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Thermal Analysis of Hot Rolled Steel Plate to Minimized the Edge Wave Effect by Using Edge Masking on Both Ends

M. S. Rajeev[1]*, Vishal Rastogi[2]

[12]Department of Mechanical Engineering, Shri Shankaracharya Engineering College, Junwani, Bhilai, C.G., India.

Abstract

The effect of an increment of water flow is translated into an increment of the thermal drop in the steel plate, but more clearly in center of the steel plate than in the edges. This can be explained by a non-uniform water distribution having a higher flow in the edges probably due to the water coming from in the center to the drainers. Residual stress is then generated by non-uniform cooling, which influences the shape of the plates. The shape of high-strength steel plates is more difficult to correct after cooling to room temperature than that of low-strength steels. Therefore, reducing the thermal buckling and stress of steel plates on the run-out table (ROT) is important.

Keywords: *Thermal Analysis; ROT; Wave Edge; Rolling.*

* *Corresponding author*

1. Introduction

Due to economic globalization, industry is facing severe competitors. To get success in this environment, the industry must significantly improve productivity and quality and reduce defect less product and waste during production. In addition to economic consideration requirement also strongly derive steel industry toward that direction therefore, there is an urgent need from steel industry for effective process quality control. Since the rolling operation is often the last process step of raw materials of several products, hence the scrap from defects at rolling stage is very costly and the quality control of rolling process has a vital role. The research has been carried out at Plate mill of Bhilai Steel Plant, SAIL to minimize the defects in hot rolling plate.

Rolling is a forming operation where the metal is compressed between two rotating rolls for reducing its cross-sectional area. The reduction that can be achieved with a given set of rolls which is called rolling stand. Two types of rolling like hot rolling and cold rolling of the metals are affecting the process of forming. In this work the various parameters which effect the hot rolling process are being included and analysed. [4]

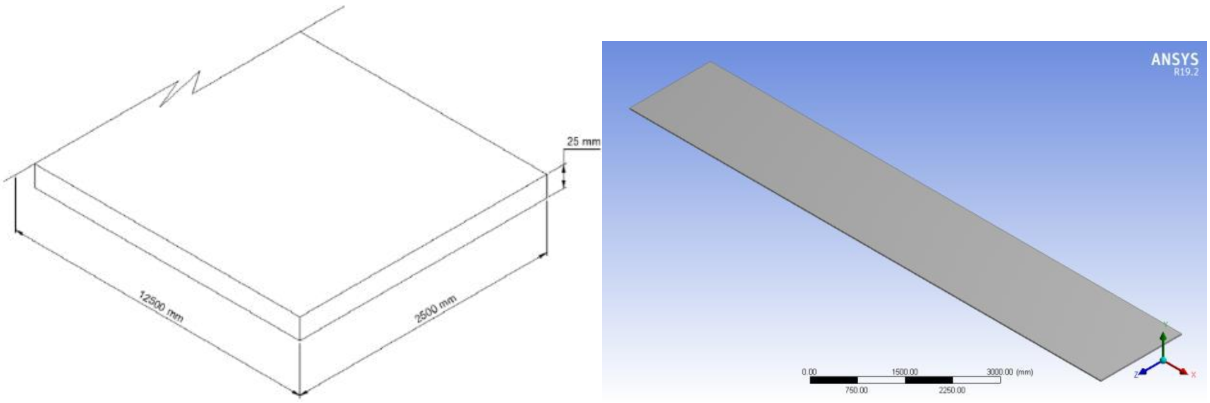
Figure 1. Edge Wave Defect in Steel Plate

2. Methodology

In this chapter the simulation tools are needed to accelerate the pace of understanding the mechanics behind the process and the search for processing parameter to achieve high flatness of the steel plates. The distortion of the steel plates is investigated by finite element analyses in this work. Scheil's additivity rule and Johnson-Mehl-Avrami-Kolmogorov (JMAK) model are considered in the phase transformation model of the thermoelastic-plastic finite element program.

2.1 Modelling of Flat Plate (Without and With Masking)

In this section will define the model of the as shown in Figure 2 shows a systemically steel plate without and with edge masking conditions. A Cartesian coordinate system is also shown in the figure. The surfaces masked for reduced cooling is shown by dark region.



