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Application of Quality Control Tools and Finite Element Analysis for Reducing Edge Wave Defect in Hot Rolled Steel

T. Anita[1], Lokesh Singh[2]
[1]*Research Scholar*, [2]*Associate Professor & head*
[1, 2] Department of Mechanical Engineering, GD RCET, Bhilai, Chhattisgarh, INDIA.
[1]anita.4992@yahoo.com, [2]lokeshsingh25@gmail.com

***Abstract*—In this paper represents a work of the different causes responsible for formation of edge wave in a hot rolled steel plate and measures to be taken to reduce the effect of these causes for improvement in the overall production of rolled plate. Hot rolled plate of plate mill display wavy edge defects that are generated after the finishing stand. Quality Control (QC) tools used in this investigation process are the Pareto chart Cause and effect diagram and Brainstorming for evaluation of various causes leading to the formation of edge wave defect to find solutions over these problems for improvements in production quality and enhancing plate mill productivity using this method affected by providing a masking near the edge of the steel plate at the end of finishing mill in the water spraying cooling process .The effectiveness of this procedure is investigated by finite element analysis.**

***Keywords*- Hot rolled plate, Quality control tools, Finite Element Analysis, Edge wave Defect, Edge masking**

I. Introduction

Hot Rolling is the process of plastically deforming metal by passing it between rolls. The metal is subjected to high compressive stresses as a result of the friction between the rolls and the rolling process metal surface. This is one of the most widely used process among all the metal working process because it's higher productivity and low cost. It generates large surface area and therefore is useful for mass production of flat as well as shaped steel products. Defects on the surface of steel plates are one of the most important factors affecting the quality of steel plates. The research has been carried out at Plate mill of Bhilai Steel Plant, SAIL to minimize the defects in hot rolling plate. During production of steel plates in plate mill is facing rejection problem for plate having grade of IS2062-250BR. The major rejection is due to the edge wave defect (Fig.1) which contributes up to1.34% from 4.10% of total rejection production.

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Fig 1 Edge Wave Defect in Steel Plate

II. Quality Control Tools and Techniques

The Quality control is aimed to satisfy the customers by delivery of defect free products. Quality management can be used as a competitive advantage for an organization. According to ISO 9001:2008, organizations should ensure that customer requirements are determined, to ensure their satisfaction. Thus, organizations need to improve their processes and for that use a set of practices, which include various techniques and tools, including most importantly quality tools. The tools and techniques most commonly used in process improvement are

A. .*Pareto chart*

A Pareto chart is drawn using the rejection data of plate mill is shown in Fig. 2 It is very clear from the figure that the Edge Wave defect found to be the major defect among all the defects and its contribution is 32.71% of total rejection tonnage. Rejection percentage of total production is 1.34%. It is primary requirement to focus on minimization of rejection percentage due to edge wave defects.

