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Study of Crack formation on Mandrel Bar surface used in PQF

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Abstract

An investigation was carried out on the mechanism of crack initiation on a mandrel bar used for the PQF operation in seamless tube manufacturing. Close observations of the mandrel bar surface suggested that crack initiation may be induced by a thermal shock. In order to check the validity of this hypothesis, a methods was proposed to improve the mandrel bar life. The paper also covers the study of temperature of various section of Mandrel Bar and its effect.

Keywords: Mandrel Bar, PQF, thermal shock, Seamless tube, mechanism

1. INTRODUCTION

Mandrel bar plays a crucial role in producing large diameter seamless tubes in modern industries. In production line, it has to bare strong and complicate stretch, compressing touching stress and high temperature cold-hot yield stress under high speed cycling. In order to reduce these stresses lubricants are used, this stably produces a seamless steel pipe of high quality, while preventing seizing marks and internal flaws. Lubricants are intended to reduce the frictional resistance between the metal and the tool in order to reduce the amount of tool wear.

For proper lubrication to take place the deoxidation taking place at the piercing mill section itself should be of good quality. For this N_2 + borax blowing is done just after the billet is formed into a bloom through the piercing mill. This bloom is then sent to the PQF line with the help of a manipulator. The bloom and the mandrel are together inserted into the PQF where the longitudinal rolling takes place resulting in the formation of the tube to be further sized down to the desired quantity.While the mandrel enters the bloom during rolling, it under goes a large amount of stress. To avoid this and reduce its effect lubricants are used. The lubricant is sprayed onto the mandrel by a lubricating tank just before the insertion. For proper coating correct amount of temperature and viscosity should be maintained .The temperature is maintained with the help of a cooling station that is divided into 4 zones each controlled and maintained according to the required quantity of water to be poured. When each parameter is maintained according to the standard values, good quality seamless tubes are produced and the life of the mandrel is increased.

2. MANDREL BAR

Mandrel is a metal bar that serves as a core around which material (as metal) may be cast, moulded, forged, bent, or otherwise shaped

2.1 Construction of PQF mandrel bar

The mandrel bar used in PQF mill is consist of three parts:

1. Working part with nose.
2. Supporting part.
3. Tail part.

2.2 SELECTION OF HOT-WORK TOOL STEELS FOR MANDREL BARS

Mandrel bars are subjected to a wide variety of stresses. A balanced combination Of material properties is necessary in order to achieve maximum service lives, and thus a high output per mandrel bar. The key properties in this context are high temperature wear resistance and toughness. Experience in the field and consistent further development work have shown that two main material groups are most suitable for use as mandrel bars. The first one is nickel alloyed hot-work tool steels which have generally balanced properties and offer particularly advantages in terms of their toughness. The second group

Table 3. Comparison of properties of hot-work steels used for mandrel bars

Grade	Hot cracking resistance	High-temp. wear resistance	Toughness	Scale adhesion
Thyrotherm 2726	++	+	++++	+
Thyrotherm 2740	+	++	+++	++
Thyrotherm 2342	++	+++	++	+++
Thyrotherm 2343	++	+++	+	+++
Thyrotherm 2344	++	++++	+	+++

+ to ++++ (ascending)

is highly alloyed chromium-molybdenum hot-work tool steels which possess particularly good high-temperature wear resistance. The chemical composition of the hot-work tool steels used for mandrel bars is shown in Table 1.

Table 1.Chemical Composition of Hot-Work Tool Steels Applied For Mandrel Bars (wt%)

Grade	C	Si	Cr	Mo	Ni	V
Thyrotherm 2726	0.26	-	.70	.40	1.40	.20
Thyrotherm 2740	0.28	-	.70	.60	2.50	.30
Thyrotherm 2342	0.35	.8	4.75	1.0	-	.85
Thyrotherm 2343	0.38	1.00	5.30	1.30	-	.40
Thyrotherm 2344	0.40	1.00	5.30	1.40	-	1.00

3. APPLICATION AND OPERATION OF MANDREL BAR :

The mandrel bar is used in:

1) Piercing

2) Controlling inner diameter

3) Control WT (wall thickness)

3.1 Mandrel Preheating System

Before introducing in circulation a new set of mandrels.

- Mandrel Preheat to lubrication Temperature (approx.. 100˚C)

- Induction furnace is used.