(a) (b)

Figure 2. Modeling of steel plate without masking (a) Dimensional view of plate (b) Modeling view of plain or without masked steel plate in Ansys 19.2

3. Results and Discussion

The results obtained from Ansys 19.2 used to predict the thermal buckling, thermal stress and strain energy developed in plate with and without masking region.

In order to validate the accuracy and credibility of present work. The convergency test or the grid impendency test solution has been employed to check the accuracy of mesh model and confirm present model. The test has been carried out with different size of grid or element i.e., 477, 1890, 7560 and 30240. From Table 5.1 to Table 5.3, it has been shown as the value of thermal buckling, thermal stress and strain energy increases as increases of the number of elements 477 to 1890. The values remains nearer or less than 1% error as the grids or elements increases beyond 1890. Hence the results or model has been verified and mesh size has been taken as 30240 i.e., finest for all cases.

Table 1. Grid impendency test performed for thermal buckling under thermal load on flat plate (without mask)

T	477	1890	7560	30240	% Error	% Error	% Error
0	0.021	0.022	0.022	0.022	5.14%	0.31%	0.35%
100	0.047	0.050	0.050	0.050	5.13%	0.32%	0.34%
200	0.074	0.078	0.078	0.078	5.13%	0.32%	0.34%
300	0.101	0.106	0.107	0.106	5.13%	0.32%	0.35%
400	0.127	0.134	0.135	0.134	5.13%	0.32%	0.35%
500	0.154	0.162	0.163	0.162	5.13%	0.32%	0.34%
600	0.181	0.191	0.191	0.190	5.13%	0.32%	0.35%
700	0.207	0.219	0.219	0.219	5.13%	0.32%	0.35%
800	0.234	0.247	0.248	0.247	5.14%	0.32%	0.35%
900	0.261	0.275	0.276	0.275	5.13%	0.32%	0.34%
1000	0.287	0.303	0.304	0.303	5.13%	0.32%	0.34%

Table 2. Grid impendency test performed for thermal stress under thermal load on flat plate (without mask)

T	477	1890	7560	30240	% Error	% Error	% Error
0	267	269	269	268	0.93%	0.19%	0.35%
100	609	615	614	611	0.93%	0.19%	0.35%
200	951	960	958	955	0.93%	0.19%	0.35%
300	1293	1306	1303	1298	0.93%	0.19%	0.35%
400	1636	1651	1648	1642	0.93%	0.19%	0.35%
500	1978	1996	1992	1985	0.93%	0.20%	0.35%
600	2320	2342	2337	2329	0.93%	0.19%	0.35%
700	2662	2687	2682	2672	0.93%	0.19%	0.35%
800	3004	3032	3026	3016	0.93%	0.19%	0.35%
900	3346	3378	3371	3359	0.93%	0.19%	0.35%
1000	3688	3723	3716	3703	0.93%	0.19%	0.35%

Table 3. Grid impendency test performed for strain energy under thermal load on flat plate (without mask)

T	477	1890	7560	30240	% Error	% Error	% Error
0	1.16E+08	1.16E+08	1.16E+08	1.16E+08	0.01%	0.01%	0.05%
100	6.03E+08	6.03E+08	6.03E+08	6.03E+08	0.01%	0.01%	0.04%
200	1.47E+09	1.47E+09	1.47E+09	1.47E+09	0.01%	0.01%	0.05%
300	2.72E+09	2.72E+09	2.72E+09	2.72E+09	0.01%	0.01%	0.05%
400	4.35E+09	4.35E+09	4.35E+09	4.35E+09	0.01%	0.01%	0.05%
500	6.36E+09	6.36E+09	6.36E+09	6.36E+09	0.01%	0.01%	0.04%
600	8.75E+09	8.75E+09	8.75E+09	8.75E+09	0.01%	0.01%	0.04%
700	1.15E+10	1.15E+10	1.15E+10	1.15E+10	0.01%	0.02%	0.04%
800	1.47E+10	1.47E+10	1.47E+10	1.47E+10	0.01%	0.01%	0.04%
900	1.82E+10	1.82E+10	1.82E+10	1.82E+10	0.01%	0.02%	0.04%
1000	1.79E+10	1.79E+10	1.79E+10	1.79E+10	0.01%	0.02%	0.04%

