Abstract— Work on straightening machine is carried out at JINDAL SAW LTD. The machine consists of six-rolls with individual feed mechanism for each roll. The capacity of machine is to straighten the tubes of diameter 33mm to 216mm. The machine is manufactured in house at US plant and imported to Nasik plant. The problem arising in the machine is the tubes below 88.9 mm were not being straightened on the machine and the tubes were damaged after passing through the rollers. On initial study it is found that the center of the pin & rollers are not aligned. Hence after aligning centerline of pin & roller, it is observed that pin hole in the base plate is eccentric. An eccentricity can be overcome by machining the base plate by dismantling the complete machine. The process of reworking is very cumbersome, costly & time consuming. So an eccentric center pin is designed to match the centers of upper roller and bottom roller which can apply required pressure to straight the tube while passing through rollers. The designing of pin involves selection of material for pin, deciding dimensions after measurement of actual eccentricity & calculating stresses for each selected material.

Keywords— Straightner Machine, Design of Centre Pin

I. INTRODUCTION

Jindal SAW manufactures SAW Pipes (Submerged Arc Welded Pipes) and spiral pipes for the energy transportation sector, carbon alloy and seamless pipes and tubes for industrial applications and ductile iron (DI) pipes and fittings for water and wastewater transportation. There domestic and exports markets are well balanced and businesses operate through four strategic business divisions including SAW Pipes, DI Pipes & Fittings, Seamless Pipes & Tubes and Mining & Pellets.

The tube straightener machine is situated in the PQF mill which is known as hot mill. The machine is six roll type machine with individual shaft input. The machine is manufactured in-house at the US plant and imported to Nasik plant.

The straightening machine is used for straightening of High Pressure Tubes, which are utilized in high pressure application. During the manufacturing of pressure tubes the last and important process is straightening. The six-roll machine became the standard for modern tube straightening. The machine consist of three pairs of vertically opposed rolls, and rolls are individually driven by motors attached to synchronization unit. The rolls grip the tube and rotate it while feeding it through the machine until the entire length has been straightened. Continuous force is essential for obtaining uniform pressure load on all three rolls which can otherwise lead to strain hardening and alter mechanical properties of tubes. After studying forces acting on various components and measuring the standard parameters of the machine the bottom base plate was selected for the modifications in which the holding pin was modified. Three eccentric pin was designed as per required eccentric distance to match the centre of upper roller and bottom rollers.
II. PROBLEM STATEMENT

The problem arising in the machine is the tubes less than 88.9mm are not getting straight on the machine due to less contact area between roller & tube. Even after multi-pass the bend from the tubes is not removed.

The tube while passing through the straightener machine get stuck in rollers causing hitch to the next passing tube and resulting to stop the machining process.

While passing the tube through the machine it is not covering/matching to top & bottom roll profile while pass. The tube is damaged due to Piching & abrasion on tube surface, which results in rejection of tube.

Reasons of Tube Bending
A. The bend in the tube is generally formed in the manufacturing process due to the shrinking phenomenon of the material.
B. The another reason for the bending is the varying temperature of the pipes throughout the manufacturing process results in continuous changing in stresses in the tubes.

III. OBJECTIVES

- To stabilize the straightening operations.
- To reduce down time caused by machine.
- To achieve tube straightness up to required accuracy.
- To reduce tube damage.

IV. METHODOLOGY

Finding out solutions for following root causes:

During shifting of straightening machine from one plant to another plant, also during reinstallation of machine at Sinner plant due care was not taken & there were misalignment of roller
center & bottom pin occurred which results into uneven distribution of pressure on pipe & malfunctioning of machine.

Pipes are not easily conveying & straightening through straightener machine.

Auto sequence of the operation gets disturbed, when pipe hold & which creates cobble to next multiple piece.

Due to limitations in process parameters, Straightness & flexibility of pipes are not controllable.

While conveying of pipe it create damage on pipe surface & pipes are rejected.

Servo motor brake problem if occurs, no option except to stop the mill.

**IV. STUDY AND MODIFICATION**

A. **Centre Column**

The centre column disassembled is being checked and found the key way slot to be wear. The reason for the wear is the tube with bigger diameter is being passed through the rollers and the corresponding distance between the bottom and upper rollers was comparatively small than the diameter of the tube. The column is subjected to be metalized or being replaced by the new one.

![Fig. B - Assembly of Centre Column](image)

B. **Centre Hub**

The centre hub to which the hydraulic lifting mechanism is connected is disassembled. The slot in which the centre column is moved is checked and found to be according to specifications.

C. **Screw Jack Mechanism**

The main screw shaft of the machine is found to be damaged due to impact loading of the tube within the roller. The damaged screw jack mechanism does not have any effect on the tube straightening process. The lifting mechanism is being replaced by the hydraulic lifting mechanism by the company which helps the column to be lifted and lowered as per required distance in the upper and bottom roller to pass the diameter with various diameters.

D. **Gears of Reduction Gear Box**

The reduction gear box was dismantled to check the gears in the gear box and the gear found to be according to specifications.

E. **Roller Roll Profile**

The working roller profiles were checked by using various measuring instruments like vernier caliper, outside caliper, micrometer. The profile found to be according to the required dimensions. The roller profiles are found to be correct since the tubes with diameter above 90mm are properly straightened in the machine.
F. Checking of Centre Distance of Pin & Roller Centre

The distance between the roller centre and pin is checked and found to be varied which can be the major concern for the tubes not getting straightened on the machine. As the centre is not aligned the pressure which is required to straighten the tube is not applied due to eccentricity of the pin.

