

On line inspection of defects using Digital Cameras (In SMS, Rolling Mills) and Deep Learning.

1.0 Introduction

Visakhapatnam Steel Plant is an integrated Shore based Steel Plant with 7.3 Mt installed capacity for steel making. This has the following facilities to produce variety of Steel products some are semi-finished in nature and some are finished goods in nature.

| Sl.No | Facility | Products | Storage Yard |
|-------|--|--|---------------------------|
| 1 | Steel Melt Shops (SMS) | Blooms | Bloom Storage Yard(BSY) |
| 2 | Billet Mill(BM) , LMMM | Billets | Billet Storage Yard (BSY) |
| 3 | Bar Mill , LMMM | Rounds, Rebars, | Bar Storage Yard. |
| 4 | Wire Rod Mills | Wire Rod coils plain & rebar of different Diameter. | Wire Rod Storage Yard. |
| 5 | Medium Merchant and Structural Mill (MMSM) | Bundles and Piles of Angles, Channels, Squares , Rounds, Beams | MMSM Storage Yard. |
| 6 | Special Bar Mill (SBM) | Rebar's, Round, Coils | SBM Storage Yard. |
| 7 | Structural Mill(STM) | Rounds,, Billets, Angles, Medium Beam, Channel, Flat, Light Beam, Flats etc. | STM Storage Yard. |

In the process of producing these products, due to process deficiencies some defectives also gets generated. These defective products are to be identified and classified. These defective products are to be segregated and given separately disposed off separately. Other products are to be declared as prime Grade and stacked.

The different categories of defectives in each product of each unit are tabulated below.

2.0 Visual Inspection and categorization of Defectives:

2.1 Inspection of Semis

2.1.1 Bloom Inspection:

Inspection of blooms for suitability in dimensions for rolling and segregation of defective bloom is carried out at Bloom Storage Yard (BSY). Exposed surface and cross-sections of the blooms are inspected for defects.

Following types of defects are generally observed in continuously cast blooms:

- I. **Double Pour (DP):** A discontinuity in material due to interruption in casting of bloom causing a weak joint. This can happen during tundish change, sequence change or any intermittent strand stoppage.
- II. **Bend:** Deviation from straightness.
- III. **Blow Holes:** Sub surface cavities / holes formed in the blooms due to entrapped gases. This takes place whenever de-oxidation is not proper or sometimes due to presence of gases like nitrogen in large amount.
- IV. **Crack:** It is discontinuity at the bloom edge or bloom surface. Bloom with internal cracks depending on their severity and proximity to surface are either declared defective or passed for rolling. These internal cracks mostly get welded up during rolling if they are small and not near to surface. Improper secondary cooling during continuous casting may leads to cracks in blooms.
- V. **Bad Surface:** Rough & uneven surface caused mainly by slag entrapment between shell and mold.
- VI. **Pipe:** Central cavity or hole in the bloom cross section along is length.
- VII. **Deep lance:** Deep cut mark on the bloom.
- VIII. **Head Piece:** First bloom of each start of the machine, consisting of dummy bar impression is termed as Head piece.
- IX. **TailPiece:** Last bloom of each machine closure is called a Tail piece.
- X. **TK Roll Mark (TKR Mark):** Blooms get pressed due to abnormal TK Roll pressure.
- XI. **Groove (Gr):** Deep cut mark along the length of bloom due to mechanical damage
- XII. **Rhombodity:** More difference between the diagonals of a bloom resulting in near diamond shape cross section.
- XIII. **Twist:** Rotation along the axis of the bloom.

Permissible dimensions of the blooms for rolling are as follows:

| | Length | Cross Section |
|-------|----------------|-------------------|
| MMSM | 5.5m – 6.08m | 250x250mm +/-15mm |
| LMMM | 6.0m – 6.40m | 320x250mm +/-11mm |
| WRM 2 | 9.0m – 12.08m | 150x150mm +/- 3 |
| SBM | 11.5m – 12.08m | 150x150mm +/- 3 |
| STM | 10.8m – 12.08m | 200x200mm +/- 3 |

2.1.2 Billet Inspection:

Billets are inspected visually in as rolled condition for any surface defects and size tolerances. For billets issued to WRM 5% of total billets in a heat are inspected for size and diagonal tolerance.

