

Effect of Thermomechanical Treatment on Mechanical – Metallurgical Properties of Re- Rolled Complex Steel Sections

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ABSTRACT: The effect of thermomechanical processing (Hot Re- Rolling) on the mechanical & metallurgical properties of intricate steel section was investigated in this experiment work. Thermomechanical process was conducted in on-line sectioning machine hot re-rolling mill, in which we were analyse the mechanical & metallurgical properties of final (Thermo-mechanical treated) complex steel sections with reverence to initial raw material. The results Conclude that the better controlled mechanical- metallurgical properties can be achieve by thermo-mechanical treatment. As compare to as- rolled product in thermo-mechanical treated sections there are advantages assemblies like, higher hardness, tensile strength, grain fineness, Batter surface finish, desired microstructure, Desire Structure Intricacy with Metallurgical homogeneities throughout the area and no any changes on chemistry (De-Carburization) of steels. This research contributes towards the new developments and installation of hot re- rolling of intricate steel section line in terms of to achieve batter metallurgical and mechanical properties of continuous intricate product. It makes possible to reduce manufacturing cost and improve product quality of the intricate hot re- rolled steel sections.

KEY WORDS: Thermomechanical process, mechanical property & metallurgical property, hot re-rolling, deformation, reduction, Complex steel section

I. INTRODUCTION

Rolling is the process of plastically deforming steel by the rolling action, also is defined as the reduction of the cross-sectional area of the steel piece being rolled, or the general shaping of the steel products, using the rotating rolls. Steel Re-rolling Mill (SRM) is a simple mechanism, where consists heating of steel Approx. above the recrystallization temp. (Near to Melting point in some cases) where rolling must be carried out in terms of thermo mechanical treatment. Thermo mechanical re-rolling will produce sections of steel at various dimensions from wire rod/coil of steel. The manufacturing process involves passing wire rods of steel at high temperatures around 850°C to 1250°C max depending on grade of steel and other parameters (Dimensions, Amount of deformation, Speed etc..). This happens through rotating rolls to reduce the thickness and shape of the sections. It further proceeds into cooling and cutting on continuous cooling bed. The benefits of thermomechanical rolling include better mechanical properties, Mass Production and energy savings. [1]

II. RELATED WORK

This paper work is related to all thermo mechanical industries, where the different types of section to be produce by the thermal and mechanical treatments together. Research work done practically and an investigated that what effects happens on steels after doing thermal mechanical treatment on various types of steel grades.

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III. THERE ARE CERTAIN FOLLOWING ADVANTAGE OF HOT RE-ROLLING.

1. To achieve desired complex geometry with tolerance.
2. Excellent metallurgical and mechanical properties on finished products.
3. Various size of sections can be easily manufacture with accurate control on dimensions.
4. No Chemical Change (decarburization) will occurs & Just Because of no longer process time is require (Less contact with environment).
5. Uniform microstructure and less distortion of grains to be obtain.

IV. FACTORS HELP TO OBTAIN BEST RESULT ON THERMO MECHANICAL RE- ROLLING PRACTICE.

1. Effect of austenitic temp. On mechanical properties of finished products.
2. Effect of transformation temperature on mechanical properties.
3. Effect of percentage of Reduction on mechanical properties.
4. Effect of cross sectional area on mechanical properties.
5. Effect of composition of Raw on mechanical properties.

At present scenario the use of re-rolled sections are widely used for many sectors like, automotive, agriculture, defence, kitchen ware, decorative, construction (TMT Bars), etc.