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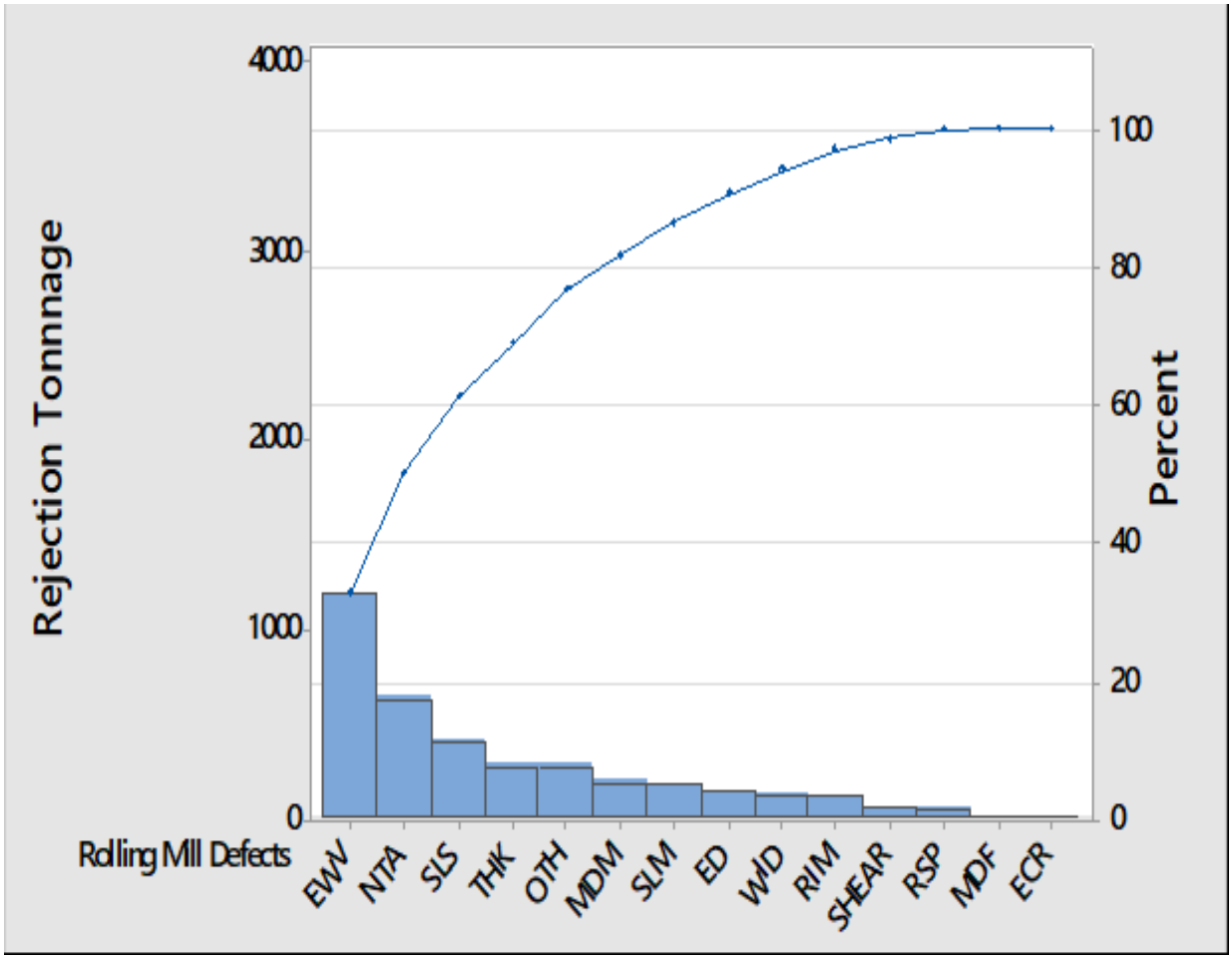

Fig 2 Pareto Chart of Rolling Mill Defects

B. Cause and Effect Diagram

The possible Causes for this defect due to various parameters and processes are foundout with the help of Cause-Effect diagram shown in Fig.3The diagram is a tool to show systematicrelationship between a result or a symptom or an effect and its possible causes. It is an effective tool to systematically generateideas about causes for problems and to present them in a structured form. In this way root cause for the formation of Edge wave defect is determine.

