Influence of the Processing Conditions on the Hot-Rolled Manganese Steel Sheet Surface Quality

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Abstract - The subject of interest of this paper is the surface quality of manganese steel sheets. The sheets are produced by hot rolling, on an industrial scale, in the Makstil AD Steel Mill in Skopje.

Several surface defects were detected; however, the appearance of edge waves in the hot rolling process was especially analyzed. For this purpose, the change of the geometrical parameters of manganese steel sheets was monitored during the hot rolling process and measurements of the sheet flatness were done. Furthermore, some of the more important technological parameters of the rolling process were followed – reduction degree, temperature, velocity and rolling force, in each of the passes, in the course of the plastic deformation.

The knowledge obtained indicates that sheets with quality surface and without edge waves are produced with higher rolling velocities, higher rolling temperatures and lower rolling forces. This finding can serve for defining optimal sheet processing conditions, at which absence of edge waves and satisfactory flatness quality of the steel sheets can be accomplished.

Keywords - Sheet Surface Quality, Edge Waves, Manganese Steel Plates, Hot Rolling.

1. Introduction

Today, the quality of steel sheets produced by hot rolling is becoming a more and more important characteristic, which defines the market competitiveness. As a result, a greater commitment in the analysis of the parameters influencing the steel sheet quality becomes a necessity [1, 2]. Faced with the possibility of the appearance of various defects, surface and internal, the companies processing steel by hot rolling are exploring different ways to influence the production of sheets with improved quality [3, 4]. Systems capable to detect and locate the defects are also developed. Furthermore, the influence of separate parameters on the appearance of defects are closely studied, in order to reduce the defects and increase the quality of the sheets, as well as their surface [5]. The most frequent surface defects occurring are flatness, longitudinal and transverse bending, symmetrical and asymmetrical edge waves, laps, rolled-in scale, scabs, tearing, longitudinal cracking, buckling, etc. [6-8].

In this paper, an analysis of the appearance of a special type of defect – edge waves on the steel sheet surface was done. Edge waves can be defined as a unevenness of the sheet surface, when the thickness discrepancy of the sheet is larger than 1,2 mm [9, 10]. The most important parameters of the process of hot rolling in the steel mill Makstil in Skopje were followed. The ultimate goal of this analysis is the discovering of the causes for the appearance of edge waves and their elimination, which would improve the flatness of the steel sheet surface and their surface quality, in general.

2. Experimental

The surface quality of the steel sheets and the critical processing parameters of the hot rolling production process in Makstil AD were followed: chemical composition of the input material, geometrical parameters of the input and output material, along with the technological parameters of the rolling processes. Statistical analysis of 34 rolling processes of steel sheets, with identical chemical composition, equivalent dimensions before the processing and corresponding final thickness of the sheets was done.

The processed manganese steel slabs, according to EN 10025-2, are labeled as S355J2, S355J2G3 and S355J0 [11]. The analyzed batches had approximately equivalent chemical composition of steel. The chemical composition of the steel sheets is given in Table 1.

The values of the carbon equivalent coefficient are estimated with the expression [12]:

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}, \qquad (1)$$

and range from 0,381 to 0,4.

Chemical composition, %					
C	**Si**	**Mn**	**P**	**S**	**Cr**
0,13-0,16	0,23-0,32	1,22-1,16	0,005-0,011	0,005-0,008	0,028-0,040

Table 1. Chemical composition of the sheets.

The imput materials are steels slabs with the following geometrical parameters: thickness – 171 mm, width – 910 mm and length – 1736 mm. During the rolling process, a sheet with thickness of 6,32 mm is produced. The rolling is done in 14 passes, with mixed technological rolling scheme. Thus, the final dimensions of the steel sheet are: thickness – 6,32 mm, width – 2814 mm and length – 15265 mm.

3. Results and discusion

The most important parameters of the hot rolling process were followed – velocity, temperature and rolling force. In all rolling processes observed, the rolling velocity varied from 1,4 to 3,5 m/s. At the beginning of the process, the velocities are to some extent lower – in the range from 1,4 to 1,7 m/s, whereas in the second part, the velocities are higher, around 3 m/s. The change of the rolling velocity vs. the number of passes is presented on Fig. 1.