V. THERMO MECHANICAL TREATMENT

Thermo mechanical processing (TMP) is a technique designed to improve the mechanical & metallurgical properties of materials by controlling the hot-deformation process in a rolling mill. This was originally designed to produce the required external shape of the product. Controlled rolling, controlled-cooling and direct-quenching are typical examples of thermo mechanical controlled processing. Such processing saves energy in the manufacture of steel by minimizing or even eliminating the heat treatment after hot-deformation, thus increasing the productivity for high grade steels. TMP process has several advantages that can help overcome issues related to the addition of major alloying elements and conventional heat treatments. [1] TMP steels with added micro alloys have been developed to manage the conflicting requirements of strength, toughness and weld ability through grain refinement. TMP effectively enables a reduction of the preheating temperature, thus lowering the rolling cost. As TMP steels afford good weld ability, they are highly valued in industries such as shipbuilding, offshore structures, pipelines and building construction. TMP is the sophisticated combination of well-defined deformation operations and well-defined heat treatment in a single production stage to control the microstructure of the steel being rolled. TMP produces steels with the desired external qualities (dimensions, shape and surface quality) and acceptable mechanical properties. [2] TMP is normally considered as the final stage in the production of steels. TMP is generally associated with hot rolling operations like hot strip mills, plate mills and bar and rod mills. For example, in case of production of hot sections of low/Medium carbon steel grades in a hot re-rolling mill, various parameters of controlled rolling in the finishing train with respect to temperature, rolling speed, rolling reductions and run-out cooling pattern are carefully selected to achieve desired mechanical properties of the hot rolled sections. [1] Traditionally, the focus of such TMP has been on metallurgical aspects of producing the microstructure which provides the desired mechanical properties after the treatment. The aspects of exterior quality such as shape and flatness, gauge consistency, surface quality, etc., have received much less attention although they are closely related to product metallurgy and processing practices.

Type of Thermo-mechanical Processes: -

There are several processes for TMP. These processes broadly fall into the following three main categories. Controlled rolling down from the normalizing temperature which is still fully austenitic (above the Ar₃ temperature) followed by a rapid cool of approximately 10 °C/sec. The aim of this process is to refine the grain size by controlled rolling and to increase the strength by suppressing the formation of ferrite and pearlite in favour of a strong tough bainite. Controlled

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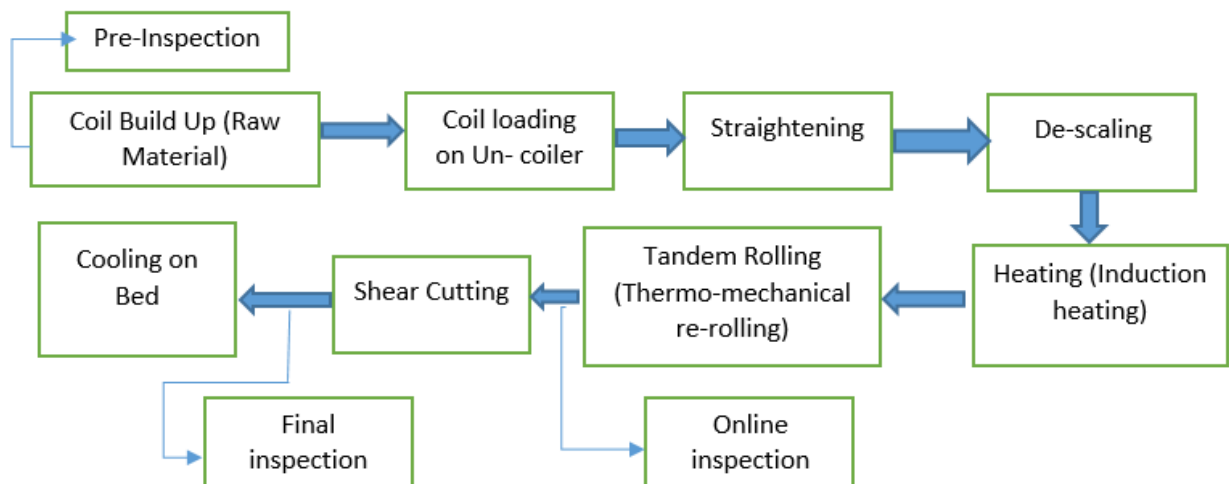
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rolling both above the Ar₃ and below that temperature, in the austenite ferrite mixed region. In addition to austenite grain refinement, the recrystallized grains are flattened, and nucleation of fine ferrite is encouraged by the deformation. At a temperature above the Ar₁, the controlled rolling is interrupted, and followed by rapid cooling to room temperature or an intermediate temperature. Controlled rolling is performed as part of a preliminary processing, followed by cooling and reheating to just above the Ar₃ temperature and then rapid cooling to well below the Ar₁ temperature. The purpose of this technique is to develop the finest equiaxed austenite grain size before the controlled cooling begins.