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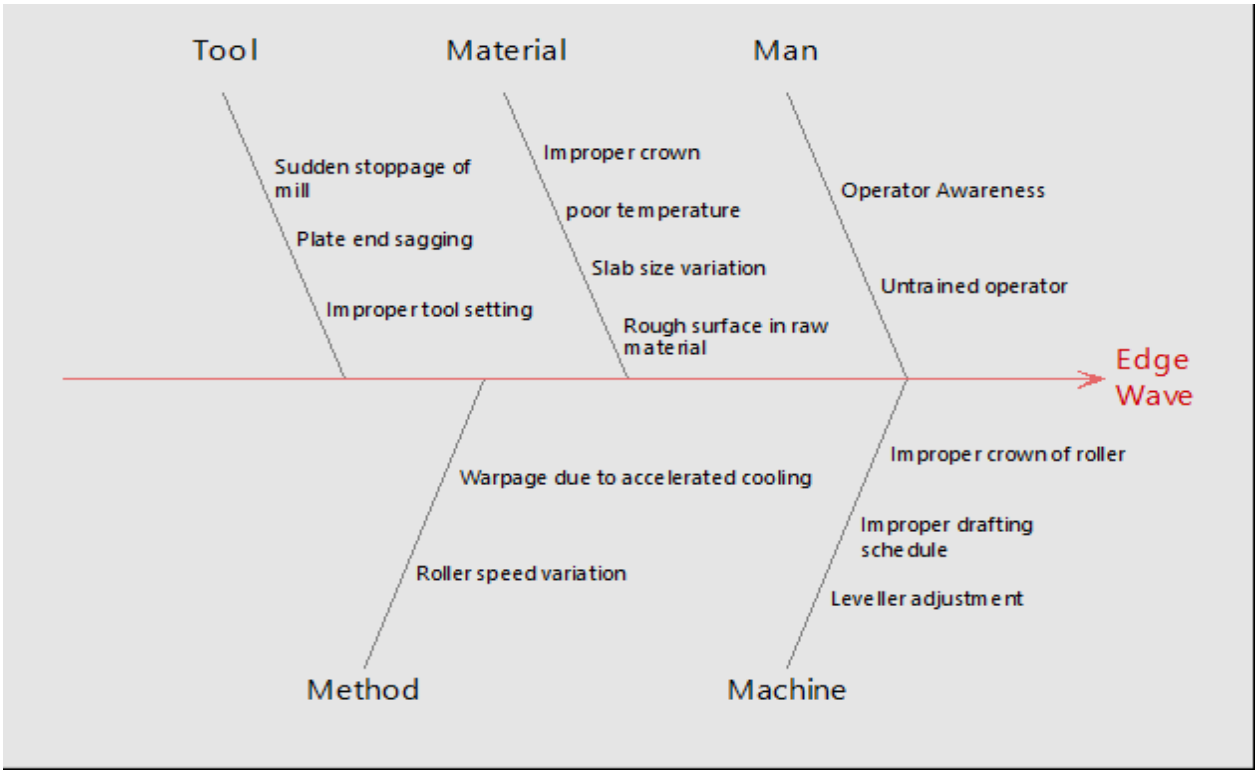

Fig 3 Cause and Effect Diagram for Edge Wave Defect

C. *Brainstorming*

It consists of the group of members in plate mill. There arefive members in brainstorming session from different department which includes Lab In charge, Quality manager, Worker at finishing stand, Inspection supervisor, and Department manager. It involves higher management members and shop floor members.

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Table I Brainstorming Result in Tabulated Form for Edge Wave

S. No	Causes	Lab Incharge	Quality Manager	Worker at Finishing stand	Inspection Supervisor	Department Manager	Rating	Rank
1	Warpage due to accelerated cooling	Yes	Yes	Yes	Yes	Yes	5	1
2	Improper crown of roller	Yes	Yes	No	Yes	Yes	4	2
3	Operator awareness	Yes	Yes	No	Yes	No	3	3
4	Rough surface in raw material	Yes	Yes	No	No	No	2	4
5	Plate end sagging	No	No	Yes	No	No	1	5

After brain storming session it was concluded that warpage due to accelerated cooling major cause for edge wave. The necessary remedial action was made in production of plates in plate mill.

II. Corrective improvements and preventive measures

The plate's edges were masked during the accelerated cooling for improvement of the temperature uniformity of the hot rolled steel plate. The effectiveness of this procedure is investigated by finite element analysis.

