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Review on 20 HI Cold Rolling Mill Rolls and Spalling

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Abstract: Deformation of rolls of rolling mill is a major problem for any industry and it affects the properties and quality of material as well as production capacity of mill. In this research paper, the materials which are used for making 20 Hi mill rolls and its heat treatment procedure during manufacturing is included. Here, various types of non-destructive techniques are also mentioned, which is used for testing of 20 Hi mill rolls. The main objective is to highlight those reasons which are responsible for the spalling of Roll and how to avoid it.

Keywords: Rolls for 20 HI mill, Steel grades for rolls, Heat treatment, Sub-zero treatment, NDT techniques, Spalling.

I. INTRODUCTION

Rolling is the most important forming process. More than 95% of ferrous and non-ferrous metals and alloys are processed to their usable shapes by rolling like plate, sheet, strip, foil and different sections like rail, beam, channel, angle, bar, rod and seamless pipe etc. Here, permanent deformation is achieved by subjecting the material to high compressive stress by allowing the material to pass through the gap between two rotating cylindrical rolls. The rolls may be flat or grooved and are kept at a fixed distance apart from each other. The rolls are rotated in opposite direction by means of electrical drive system. When rolling of a material is done at room temperature or below the recrystallization temperature of the material, it is called cold rolling. The rolling mill consist of rolls as the main tool and depends upon number of rolls used in rolling mill, it can be designed as 2 Hi, 4 Hi, 6 Hi, 8 Hi, 12 Hi and 20 Hi rolling mills. In recent trends in India, mostly 4 Hi and 20 Hi rolling mills are installed in steel production plant. the life of the rolls for perspective mill is depend upon mainly the selection of material, the production method, heat treatment and machining process. Here, the description about manufacturing and deformation of rolls of 20 HI rolling mill is discussed.

II. ROLLS FOR 20 HI MILL

20 Hi mills are unique in feature as they have chock less floating work rolls and a cluster configuration for the back-up bearings. It consist of 2 work rolls, 4 intermediate rolls, 2 idol rolls, 4 drive rolls and 8 back-up bearings.

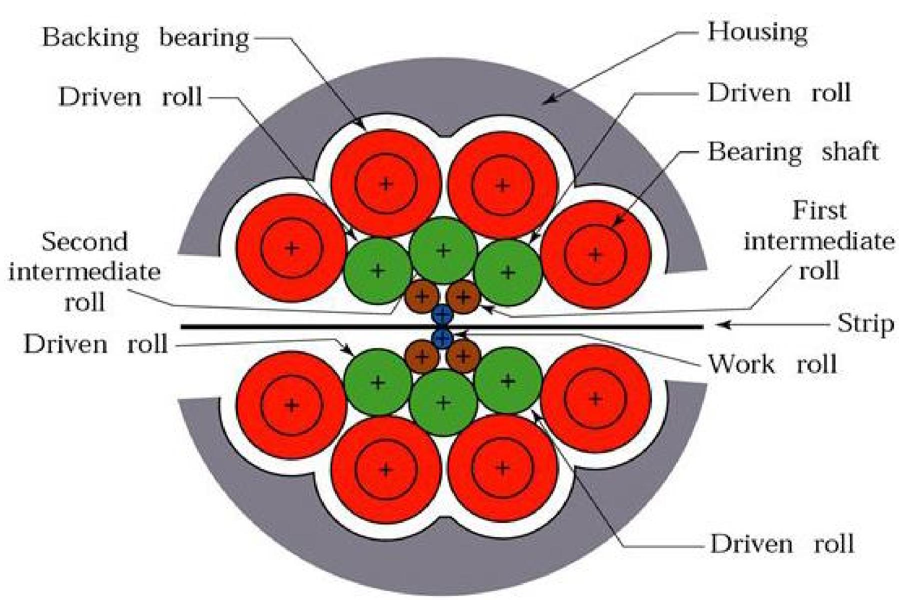

Fig. 1 Configuration of 20 HI mill rolls

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In 20 Hi mill different materials and hardness are used depends upon various application of mills. General steel grades and hardness of 20 Hi mill rolls are,