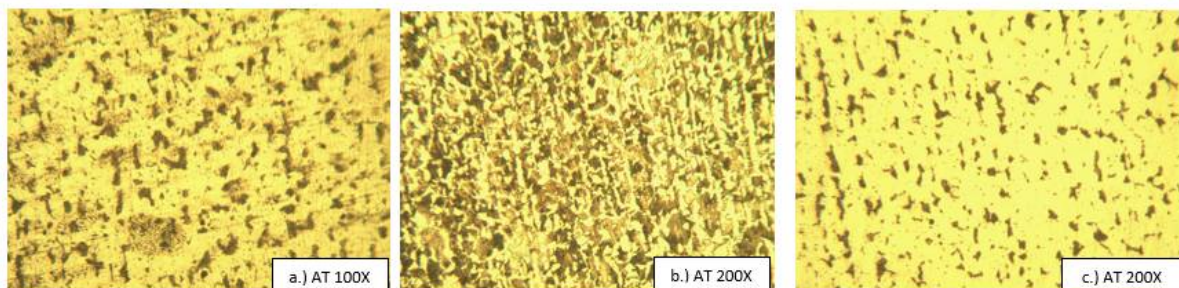
VI. EXPERIMENTAL WORK

a. Schematic Flow for Re - Rolling Section Mill: -

The flow Diagram indicate the over-view of experiment work. And inspection stages at different places.



b. Microstructure evolution of Raw material:-



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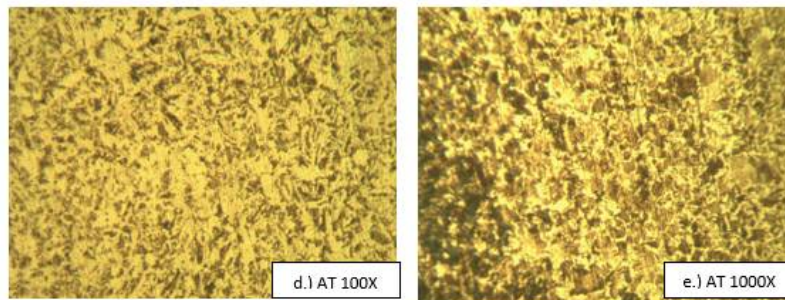


Fig 1:- Micro-structural examination of as rolled steel a.) AISI 1010 32 Ø b.) S43C c.) St. 37.2 d.) AISI 1010 16 Ø e.) EN 09

Evaluation cover the metallography examination of raw material, which indicate the initial structure pearlite and ferrite. Amount of different phases are getting differ according to the amount of carbon contain which is mention in below Table 1.