A. *Edge Wave (EWV)*

If rolls are elastically deflected, the rolled plates become thin along the edge, whereas at centre the thickness is higher. Similarly, deflected rolls results in longer edges than the centre. Edges of the plate elongated more than the centre. Due to continuity of the plate, the centre is subjected to tension while edges are subjected to compression. This leads to waviness along edges.

B. Edge Masking

Edge Masking is thought to be an effective process for reducing residual stress on ROT. It needs to install an extra device on the ROT to shelter the cooling water nozzles above or below the edge of the plate. The steel plates are produced by rolling followed by accelerated cooling or inline direct quenching in order to obtain high strength, high toughness and good weldability. The high strength and toughness can be attributed to the fine and uniform acicular ferrite microstructure in steel. The accelerated cooling process results in complicated thermal stress and distortion in steel plates. In order to maintain dimensional and shape accuracy, it is critical to control the uniformity of cooling during the process. The plate's edges were masked during the accelerated cooling step for improvement of the temperature uniformity of the steel plate. It may take months or years for engineers to find out appropriate edge masking amounts to decrease the

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distortion of the plates.

C. *Finite Element Analysis (FEA)*

Modeling and analysis of hot rolled plate

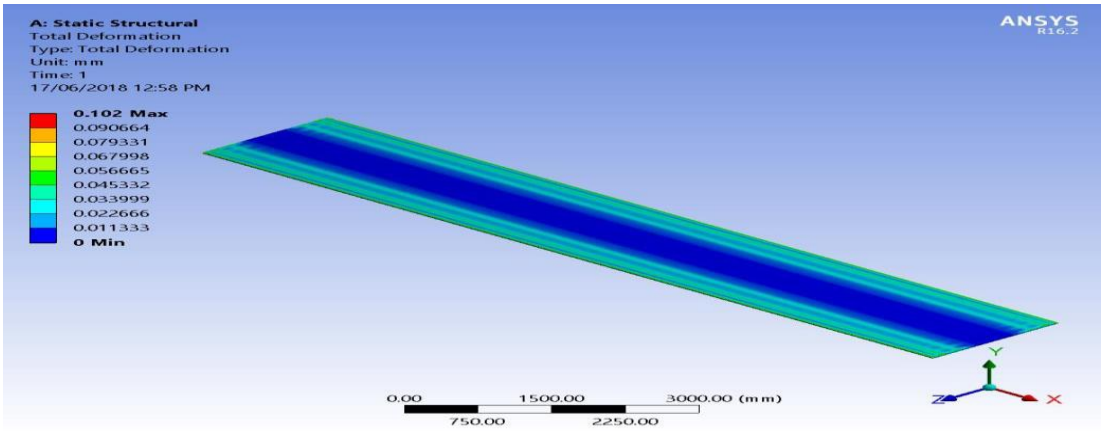
- Software used : ansys 16.2
- Type of model : 3D
- Type of analysis : 3D static structural

1. Analysis of without masking edge of plate
   - Material : Mild steel
   - Modeling software : creo / parametric
   - Geometrical properties
     - Length : 12500 mm
     - Thickness : 25 mm
     - Width : 2500 mm

Results of Without Masked Region

Based on the basic model, several finite element models are established to analyze the effect of the several cases in reducing residual stress. Several cases are considered to determine the best conditions. The conditions of edge masking are of different widths of masking on the edge cooling refers to a lower density of water jets on cooling zone than intensive cooling. The set water cooling zone at posterior of the ROT is different with air cooling. Initial transverse. Every condition of the models is compared with the finite element model to determine the best conditions.

The Fig.4 (a) and (b) has been shows the results of total displacement and residual stress generated in steel plate which is obtained from ANSYS 16.2 simulation software for without masking surface of steel plate.