Size Tolerance : 125mm +/- 4mm (121mm to 129mm)
 Diagonal Tolerance : 164.35mm +/- 7mm (157.35mm to 171.35mm)

Length 9.8m to 10.4m to issue for WRM

Rhombodity: 8mm

Camber: not to exceed 100 mm in overall length limited to 10mm/M

Exposed surfaces and cross section are visually inspected for identifying the defects defined below:

- I. Crack: A discontinuity in the material.
- II. Uncut ends(Bad ends) : The jagged ends of rolled products resembling the tail of a Fish.
- III. Bad surface : Manifested by uneven and rough surface mainly due to opening of Subsurface pin holes/blow holes during rolling.
- IV. Bend: Deviation from straightness.
- V. Burnt surface: Rough and uneven surface due to over heating of bloom in the furnace.
- VI. Twist: A condition wherein the ends of a rolled billet have been forced to rotate in opposite direction about its longitudinal axis (Rotation along the axis of the billet). Billets having above defects are declared defective.
- VII. Camber: Curvature measured by the maximum deviation of the middle region from the straight line joining the ends.
- VIII. Rhomboidity: More difference between the diagonals of a bloom resulting in near diamond shape cross section.

2.2 Inspection of Finished Product:

2.2.1 Inspection of Rebar's:

The Rebar's are inspected on line during rolling (by cutting a sample in case of bars) for surface defects.

- I. Absence of longitudinal rib: When there is no longitudinal rib on the rolled rebar.
- II. Absence of Transverse rib: When there is no transverse rib on the rolled rebar.
- III. Axial: Caused due to the misalignment of top and bottom rolls giving rise to a step (Protrusion) as this corner for the full length.
- IV. Lap: A defect appearing on the surface caused by a portion of steel being folded over on itself and failing to be welded upon in further rolling.
- V. Metal deposition: Deposition of metal blocks on rebar's caused by chip off on finishing rolls.
- VI. Guide / roll mark: Marks or scratches on the surface of the section at regular interval or continuous marks throughout the length.
- VII. Rough surface: This defect of unsmooth surface maybe caused by rough roll surface or high rolling temperature.
- VIII. Cracks: Discontinuity in the material.

2.2.2 Inspection of Plain Bars / Coils:

The Plain bars are inspected on line during rolling (by cutting a sample in case of bars) for surface defects as well as dimensions of the bar.

- I. Out of Tolerance: Measures of diameter (minimum and maximum) and ovality (difference between minimum and maximum diameter) of wire rod / Bar when crosses that of tolerance.

- II. Fin : Protruding rib of metal, running longitudinally along the wire rod either on one Side or both sides.
- III. Guide mark: Marks/scratches on the surface along the length continuous in nature caused by guides.
- IV. Lap: A surface defect caused by folding of a surface against itself.
- V. Scab: Irregular shape protrusions/patches arising from adhered layers of metal.
- VI. Cracks: Discontinuity in the material.
- VII. Flatness: Spreading of the material in transverse direction.
- VIII. Dent: Small crevice surrounded by brownish removable scale.
- IX. Bad material: Rough & uneven surface on the coils.
- X. Ring / Roll Mark: Marks on the coil surface along the length at regular interval.
- XI. Multiple Ends: Having more than two ends Front & Tail end in a single continuous coil.
- XII. Jumbled coils: Coils improperly laid or jumbled due to jamming.
- XIII. Short bar: Short bars less than 12Mt in the bundle.

2.2.3 Defects in structural:

- I. Out of tolerance: Deviation from the allowed dimensional tolerances.
- II. Blunt apex: Occurs in case of angles. The apex of the angle is rounded or stepped Instead of being sharp.
- III. Out of squareness: The both the flanges of a beam or channel are to be parallel and the flanges are to be at right angles to the center line of web. . (Back of square and centerline of web are to be parallel.
- IV. Waviness: uneven surface of flange of web in structural is called waviness.
- V. Camber: The convex curvature along the length of the structural.
- VI. Sweep: The concave curvature along the length of the structural.
- VII. Scabs: Scabs are irregularly shaped, flattened protrusions caused by splash, boiling or other problems from casting.