TABLE I
VARIOUS STEEL GRADES AND HARDNESS OF 20 HI MILL ROLLS

Rolls	Steel Grades	Hardness Range
Work Rolls	AISI D-2 AISI M-2 AISI M-1 AISI M-35 ASP-2023 ASP-2030	60/64 Rc 61/65 Rc 61/65 Rc 62/65 Rc 61/67 Rc 61/67 Rc
Intermediate Rolls	SPZ (H-11 M) AISI H-13 AISI H-12 AISI D-2	55/60 Rc 53/56 Rc 54/57 Rc 55/60 Rc
Drive rolls	SPZ (H-11 M) AISI H-13 AISI H-12 AISI D-2	55/60 Rc 53/56 Rc 54/57 Rc 55/60 Rc
Idler Rolls	SPZ (H-11M) AISI H-13 AISI H-12 AISI D-2	55/60 Rc 53/56 Rc 54/57 Rc 55/60 Rc

TABLE II
Chemical Composition of Material Used To Make Rolls

	C %	Si %	Mn %	Cr %	Mo %	V %	W %	Co %
AISI D-2	1.4-1.6	0.3-0.5	0.3-0.5	11-13	0.7-1.2	0.7-1.0		
SPZ (H-11 M)	0.4-0.45	0.8-1.2	0.25-0.5	4.75-5.5	1.25-1.5	0.3-0.5		
AISI H-13	0.3-0.4	0.8-1.2	0.2-0.4	4.75-5.5	1.25-1.75	0.8-1.2		
AISI H-12	0.3-0.4	0.8-1.2	0.2-0.4	4.75-5.5	1.25-1.75	0.1-0.5	1.0-1.7	
AISI M-2	0.78-0.88	0.2-0.4	0.2-0.4	3.75-4.5	4.5-5.5	1.6-2.2	5.5-6.75	
AISI M-1	0.75-0.85	0.2-0.4	0.2-0.4	3.75-4.5	7.75-9.5	0.9-1.3	1.15-1.85	
ASP 2023	1.28			4.0	5.0	3.1	6.4	
ASP 2030	1.28			4.0	5.0	3.1	6.4	8.5

III. HEAT TREATMENT

Heat treatment of rolls is carefully done in gas fired neutral salt bath furnaces. The advantages of salt bath are, superior temperature uniformity, lesser surface oxidation and scale formation. The uniformity of microstructure through the entire length and section comes from accurate of temperature and precise residence time in the salt bath. Firstly, they are Austenitized to suitable temperature; residence time in the bath depends on the section and composition of material. Rolls are then quenched suitably to attain the desired mechanical properties. Rolls are multiple tempered to required harness. Hardness is checked at extreme ends and at the middle by Indentation type testers as well as Equotip tester.

IV. SUB-ZERO/ CRYOGENIC TREATMENT

While heat treating work rolls, some amount of austenite is retained after heat treatment which gives softness in the microstructure of rolls. To reduce retained austenite and to convert the same into martensite, sub-zero treatment is recommended.

In sub-zero treatment, work rolls are hardened as per normal HT cycle. After initial tempering they are cooled to sub-zero temperature i.e. between 70°C-80°C. At this temperature retained austenite is transformed to martensite. Rolls are held at this temperature for 6 to 8 hours. Finally rolls go through tempering cycle to achieve suitable hardness. Due to stabilisation of metal, stresses and strains are removed and better life is obtained. Sub-zero treatment is much useful to D2/D3 steels and also for high speed steels.

Cryogenic treatment is done by evaporation of liquid nitrogen, where temperature goes down to -185°C. After this treatment rolls are allowed to come to room temperature and then multiple tempered for required hardness. Hardness by Sub-zero/Cryogenic treatment increase by ½ HRC.