VII. EXPERIMENTAL PRACTICE

The current paper investigates the effect of thermo-mechanical re – rolling treatment on mechanical, metallurgical and physical properties of as rolled steel wire – rod. During experimental work here performed thermo-mechanical re – rolling treatment on various grades and diameters (as mention in below Table no.1) of steel wire rod. At the initial stage we had collect the nos. of raw material steel samples for analysis of mechanical, metallurgical and Physical properties. As shown in below Table 1. (Sr. No. 1-7). In the main stage of thermo mechanical (Re-Rolling) treatment, various grades & Diameter's of steel wire rod had rolled at different controlled parameters. (Shown in table no-1) to achieve complex steel sections with predefined properties. In-line rolling process there were many of parameters to be controlled and observed. At the primary stage of rolling the various steel wire rod continuously heated with the help of electrical resistance furnace heated majorly up to the 1250 Degree Centigrade (Temperature is decided accordingly to the steel grades and other suitable parameter). At preheating stage many parameters to be noted – controlled like, rolling temperature (according to grade & Diameter), line speed, descale speed etc. All the parameter closely controlled as per standardized parameter by the practice of trial and error method. Section making is an art of hot rolling. Rolling temperature maintain by controlling the voltage, line speed & Cutter – Descale speed etc. In the rolling of flat, intricate and thin products, that time more rolling temperature and speed required compare to the thick and simple shape. At the secondary stage of thermo mechanical treatment, there were total 4 stand (selection of stand depends on design and area of section) of rolling stand available according to the section design and complicity number of stand to be used, we can't get desired shape in the single stage because it leads to drastically change in the Metallurgical properties. [5] Ex. For the flat and simple section there is two stands used but at the same flat section having taper end at one side need 3 stands for achieve desired section. In the rolling of sections different type of roll setting to be done on each respective stand according to the shape and size of section. In each stand there are 2 rolls used (one is top roll and other is bottom roll), both the roll is driven by mechanical drive, top roll is movable in up-down direction to adjust the rolling gap between two stands (top roll is hydraulically pressurised toward bottom roll). Each stand having different gap according to reduction divided/ stand. As per design of section the section of stands and reduction to be maintain. During the rolling lower pressure water spray is apply on the contact angle of roll and hot steel to avoid the stick and improve the life of roll. Generally, H13 roll used for rolling. Each stands roll to be Nitride before use at definite nitriding cycle. At the last stand of rolling mill the section dimension to be achieve closely. All the mechanical and metallurgical requirements to be measured after getting the proper dimension of section once the all properties achieve the production start with full capacity.

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VIII. THERMO MECH. RE – ROLLING DATA ANALYSIS

All the properties achieve by thermo-mechanical treatment as mentioned on below table.

Table 1: - Comparative Technical data of As- rolled & Finish Products.

SR NO	Details	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
		POLE SHOE (ELECTRICAL COMPONENT)	LOCK RING (AUTOMOTIVE COMPONENT)	SIDE RING (AUTOMOTIVE COMPONENT)	CHAMFER (CONSTRUCTION COMPONENT)	SICKLE (AGRICULTURAL COMPONENT)
1	GRADE	AISI 1010	S 43C	ST 37.2	AISI 1010	EN 09
2	INITIAL SHAPE	CIRCULAR BAR	CIRCULAR BAR	CIRCULAR BAR	CIRCULAR ROD	CIRCULAR ROD
3	INITIAL CROSS-SECTIONAL AREA (MM ²)	803 (32Ø)	706 (30 Ø)	706 (30 Ø)	200 (16 Ø)	153.86 (14 Ø)
4	OVALITY	0.15 MM	0.10 MM	0.10 MM	0.19 MM	0.10 MM
MECHANICAL PROPERTIES (As Rolled)						
5	1. HARDNESS (BHN)	100	192	100	109	180
	2. TENSILE STRENGTH (N/MM ²)	345.12	613.2	351.1	362.5	570
	3. YIELD STRENGTH (N/MM ²)	228.5	420.1	232.4	240.6	385
	4. ELONGATION (% SEQ. ROOT AREA)	35.7	18	37.5	35.2	14
METALLURGICAL PROPERTIES (As Rolled)						
6	1.Spectro Analysis	C- 0.10 P- .008 Mn- 0.45 Si- 0.090 S- 0.001 Al- .031	C- 0.44 P- 0.016 Mn- 0.78 Si- 0.230 S- 0.016 Al- 0.029	C- 0.080 P- 0.015 Mn- 0.45 Si- 0.060 S- 0.005 Al- 0.027	C- 0.096 P- .015 Mn- 0.42 Si- .075 S- 0.003 Al- .038	C- 0.540P- 0.015 Mn-0.730 Si- 0.214 S- 0.014Al- 0.025
7	1. MICRO CONSTITUENT (IN %)	15- 17 %Pearlite	30 – 35 % Pearlite	10-12 % Pearlite	15-20 % Pearlite	35-40 % Pearlite
	2. THICKNESS OF DECARB LAYER (IN MICRON)	No Decarb	No Decarb	No Decarb	No Decarb	No Decarb
	3. ASTM GRAIN SIZE (ASTM E 112: IS 4748)	6.53	8.77	8.5	8.09	8.88
	4. INCLUSION (mic)	A- 1.0 C- 0.5 B- 1.0 D-1.5	B- 1.0 C- 0.5 B- 1.0D-1.0	B- 1.0 C- 0.5 B- 1.0 D-1.5	B- 1.0 C- 0.5 B- 1.0 D-1.5	B- 1.5 C- 1.0 B- 1.0D-1.5