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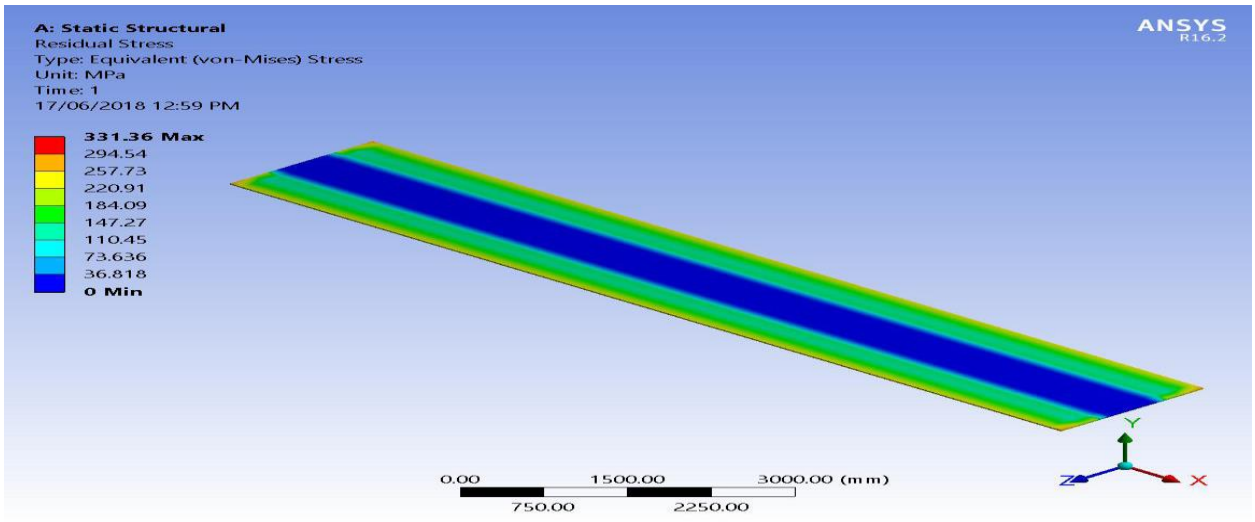

Fig. 4 Without Masking (A) Displacements of The Side Surface
(B) Residual Stresses Generated in the Surface

2. Analysis of with masking edge of plate
   - Material : Mild steel
   - Modeling software : creo / parametric
   - Geometrical properties
     - Length : 12500 mm
     - Thickness : 25 mm
     - Width : 2500 mm
     - Edge masking width : 300 mm

Results of With Masked Region

The Fig.5 (a) and (b) has been shows the results of total displacement and residual stress generated in steel plate which is obtained from ANSYS 16.2 simulation software for with different masking surface on steel plate.

