Improvement in New Grades of Work Roll for Hot Strip Mill Through NDE

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ABSTRACT

Due to increase in market demand and stringent quality demand of hot rolled flat product, it is very essential to increase the productivity without compromising on the product quality of hot strip mill. To increase the productivity and reduce the mill down time it is also very essential for hot strip mill to increase campaign length of rolling. To fulfill the mill requirement new grades of rolls have been developed. This development has been done through NDE like analyzing microstructure, ferritoscope value and ultrasonic testing results of previously cast rolls and new grades of rolls. These new grades of rolls will not only increase the mill productivity but at the same time also take care of the quality of the product.

Introduction

Introduction of newer grades of Steel Mill roll materials is an important activity of Tayo Rolls Limited. NDE plays a very important role in this regards.

Some of the New Grades of Rolls are listed below.

(i) **Super Nickel Grain Rolls:**

These are bimetallic roll consisting of outer layer (shell) in highly alloyed material, and inner tougher layer (core) in spheroidized graphite (SG) cast iron .These rolls are produced by centrifugal casting process. This is an improved version of normal indefinite chill double poured (ICDP) roll which is mainly used in the later finishing stand of any hot strip mill. These rolls have been developed as per mill operating parameter by evaluation of the microstructure and Ferritoscope value, and ultrasonic testing.

(ii) **High Speed Steel Roll**

These rolls are produced through centrifugal casting method and consist of three different properties metal bonded together. These are used in initial finishing stand against normal Hi-Cr Iron rolls for improved wear resistance & higher campaign length.

(iii) **Modified High Chrome Iron Roll**

These rolls are produced through centrifugal casting method and consist of three different properties metal bonded together. These are used in initial finishing stand for improved wear resistance & higher campaign length.

(iv) **Anti Fire-Crack High Chrome Steel Roll**

These rolls are produced through centrifugal casting method and consist of three different properties metal bonded together. These rolls are used in Roughing stand of any Hot Strip Mill.

Application of NDE in process modification of Work rolls used in Hot Rolling Mill

Examples of the application of NDR techniques for specific features in rolls

(i) **Detection of weak bond area at both barrel ends during pre machining stage**

All these rolls are cast through horizontal centrifugal machine. As a nature of this process all the inclusions (metallic or non-metallic) are deposited at both end of the barrel due to centrifugal force. All these rolls are made of two or three different kinds of metal, so it is very important to have a good bonding between these metals. During pre-machining ultrasonic testing (bond test) is carried out with the help of either 1, 2 & 4 MHz normal probe. By this process weak bond area's are early detected and that area may be removed (As per as cast roll dimension and actually required dimension) If there were any inclusions / defect at the interface, the defect will appear on the machine and accordingly barrel is shifted to get defect free barrel. This helps in reducing internal rejection and also sometimes prevent in further value addition.

(ii) **Evaluation of Shell Depth in double poured Roll**

In all hot strip mill a customer has specific mill requirement of working shell as per mill configuration. Working shell is the shell which is usable in the mill and after that the roll will be scrapped. During methoding roll design shell depth is calculated considering working shell depth, shrinkage & machining allowance, remelting allowances and support (extra) shell. During machining shell depth is ultrasonically tested. This process is done through 2 and 4 MHz normal probe. The interface echo coming from the shell-core interface is considered as the shell depth. By this testing procedure actual shell depth is compared with desired shell depth. It is to be noted that shell depth must be optimum so that compressive stress of shell material must balance the tensile strength of core material. Higher shell depth may lead to barrel breakage of roll during its use lower shell depth will also cause spalling of roll when it reaches to its scrap diameter. So, by applying this process this operating parameters of new grades of rolls have been optimized to get the desired shell depth for normal rolling in the mill.

(iii) **Bonding between Shell & Core material**

For double poured rolls, it is essential to make proper bonding between shell & core material. If the bonding between shell & core is weak, then there is a chance of failure of the roll during use in the mill. This is not at all acceptable. After final machining, the roll barrel is ground for ultrasonic testing. Ultrasonic testing (bond test) is carried out with the help of 1, 2 & 4MHz normal probe. NDE helps to judge the bonding between shell & core interface and optimizing the process parameters to produce a defect free roll. There are different norms for judging the bonding between shell & core. In all the norms, the objective is to ensure good bonding between shell & core. Some of the norms are illustrated below for better understanding

(a) **Cut-off dB concept:**

In this process cut-off dB (100 % back wall echo height value) is measured on a standard block made of same shell material by using normal probe on a standard block made of same shell material and that is fixed for testing the roll. Now roll is tested on a 100 mm range keeping higher dB value and interface echo is reduced to 30 % height.The norms is that at no place 30 % interface echo dB value should be less than cut off dB value +5.

