking load increases with increase in temperature from 650 ºC to 750 ºC and then decreases to a further rise in temperature up to 850 ºC. The similar trend is also observed for the average length of the bearing area. This is presented in Figure 6.

5. Conclusion
The bagasse carrier conveyor chain link was manufactured by employing a hot piercing method to enhance the breaking load. The hot piercing was performed at three temperatures from 650°C to 850°C with an interval of 100°C, by keeping variable clearance between punch and die. The bearing length and the breaking load were analyzed. Comparative study for cold piercing and hot piercing is reported. Based on the work, the following conclusions are drawn:

- The breaking load and average length of bearing area are observed lesser for cold piercing as compared to hot piercing.
- The bearing length and the average length of bearing area increases with increase in temperature from 650°C to 750°C and further decreases with increase in temperature up to 850°C.
- The maximum bearing length is noted as 3.7 mm and breaking load as 689 KN at the temperature of 750 ºC.

This study is useful for Conveyor Manufacturing Industry, especially for Sugar industry-related applications.

References

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