3.0 Present Inspection Scenario:

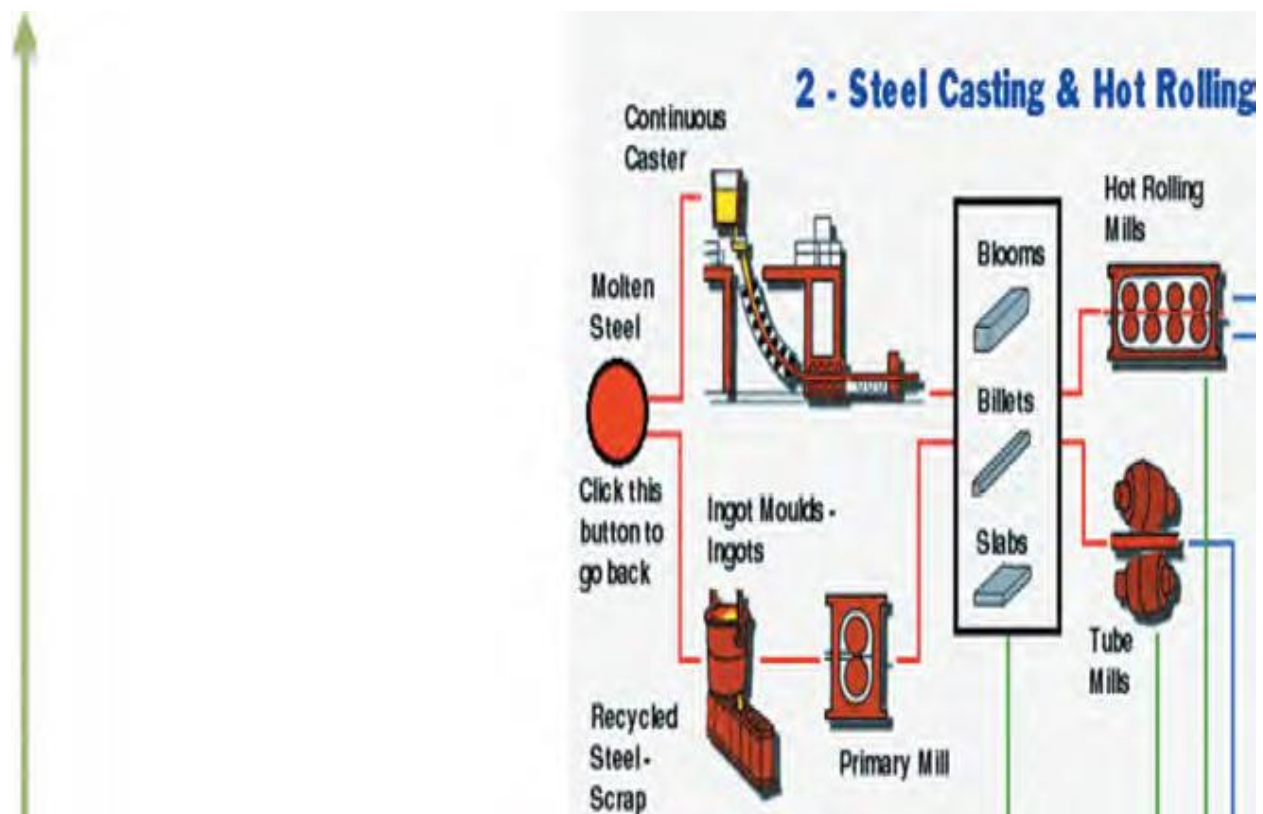
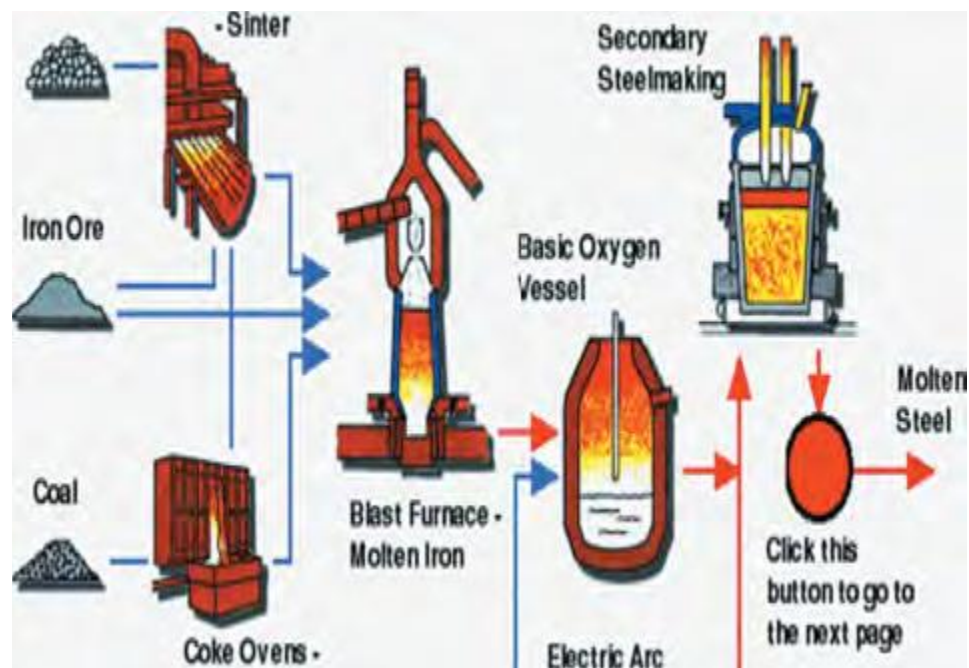
These products are inspected mostly during their production and cross checking in stack in the yard. These products are manually inspected for physical deformities or defects in each product.