(b) **Repeat echo concept:**

In this process a flat bottom hole of specified diameter in a standard block of same material is made. Echo height value is noted from that FBH and that is recorded (say, Q). Now, while testing the roll dB is fixed at Q+4 or Q+8 (As per the roll grade). Now the roll is tested on a broad range and norms is fixed that there should not be any repeat echo.

(c) **Comparison dB concept:**

In this process on a standard block made of same material is tested. dB value for getting 100% back wall echo (say, R) is noted. Now expected good bond area interface dB value on the roll body is also noted down (say, S). After that the whole barrel is scanned with cut-off dB as (S-R)X 0.5+R. At any place the interface dB value should not be less than the cut-off dB.

(d) **Indication of Bond Strength between Shell & Core material**

For trouble free performing of any roll in the mill, bond strength between shell & core is very important. Experience ultrasonic experts can also judge the bonding strength by seeing the nature of the interface echo.

(e) **Indication of change in graphite morphology in shell material**

In ICDP rolls, which are used in later finishing stand in hot strip mill, must have to contain free graphite in its microstructure. This free graphite acts as a lubricant during hot rolling. For this purpose shape, size and amount of free graphite needs to be optimized for smooth rolling. So, in the shell microstructure graphite clustering is not desirable.

During ultrasonic testing graphite morphology can also be judged. So, by applying this process parameters can be suitably modified.

(f) **Speed test**

In this process, nodularity of graphite can be judged by seeing the speed of sound in that material through ultrasonic testing. As we know speed of sound varies from grey iron to noduloar iron. If speed of sound is more than 5400 m/s, the material is considered to be a good spheroidal graphite material. Below 5400 m/s, the material is considered as grey iron. For duplex roll requirement of core material is SG. In a finish product this can be tested by speed test. So, by applying this, process parameters can be suitably modified.

(g) **Ferritoscope Value (FS) checking**

The work rolls, used in the hot strip mill, are all high carbides roll. Basically their matrix is bainitic or martensitic and carbides are distributed on this matrix. These rolls are heat treated and in this process austenite transformed to martensite or bainite. Retain austenite level to be minimized in these rolls as this is not desirable at all during rolling operation.

Method for actual residual stress measurement is done either by X-ray diffraction method or by strain gauge which is very time consuming and the instruments are also very costly. For day to day work indicative comparative value of residual stress can be judged by measuring FS value with the help of ferritiscope instrument. Higher the FS value lower is the residual stress. This process also ensures the effectiveness of tempering during heat treatment.

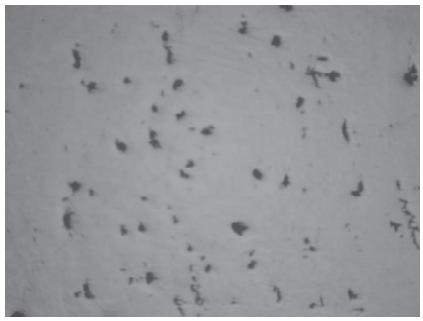
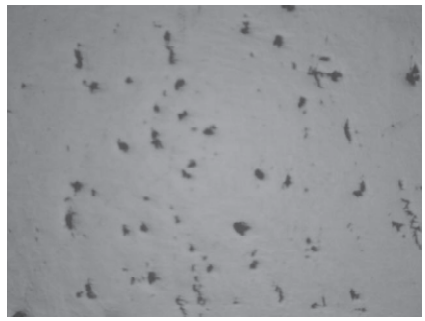
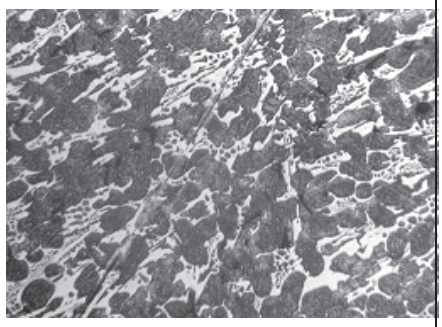
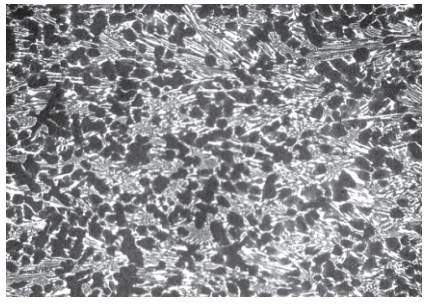
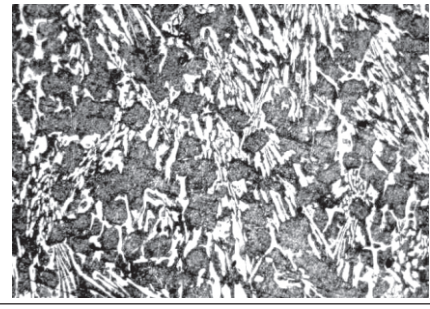
(h) **IN-SITU microstructure analysis**

In a finish product microstructural analysis is done through In-Situ microscope. Barrel end sample may not be representative for whole barrel as casting speed varies and hence solidification pattern varies. By In-Situ microscopic analysis actual microstructure is compared with the desired microstructure. Also roll performance comparison can be analyzed on the basis of In-Situ microstructure. So, by applying this process parameters can be suitably modified.