- Thin layer of mandrel is heated up, lubrication is sprayed.

- Mandrel dia. range: 147.3-175.4 mm

- Mandrel length (to be preheated) = 10.7 m

3.2 Mandrel Lubrication

Lubrication is the process, or technique employed to reduce wear of one or both surfaces in close proximity, and moving relative to each another, by interposing a substance called lubricant between the surfaces to carry or to help carry the load (pressure generated) between the opposing surfaces.
Lubricant is based on an aqueous suspension of laminar graphite and is sprayed onto the mandrel while hot.

a) Effect of lubricant on life of mandrel

An effective lubrication of the mandrel bar is essential for the PQF process.

- It keeps the retainer forces low.
- It keeps rolling forces low.
- It protects the mandrel bar against damages.
- It limits friction during rolling.
- It reduces the consumption of energy,

- It gives good internal quality to finished product.

b) Powder Characteristics

- Graphite lamellar type, natural or synthetic: 75%
- Carbon contents: 94% min. by weight.
- Additives: 25%
- Humidity max: 3% by weight
- Apparent density (DIN 51705 e1305): 0.30-0.40 g/cm3

c) Lubricant ready for use characteristics

- Composition Powder: 30%
- Water: 70%
- pH value: 10.5-11.5.

Mandrel Lubrication System

The spraying system or station shall be concentric with the mandrel in order to create the best coating conditions of the sprayed on surface.

3.3 Mandrel Cooling System

a) Mandrel Cooling Times

- Cooling after rolling makes temperature fall between 90˚C and 120˚C

- Temperature favours most suitable lubrication

- After rolling, non-uniform temperature along mandrel.

- Times are adjusted so that temperature will be uniform along the mandrel length.

- Cooling tunnels are used when the production rates are higher.

3.4 Deoxidation System

From Piercer to PQF Inlet

The hollow bloom, which has been kicked out from the outlet table of the piercing onto an intermediate station for internal cleaning is transferred by a hollow bloom manipulator (overhead transport equipment) directly to the inlet side of PQF, where the mandrel is inserted. Temperature of bloom drop from 1220 to 1132 ◦C.

Composition of the deoxidizing agent

The agent is composed of (% of weight):

- Anhydrous Sodium Tethraborate ($Na_2B_4O_7$) 30-35%
- Sodium and potassium soaps 10-15%
- Sodium sulfate (Na_2So_4)

Table 2 .Types of Scale Formed 20-25%

4)FACTORS AFFECTING THE LIFE OF MANDREL

Primary scale (FeO)	Secondary scale (Fe_2O_3)	Tertiary scale (Fe_3O_4)
☐ It is black in colour, is hard and cannot be removed easily. ☐ It has to be converted into a soft substrate	☐ It also black colour and is hard ☐ At the beginning of scale development this kind of scale is sticking tight on the surface but later it develops plates that can be removed	☐ It is not developing after piercing

4.1Tag end problem

Tag end problem happens in cross rolling piercer. It occurs due to difficulty of the end portion of material to flow over the plug because of high friction forces between ID & plug itself. Strip and coin formation on the tube enhances the removal of lubricant over the mandrel surface during the insertion into the hollow bloom**.**

Fig 1. Strip and Coin Formation

4.2 Lubricant removed while mandrel insertion to the hollow in the PQF

☐ Misalignment of hollow bloom and mandrel bar during insertion results in removal of lubricant from the mandrel surface.
☐ Wearing out of the rollers on the push rod enhances the removal of lubricant.