This manual process causes delay in the process to declare the steel Grade and dispatching the same to the customer or to the branches.

4.0 Proposed Inspection Scenario:

In the process line, Hi resolution cameras may be fitted and there may be computer vision analytics software to identify the defects with proper AI training. The AI Software shall classify the defects. This will save lot of time for production and improves the productivity. This ultimately contributes to the bottom line of the company.

5.0 Photos in the Process Line:



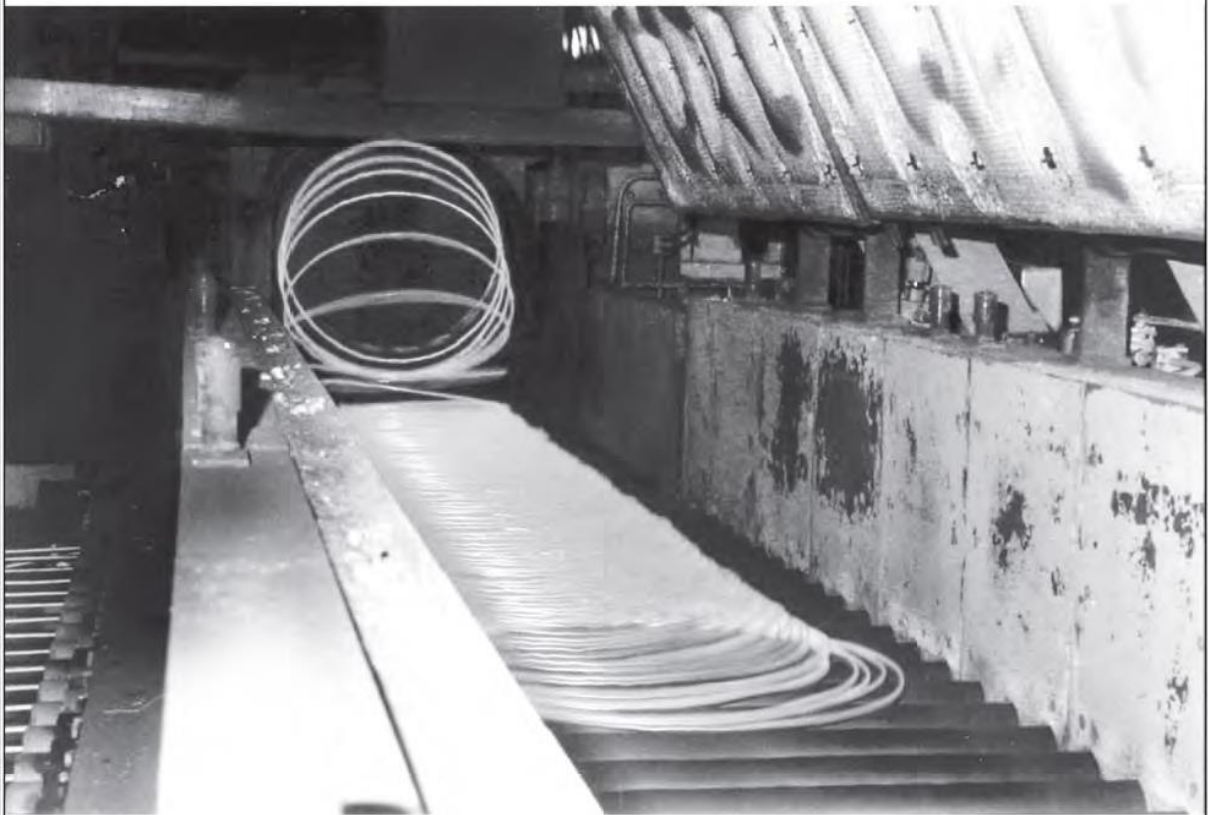


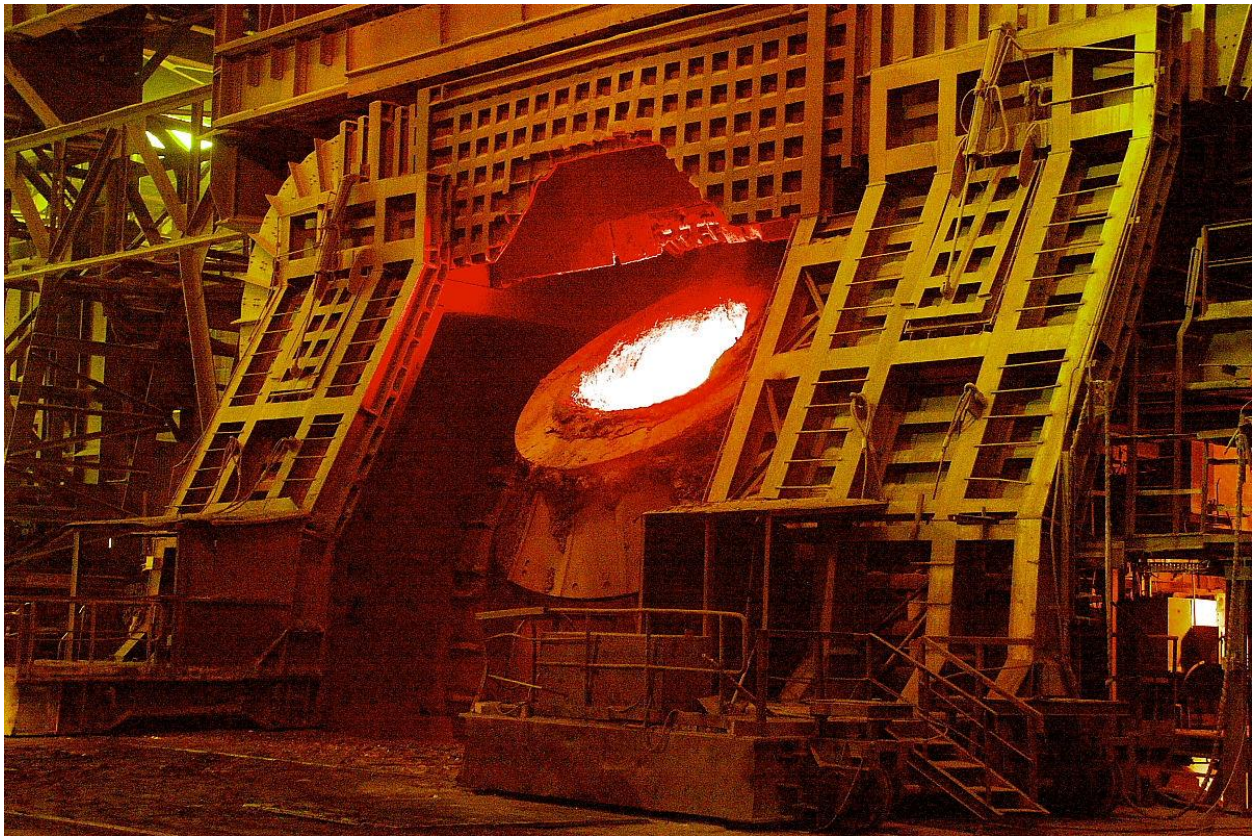
Light Medium and Merchant Mill

Medium Merchant and Structural Mill



WIRE ROD MILL







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