Benefits of sub-zero treatment:

1) Life of roll increases.
2) Soft spot are reduced.
3) Wear resistance improves.
4) Dimensional stability is achieved.
5) Higher hardness is achieved.
6) Less susceptible to surface cracks.
7) Stable and compact micro structure is obtained.
8) Longer runs and better polish ability of rolls.t

V. NON-DESTRUCTIVE TESTING

Once a roll is completed, whatever defect is inside the roll cannot be seen with naked eyes. From outside; roll appears to be normal. There is every possibility that there are minute surface and sub-surface defects, may be due to Raw material or Heat treatment. These defects are to be determined by Non-destructive testing. Here, four NDT methods are described below,

A. Ultrasonic Test

Ultrasonic test is used to detect internal cracks by pulse echo contact method or back reflection technique. Piezo electric waves are generated by a probe. While contracting object by probe, these waves propagate in the object and get reflected if any phase change take place. If there is no phase change, then wave gets reflected from other end of object which return from full depth ofmaterial.in case of discontinuity waves are reflected from crack. Representation on screen will tell whether there is flaw or discontinuity in the material.

Test is conducted as per ASTM A388/A388M rejection criteria is,

1) Loss in back wall echo exceeding 20% of initial echo.
2) Travelling discontinuity more than 5% of initial echo.
3) Any discontinuity flaw equal to or greater than 10% of the backward echo.

With the use of suitable probe internal defects can be detected. Sometimes there is a signal indicating a flaw at surface, but it is not visible with naked eyes. In such cases acid etching is done to ascertain surface defect.

Ultrasonic test can throw light on following defects;

a) *Internal cracks / flaws:* These generally occur where there is drastic change in cross section and crack propagates along the axial or longitudinal direction.
b) *Piping defects:* These are forging defects and can be along with the axis in the core zone.
c) *Slag inclusion:* These occur during casting the ingots for forging.
d) *Shrinkages:* These are generally due to less material while casting the ingots.
e) *Internal forging lap /folds:* These are forging defects and are caused due to overlapping of ingots.
f) *Porosity:* These are due to trapped gases or fumes during casting the ingots.

B. Acid Etching Test: Surface to be examined is cleaned by alcohol. Then it is etched with 1:3 or 1:4 solution of nitric acid in methanol. Overheated areas, grinding cracks, bruise marks and surface cracks become visible after acid etching. The process of etching indicates clearly the defective regions.Ultrasonic test in conjunction with acid etching is very reliable.

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C. Magnetic particle test

This test is conducted to detect cracks on surface and sub-surface layers in ferrous material only. Normally, Iron particles are suspended in spirit or petrol and the solution is spread over the surface of rolls after magnetising the surface. Accumulation of iron particles over surface of rolls indicates cracks. Magnetic particles test is conducted as per ASTM SA 275 and SE 709. Any magnetic particles build up having width more than 1.0 mm and ratio of length to width more than three times will mean defect/crack.

Following defects can be traced by magnetic particle test,

1) *Forging bursts:* These defects are due to temperature of the metal, lesser than required.
2) *Flakes:* These cracks may occur at the surface of sub-layer the material and are due to rapid cooling of the rolls during heat treatment.
3) *Grinding cracks:* These surface cracks are developed due to improper grinding.
4) *Local heating cracks:* These cracks are developed when the rolls are in service where high pressure forces are in application resulting high work hardening.
5) *Stress cracks:* These are developed while material is in use / in service where material is subjected to heavy alternating or fluctuating stress.

D. Dye Penetrant Test

This test is conducted for detecting surface cracks in ferrous and non-ferrous material by application of developer and penetrant. Any dark hair line will be treated as defect. This test is performed after grinding.

Following fine surface defects can be traced by Dye Penetrant Test,

1) *Surface hardening cracks:* This type of crack generally occurs when the hardness of the surface layer is more than the sub-layer hardness.
2) *Pitting:* These are pin/punch type marks and occur at the surface.
3) *Grinding cracks*: These are due to grinding heat and are called heat checks.
4) *Local heating cracks:* These cracks are developed at the surface when the rolls are in service where high pressing forces are in application resulting in high work hardening.