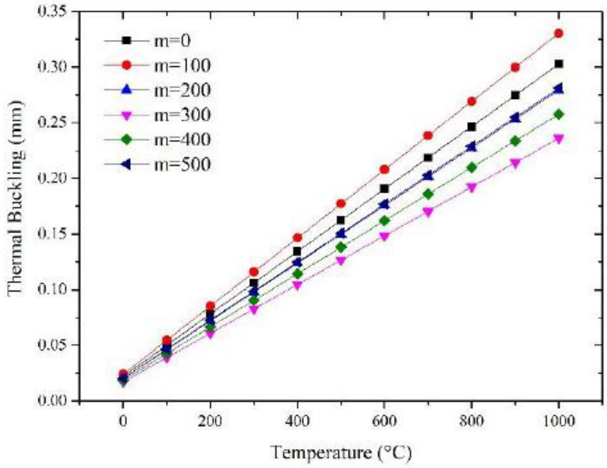


Figure 3. Variation of thermal buckling under variation of thermal load without and with masked surface with different width

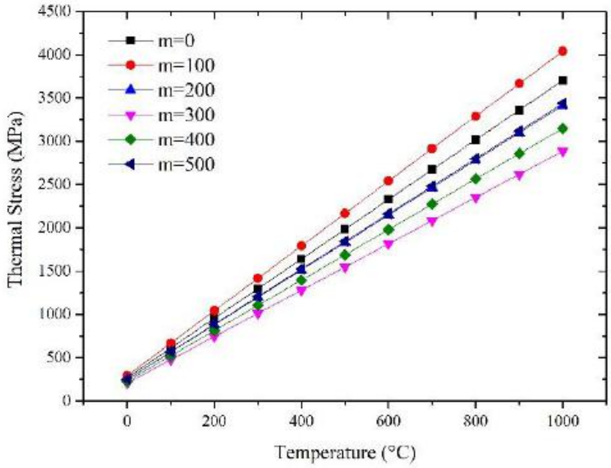


Figure 4. Variation of thermal stress under variation of thermal load without and with masked surface with different width

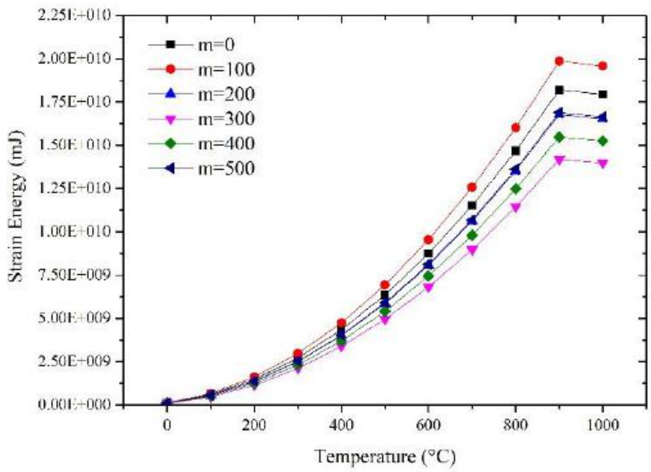


Figure .5 Variation of strain energy under variation of thermal load without and with masked surface with different width

4. Conclusion

A thermal analysis for predicting edge wave behavior of hot rolled steel during ROT cooling has been investigated using a three-dimensional finite element analysis (FEA). The thermal buckling, thermal stress and strain energy has been determined with respect to the variation of thermal load simultaneously during the computation, and the edge wave of the hot rolled steel is reproduced successfully based on the proper thermal boundary conditions. The computed results demonstrated that the distribution of the thermal stress on the transverse of the steel plate after cooling is stress on the edges and on the central section. Thus, the flatness of the steel plate tends to develop edge waviness according to shape theory. In this analysis it has been observed that the thermal buckling, thermal stress and strain energy is decreased with presence of edge mask on its ends. A per maximum strain energy theory, the failure will occur when the strain energy per unit volume due to the applied stresses in a part equals the strain energy per unit volume at the yield point in uniaxial testing. The minimum thermal buckling, thermal stress and strain energy is found at the edge masking width is 100mm. The simulated results also showed that both increasing the width of the edge mask and removing the inspectors could reduce the edge wave of the final product. This present program has a potential to be used as a tool to predict qualitatively the deformation and residual stress of steel plates to reduce the rejection of plates due to bending defects.

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