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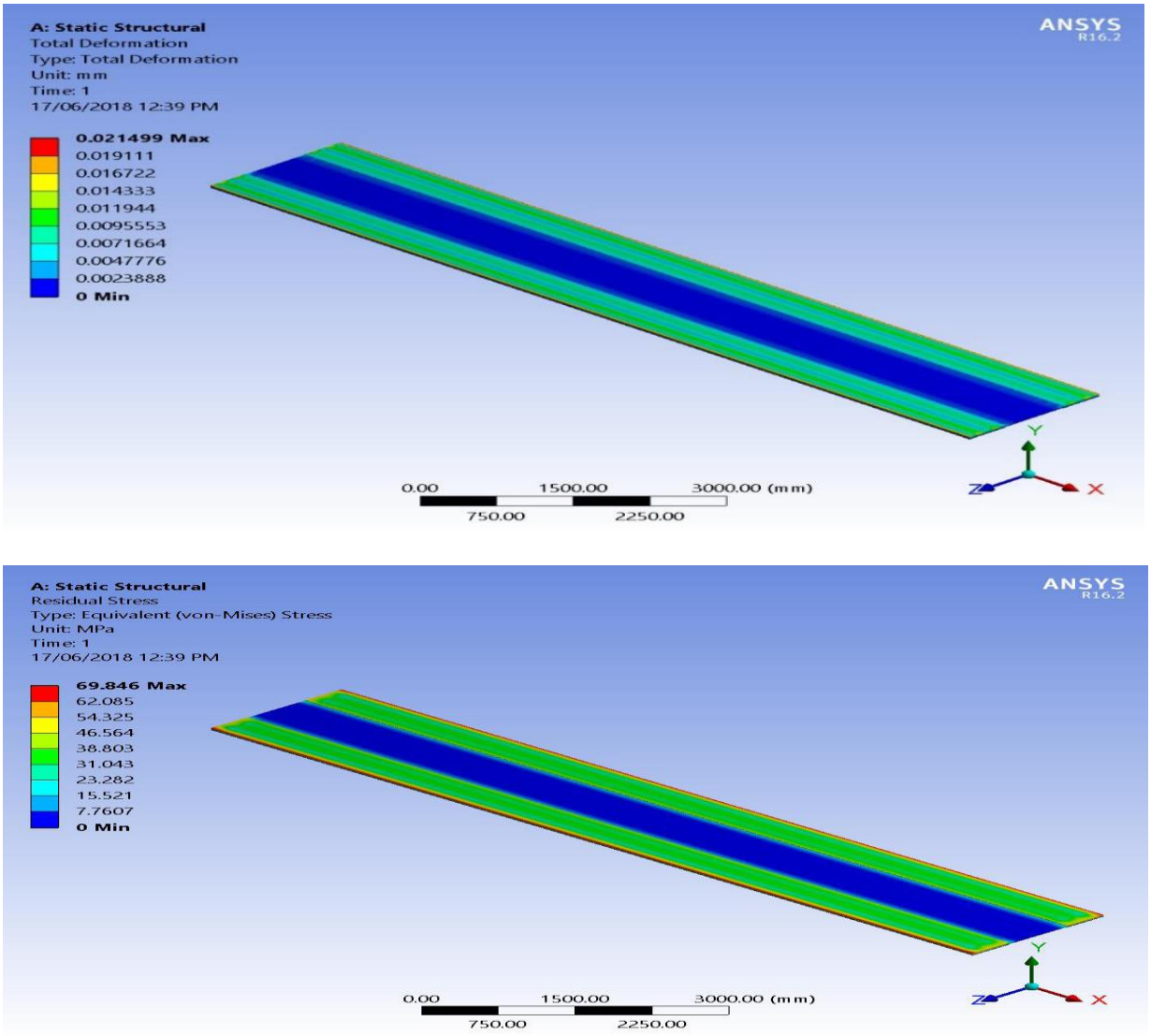

Fig. 5 With Masking (A) Displacements of The Side Surface
(B) Residual Stresses Generated in the Surface

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III. Result and Discussions

The results obtained from ANSYS 16.2 used to predict the deformation and stress developed in plate with and without masking region. In case of without masking of steel plate surface displacement and residual stresses are developed on the edge of steel plate increasing the chances of edge wave defect formation.

In this work assumption have been providing a suitable edge masking on the edge of the steel plate, the residual stress and displacement levels on the edges can be greatly reduced.

- Maximum stress and displacement developed in without masked edge of the steel plate 331.36MPa and 0.102000mm.
- Maximum stress and displacement developed in with masked edge of the steel plate 69.846MPa and 0.021499 mm.

IV. Conclusion

The corrective identification of the Edge wave defect at the initial stage is essential for taking remedial actions. This paper presents the systematic approach to find out the root cause of one of the major defect Edge wave in plate mill of Bhilai steel plant . The origin of the edge wave was identified by Quality Control tools. Finally it was found that warpage due to excessive cooling was the root cause for this major defect. Finite element analysis was done in ANSYS software, after analysis of ANSYS software the optimum value of width of edge masking was 300mm taking for reducing distortion of steel plate. This systematic study proves that by means of effective analysis of tools and processes, it is possible to eliminate/control the edge wave defects.

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