VI. SPALLING OF COLD MILL ROLLS

Chipping off, flaking off, dismembering of a portion of roll from the roll barrel is known as spalling. Spalling can occur both in work rolls as well as in back up rolls is usually the end effect of crack generation and propagation.

Normally, factors responsible for crack generation are;

A. Residual Stresses

Develop in roll manufacturing process such as heat treatment and roll grinding. Crack propagation could be rapid rolling under stress and rapid premature failure takes place in case of extremely high residual stresses left in roll.

B. Thermal Gradients

Crack develops in regions between top hardened surface and sub-surface below, during grinding stage. Gradually crack develops and propagates.

C. Contact Fatigue

Crack initiates due to compressive stresses experienced during contact between roll and strip while rolling. Mostly cracks grow under fatigue conditions.

D. Hydrogen Embrittlement

Under inadequate supply of coolant, hydrogen is released due to decomposition of coolant/lubricant, when temperature between roll surface and strip becomes high. This hydrogen is picked up by roll surface where structure is martensite.

E. Local over stressing of roll surface:

Local over stressing of roll surface can be caused due to several reasons such as,

1) Stopping the roll under screw down/hydraulic pressure.
2) By excessive roll face pressure during starting the mill.
3) Excessive body pressure caused by insufficient or uneven camber.
4) Skidding during rolling.
5) Laps and laminations lead to local overheating of the rolls.
6) Shifting and folding of strip during rolling.
7) Strip rupture / Pinching / Power failures.
8) Local over-heating.
9) Rolling narrow width strip on one rolling bath.
10) Uneven cooling of roll.
11) Excessive work hardening.
12) Annealing residue/ foreign bodies in roll gap.

Spalling is usually found in the area of highest contact pressure between the work and back up roll. It is desirable, therefore, to provide a uniform contact pressure distribution across the faces of the rolls. However, due to such factors as mill design, roll wear, chamfers, mechanical crowns, thermal crowns, roll bending forces etc. the pressure is generally not uniform.

In case the cracks propagate towards each other, they result in a big spalling or in case the cracks propagates in opposite direction to each other, they result in two small areas, chipping off. It must always be remembered that the spalling originates in small incipient cracks or fractures on or just below the roll body surfaces. These discontinuities widen under rolling pressure in a circumferential direction. Fatigue fractures occurs and sooner or later the spall appears on the roll surface.

“Spalling” is the eventual major failure of a roll surface leading to the roll being rendered in most cases as useless; although its origin may be in an apparently small and insignificant surface flaw. Spalling is not a spontaneous process, by taking precaution it could be minimized.

F. How To Avoid Spalling

1) Coolant should be sufficient and should be of good quality.
2) HNO3 solution whenever strip breaks or skids, roll should be checked for damage with the help of magnifying glass with use of 3-5%.
3) Stress relieving should be done for 4 hours at 160°C / 180°C, after 3 or 4 regrinding.
4) Sufficient stock removal is recommended to remove work hardened layer. Hardness should be brought back to original level.
5) Strict physical examination of every roll should be done after taking them out.
6) Die penetration testing / ultrasonic testing / eddy current testing to be performed to ensure that the going into next campaigns is free from defects.
7) Check hardness of every roll before and after use, work hardening should not be more than 2 HRC and work hardened layer should be removed completely in regrinding.
8) For regrinding of skin pass mill rolls, resin or shellac bonded wheel is recommended to avoid chattering and micro cracks.

VII. CONCLUSION

It can be analyzed that selection of material, proper heat treatment and cryogenic treatment are have vital importance on the life of roll. Also, in the working condition of mill periodically testing of roll with NDT techniques is important to identify the defects. The reasons responsible for spalling of roll in cold rolling mill and methods to avoid it were highlighted. It is identified that the primary cause of roll defects is roll spalling and it is induced in the rolls through various mill operational aspects. With the use of various NDT techniques, the early detection of surface and sub-surface defects is possible. These can be eliminated by the process of roll grinding and reduces the chance of spalling.