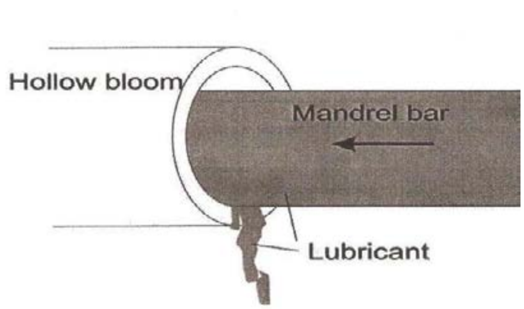


Fig 2 . Lubricant Removed While Mandrel Insertion to The Hollow in the PQF

4.3 PQF FORCES

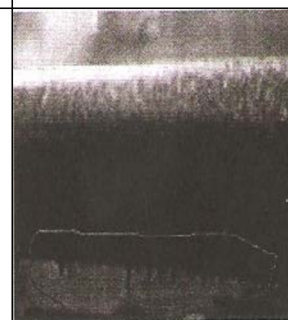
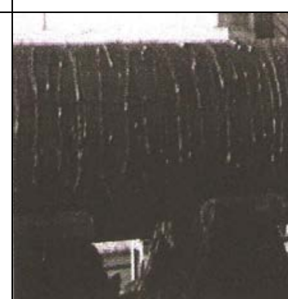
Large forces acting over the shell and mandrel bar as mentioned below for wall thickness reduction for which hot material slip over the mandrel bar. It causes surface erosion of mandrel bar.

4.4 Process Parameters

1)Temperature

For good lubricant layer, the mandrel temperature should be on a low level.

Table 3. Effect of Temperature on Lubrication on Mandrel Bar

Temperature	**Photo**	**Effects**
Low temperature		- Lubricant will not dry during cycle time. - Will appear soft and wet. - Less adhering to mandrel's surface.
High temperature		- Water in the lubricant evaporates quickly. - Formation of bubbles.
Recommended Mandrel temperature		- Uniform Coating.

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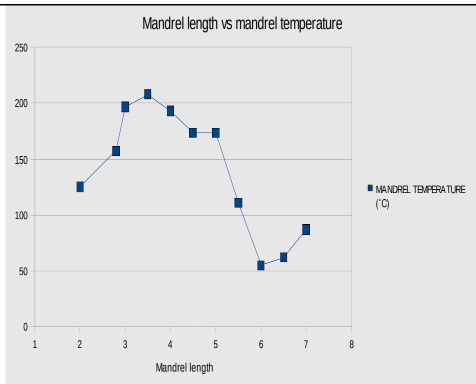
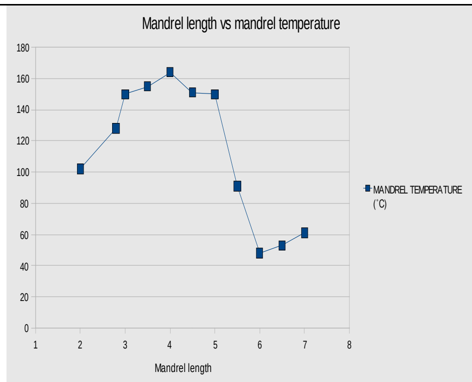
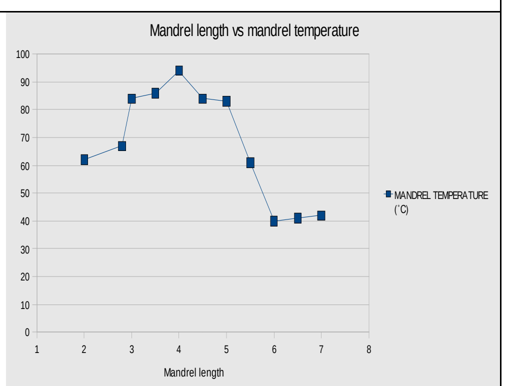
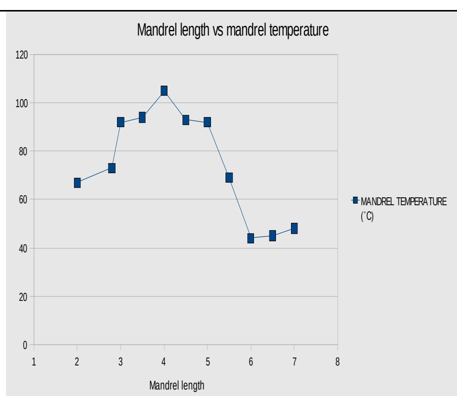
<table>
<tr><td>After Rolling</td><td>
</td></tr>
<tr><td>Before cooling</td><td>
</td></tr>
<tr><td>After cooling</td><td>
</td></tr>
<tr><td>After one minute idle rest</td><td>
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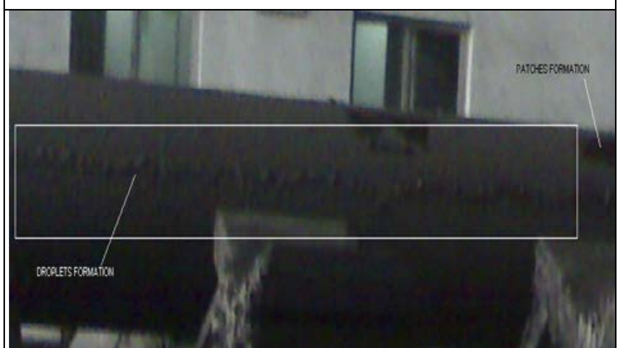
Conclusion from the Results:

- Even if mandrel stops for 1minute the heat conducts from core to mandrel surface that results in rise of temperature by nearly 8-10˚C and the temperature returns to 100-105˚C.
- The maximum temperature was observed between 3.5-4m of the mandrel.
- If the temperature is correct the mandrel looks smooth and uniform.
- If interruptions of rolling are greater than 30 minutes, all mandrel should be cooled and lubricated in normal cycle time.

Fig .5 Effect of Viscosity of Mandrel Bar

Low Viscosity



5.SUGGESTION TO ENHANCE THE LIFE OF MANDREL

5.1 CHROME REPLATING

Thereis only 45 to 55 µm thickness of chromium on the mandrel of hardness about 65 HRC which gradually decreases over the production so its hardness also decreases. After than continuous production, Overheating of mandrel bar and gas cutting of tube affect the surface of mandrel bar.so if we perform the replating , it will enhance the life of mandrel bar.

5.2 SELECTION OF LUBRICATION:

Graphite base lubrication have certain disadvantages such as carburization phenomenon which results in decrease in toughness and strength , spot welding effect occur between mandrel and shell due to which surface of mandrel suffer deterioration.So it is suggested to use gas forming additive contains at least one carbonate of at least one divalent metal, preferably an alkaline earth metal. Calcium carbonate causes the formation of a gas cushion between the mandrel and shell whereby the amount of force required for the intended shaping operation is greatly reduced. In addition calcium carbonate is very soft and in the solid condition has good polishing properties un decomposed components of calcium carbonate thus have additional separation properties which further improve the separation capability of molten phosphate and further reduce the frictional resistance between shell and mandrel. The inner surface of shell is smoothed by the polishing properties of the solid calcium carbonate without the surface of being grind or lapped with emery and without scoring and scratching occurring in that situation. Gas forming additive contained in lubricant are present in form of powder of grain size 2 to 50µm or 2 to 30µm. Gas forming additive are 5 to 50% by weight, particularly preferably 25 to 30% by weight. Lubricants contains 55 to 69% by weight of P , 14 to 45 % by weight of Na, 5 to 27% by weight of K, 10% by weight of M, where M is a divalent metal preferably Zinc, Manganese or Magnesium.[4]

5.3 POSSIBLE SOLUTIONS TO SOLVE TAG END PROBLEMS (STRIP AND COIN):

The tag end problem is a typical phenomenon of every Cross Rolling Piercer; it is mainly due to difficulty of last portion of the mandrel bar over the plug because of the high friction forces between I.D. and plug itself.

According to shape of plug and rolls, the tag end configuration can vary from a 'coin' type to 'strip or ring' type that can be detach or remain attach to hollow bloom. The tag end enters in the hollow bloom during mandrel insertion, damaging the final tube(that will be rejected) or , in the worse case damaging the mandrel . when the tag end detach from hollow bloom the problem can be limited to a more frequent maintenance operations on the piercer itself. Basically the combination of barrel type piercer with rounded plug leads to strip/rings of Cone Type rolls, and flat nose plugs with Cone Type rolls leads to'coin type' tag end even though when the plug is worn it becomes closer to rounded nose configuration and strip /ring tag end. A small change in any of the parameter (i.e. plug/rolls wear, rolling speed, steel grade ,material temperature and quality etc.) can lead to new appearance of tag ends.

The possible solution that can be adopted to solve or minimize the problem are the followings :

1. A backward movement (15-20mm)of the plug at the end of rolling process was foreseen for other purpose (compensation closed end due to very high expansion) and it was found positively effective for tag ends minimization as well.
2. Speed up of rolls motors at the end of rolling process, this could help material not to detach from the hollow bloom.

6. CONCLUSION

From this Report, We concluded that life of mandrel bar can be increase to great extent by using proper lubrication additive and performing proper repairing technique. As a result, the cost per shell get drastically decreased.

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