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ROLLING TREATMENET						
8	ROLLING TEMPRATURE (in deg. Cen.)	980 +/- 20	975 +/- 20	980 +/- 20	960 +/- 20	970 +/- 20
9	NO OF ROLLING STAND	3	2	2	2	2
10	1. TOTAL % OF REDUCTION	49.31	39.09	50.56	44.93	61.04
11	ROLLING SPEED (mpm)	4.52	9.02	7.50	11.20	3.20
12	COOLING TYPE	NATURAL	NATURAL	NATURAL	NATURAL	NATURAL
FINISH GOOD ANALYSIS						
13	SHAPE	INTRICATE	INTRICATE	INTRICATE	TRIANGLE	FLAT
14	AREA (in mm seq.)	407	430	349	110.13	59.93
MECHANICAL PROPERTIES						
15	1. HARDNESS (BHN)	110-115	200-210	105-110	110-115	215-235
	2. TENSILE STRENGTH (N/MM2)	352	710	359.64	392	690
	3. YIELD STRENGTH (N/MM2)	245	451	269.73	259	483
METALLURGICAL PROPERTIES						
16	1. MICRO CONSTITUENT (IN %)	24.40 % Pearlite	35.60 % Pearlite	29.70 % Pearlite	37.90 % Pearlite	55.40 % Pearlite
	2. THICKNESS OF DECARB LAYER	No Decarb	No Decarb	No Decarb	No Decarb	No Decarb
	3. GRAIN SIZE	7.19	7.49	8.9	9.49	9.5
	4. INCLUSION	A- 0.5 C- 0.0 B- 0.5 D-0.5	B- 0.5 C- 0.0 B- 0.5 D-0.5	B- 0.5 C- 0.0 B- 0.5 D-0.5	B- 0.5 C- 0.0 B- 0.5 D-0.5	B- 0.5 C- 0.0 B- 0.5 D-0.0

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IX. RESULTS OF ANALYSIS

Evaluation concludes the different rolling parameters, metallurgical and mechanical properties which are briefly described in the above mention Table 1.

Metallurgical surveillance of different Re – Rolled Sections and its appearance:-

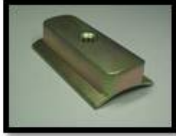
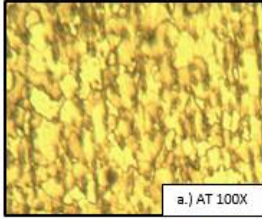
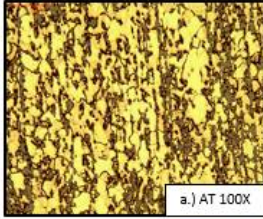
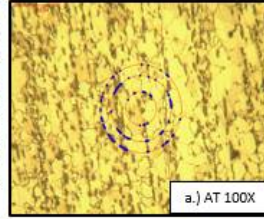

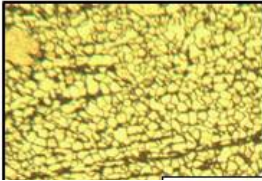
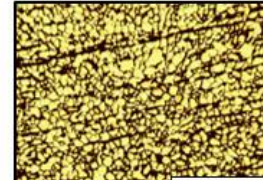
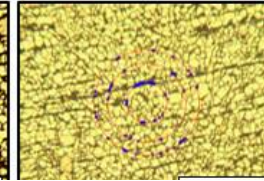