(i) **Dye Penetrant Test**

Dye penetrant test is carried out for detection of defects which are open to the surface but usually not visible with the naked eye on any material. When the penetrant applied on the properly cleaned surface it will penetrate into the discontinuities by the capillary action during the dwell time and after application of developer it will form the indication on the surface as it blot out the penetrant from the discontinuities. Fine shrinkage/ cavities at the interface in highly alloyed rolls can cause spalling during heat treatment. This can be easily visualized through dye penetrant test and hence corrective action can be taken before heat treatment.

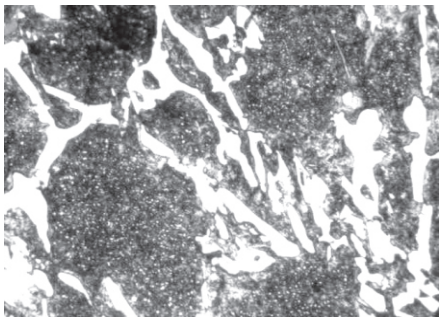
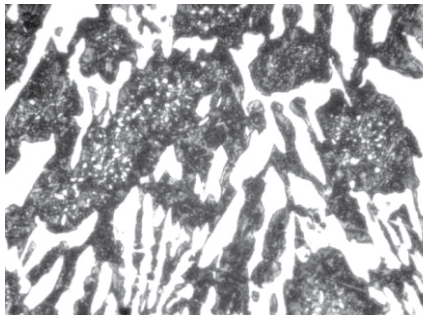
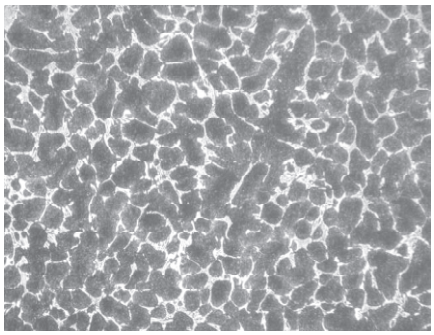
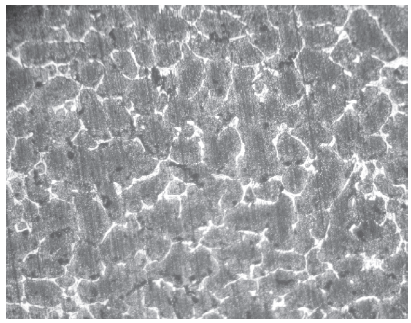
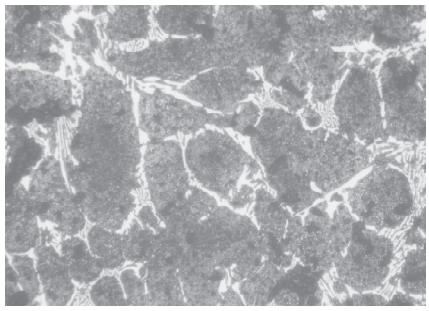
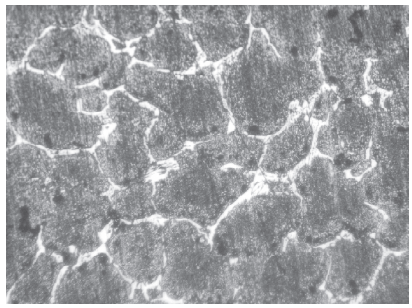
Process modification through NDE

Grade	Earlier Grade	Modified Grade
ICDP (Shell) UN-etched 50X		
ICDP (Shell) Etched 100X		
Hi-Cr Iron (Shell) Etched 100X		

Conclusions

Based on the investigations carried out, it can be concluded that for improved performances of Rolls which are used in Steel Mills, proper usage of NDE helps in

a. Reducing internal rejection and preventing further value addition.
b. Defect free product supply to the customer
c. Process parameters improvement
d. Development / Improvement in existing roll grades
e. Roll Failure investigation internal as well as at customer end
f. Making correlation between process parameters adopted and result achieved

Grade	Earlier Grade	Modified Grade
Hi-Cr Iron (Shell) etched 400X		
Hi-Cr Steel (Shell) etched 100X		
Hi-Cr Steel (Shell) etched 400X		

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