V. EXPERIMENTAL DESIGN

The below diagram shows the eccentricity of the upper and bottom roller which is found to be as follow:
Roller 1: Eccentric by 12MM from upper roller. Found 9mm eccentric by centre line of other two rollers. 7MM eccentric by supporting column. The bottom supporting base found to 54° eccentric which results in jamming of tube.
Roller 2: Eccentric by 6MM
Roller 3: Eccentric by 5MM
VI. SUGGESTED MODIFICATIONS

As calculated from the above experimental design the roller centres of the top and bottom rollers which should be aligned through same pass line is varied at all the rollers. As the centre of the rollers is not in same pass line of the pressure point which is required to straighten the tube. The required centre point can be aligned by shifting the bottom roll which is mounted on the base plate which is holded by the holding pin. So by designing the eccentric pin as per required distance that the roll can match the centre point the above problem can be rectified.

**Design of Pin**

![Fig. F- Modified Eccentric Pin](image)

![Fig. G - Catia Models for Eccentric Pin](image)

G. Calculations For Pin:
CONSIDERING MAXIMUM FORCE ACTED BY ROLLER = 4000Kg.(COMPANY DATA SHEET)

VERTICAL FORCE ACTED BY ROLLER:

\[ F_V = m \times g \]

= 4000 x 9.81
= 39420 N

HORIZONTAL FORCE ACTED ON PIN:

\[ F_H = 2 \times \mu \times R_N \]
\[ \mu = 0.48 \]
\[ F = 2 \times 0.48 \times 39420 = 37843.2 \text{N} \]

SHEAR FORCE CALCULATION ACTED UPON PIN:

\[ \tau = \frac{F}{A} \]
\[ F = \tau A \]
\[ A = \frac{\pi}{4} \times D^2 \]
\[ A = \frac{\pi}{4} \times 100^2 \]
\[ D = 100 \text{mm} \]

\[ A = 7853.98 \text{ mm}^2 \]

\[ \tau = \frac{37843.2}{7853.98} \]
\[ \tau = 4.81 \text{ N/mm}^2 \]

II. Selected Materials for Pin Manufacturing:

Table-I

<table>
<thead>
<tr>
<th>I. Fe290:</th>
<th>YIELD STRENGTH</th>
<th>TENSILE STRENGTH</th>
<th>ELONGATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>255</td>
<td>410</td>
<td>22%</td>
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</table>

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<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>N</th>
<th>P</th>
<th>S</th>
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</thead>
<tbody>
<tr>
<td>max 0.25</td>
<td>-</td>
<td>1.25</td>
<td>max 0.012</td>
<td>max 0.045</td>
<td>max 0.045</td>
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</tbody>
</table>

Table-II

<table>
<thead>
<tr>
<th>EN8 – Mechanical Properties</th>
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</thead>
<tbody>
<tr>
<td>Max Stress 700-850 n/mm²</td>
</tr>
<tr>
<td>Yield Stress 465 n/mm² Min</td>
</tr>
<tr>
<td>0.2% Proof Stress 450 n/mm² Min</td>
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<tr>
<td>Elongation 16% Min</td>
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<tr>
<td>Impact KCV 28 Joules Min</td>
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<tr>
<td>Hardness 201-255 Brinell</td>
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</table>
Chemical composition

<table>
<thead>
<tr>
<th>Element</th>
<th>Range</th>
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<tbody>
<tr>
<td>Carbon</td>
<td>0.36-0.44%</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.10-0.40%</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.60-1.00%</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.050 Max</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.050 Max</td>
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</table>

Related European grades: C45
US Grades: SAE (AISI): 1040

Table-III

<table>
<thead>
<tr>
<th>YIELD STRENGTH</th>
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<th>ELONGATION</th>
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<td>255</td>
<td>410</td>
<td>22%</td>
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</table>

I. Why EN8 is Selected?
The Eccentric pin are made of EN8 special steel that has very good mechanical properties combined with extraordinary good machinability.
Also material upper & base plate is EN8 in which pin is to be mounted. So by considering the hardness value of both, the pin and base plate, EN8 material is selected for the pin

J. Software Analysis for Eccentric Pin:

By analysis of eccentric pin in ANSYS Software it is calculated that max stress acting on pin is 20.2 N/mm² and min stress acting on pin is 0.0078095 N/mm². By analysis of colour coding we can see that max stress acting is 4.495 N/mm² throughout the pin.

<table>
<thead>
<tr>
<th>ANALYTICAL RESULTS</th>
<th>SOFTWARE RESULTS</th>
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<tr>
<td>4.81 N/mm²</td>
<td>4.495 N/mm²</td>
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</table>

The percentage deflection between the results calculated is 6.54%.
VII. CONCLUSION

It is concluded that by designing the eccentric pin the pressure point required to match of both the upper and bottom rollers is matching, resulting in proper straightening of tube. By designing the pin the shear stress acted on the pin considering maximum loading on the pin is calculated to be 15.36 N/mm². Also by designing the pin the total cost required which was estimated for total machining of the machine is saved by 96.15% and approx. 15 days was saved which were further utilized for manufacturing of tubes.

REFERENCES

[1] Metal Forming Process By: Dr. Pulak M. Pandey
[2] The Complete Technology Book on Hot Rolling of Steel By: NIIR Board of Consultants & Engineers