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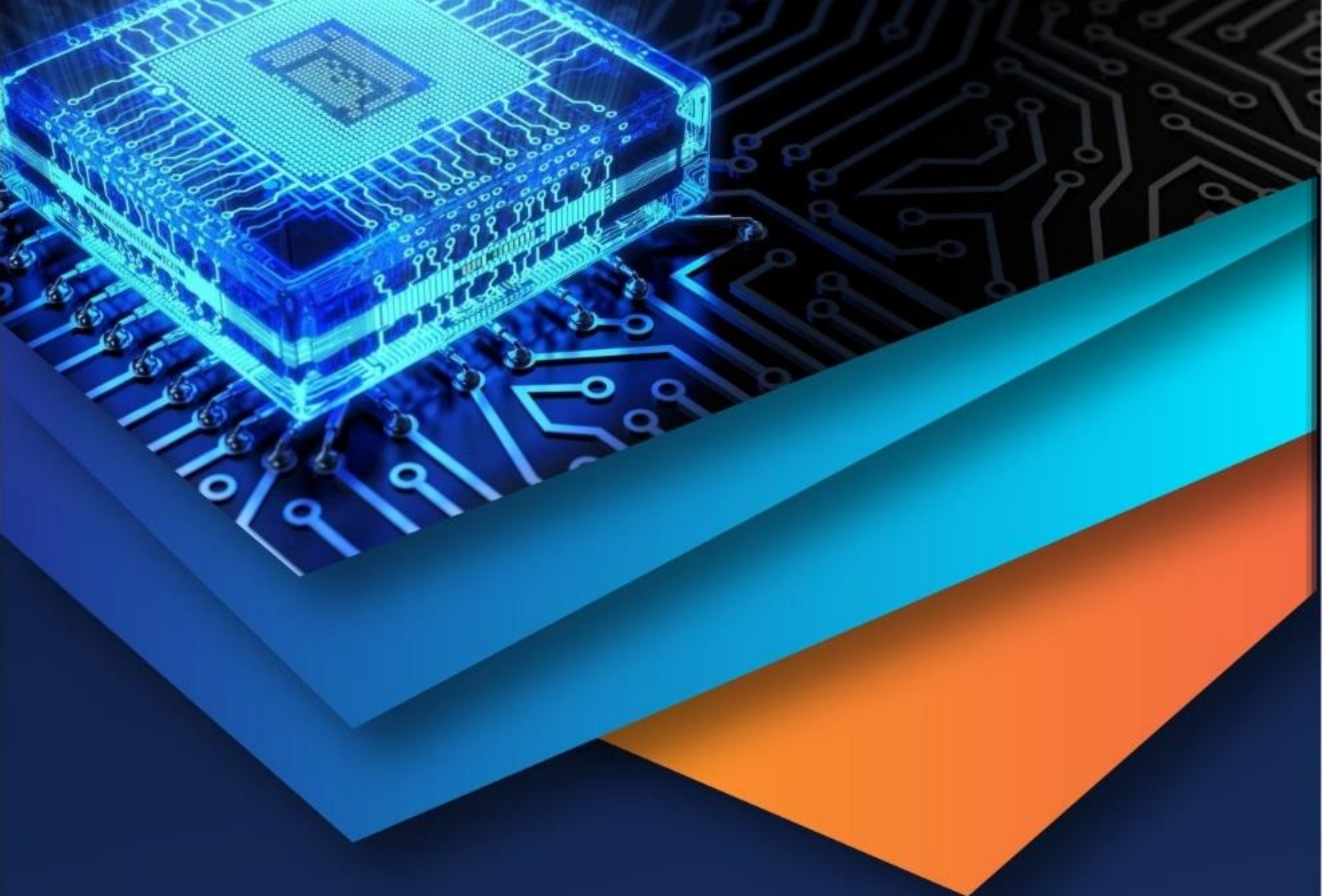

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