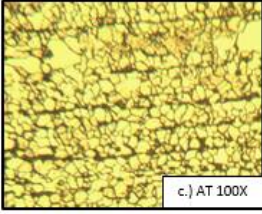
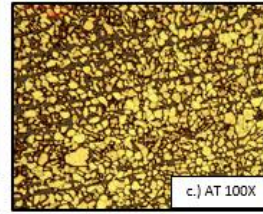
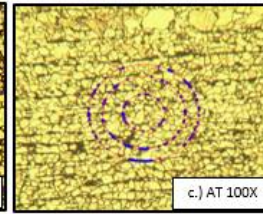
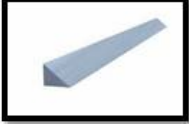
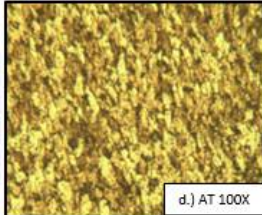
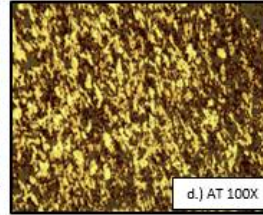
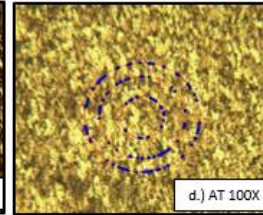

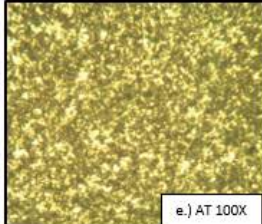
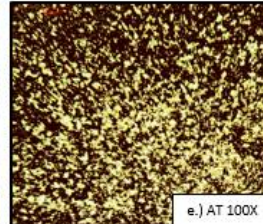
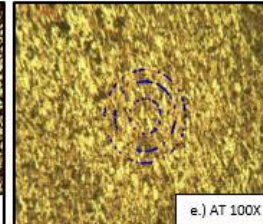
SECTION	MICRO-STRUCTUR	PHASE ANALYSIS	GRAIN SIZE MEASUREMENT
	 a.) AT 100X	 a.) AT 100X	 a.) AT 100X
			
	 c.) AT 100X	 c.) AT 100X	 c.) AT 100X
	 d.) AT 100X	 d.) AT 100X	 d.) AT 100X
	 e.) AT 100X	 e.) AT 100X	 e.) AT 100X

Fig -1: Metallographic examination of finished thermo-mechanical treated steel sections. A.) AISI 1010 b.) S43C c.) St. 37.2 d.) AISI 1010 e.) EN 09

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X. DISCUSSION OF INVESTIGATION

The effect of thermo-mechanical treatment on mechanical and metallurgical properties of complex sections were investigated. There are numbers of factors has been observed. Several as, temperature of hot rolling, speed of line, % amount of reduction, grade of raw material etc. Some other minor factors may also have affected on the final properties of steel products are, diameter of wire rod and initial mechanical & metallurgical properties of steel. The table No. 1 shows the comparative results of as- rolled and re- rolled section (thermo-mechanical treated) effects. Majorly selected grades come in the category of LCS & MCS (Low and Medium Carbon steel) so the rolling temperature had decided in the range from 960-980 +/-100oC (Above recrystallization temp.). At this temperature all treated grades comes in red hot condition, so material can easy to rolled or treat at desired % of reduction.

- 1) If the rolling speed increase, the temperature of rolling will be decrease hence the grain refinement and mechanical properties drastically changed.
- 2) More the percentage of reduction, more will be the grain fracture hence enhance mechanical properties achieved but the chances of Surface distortion are slightly high.
- 3) More the rolling temperature with lower the rolling speed, it will lead to reduce the mechanical properties by increasing the size of grain.

Research work clearly conclude that the more the reduction higher the hardness, tensile strength and fine grains achieved. In as- rolled wire rod the mechanical & metallurgical properties are lower than the re- rolled section, it is represented that the effect of thermo mechanical treatment is Carried out.

Thermo- mechanical treatment is control rolling process therefore we can achieve desired mechanical & metallurgical properties by changing on process parameters.

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