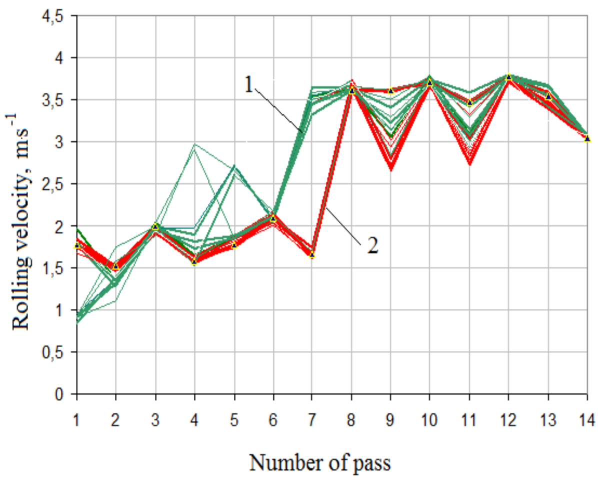

Figure1. Rolling velocity of steel sheets vs. number of pass 1 – sheets without and 2 – sheets with edge waves.

The sheets without edge waves are highlighted with green and marked with 1, whereas with 2 and red – the sheets with edge waves. As can be seen from the Fig.1, at higher rolling velocities, most of the sheets are with good quality. However, the rolling velocity is not a determining factor for the appearance of edge waves.

From Fig.1 it can be observed that among the sheets with edge waves, there are several rolled with higher velocities. On the sheets with edge waves, a lower rolling velocity in the seventh pass can be noted, which coincides with the rotating of the sheet for 90^{o}, in accordance with the mixed rolling scheme.

At the beginning of the rolling process, the slab temperature is approximately 1170 ^{o}C, with slight variations. In the course of the rolling the temperature drops and in the final stage, it extends from 540 to 740 ^{o}C, wirh rare exceptions, when it is above 740 ^{o}C. The statistical analysis of the temperature change during the rolling of sheets with discernible edge waves has shown that theses sheets were rolled at lower temperatures in the course of the entire process.

In the following section, the temperature of the plates during the rolling process is shown. The changes of the temperature throughout the rolling process, when sheets with edge waves were produced, are given on Fig. 2 and, in the case of sheets without edge waves – on Fig. 3.

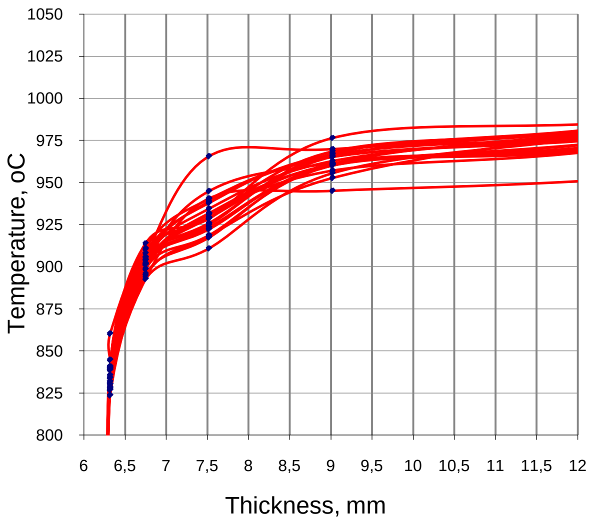

Figure 2. Temperature change during the processing of steel sheets with edge waves.

On Fig.3 it can be noticed that all followed processes, for example the one with sheet thickness of 11 mm, were conducted at temperature lower than 1000 ^{o}C, namely between 950 and 980 ^{o}C. On the other hand, the comparison of the temperature changes data for the process of rolling sheets without edge waves (Fig. 3) with equivalent thickness of 11 mm, reveals rolling temperatures in the range from 1000 to 1020 ^{o}C. The same can be noted for thickness of 7 mm – the sheets with edge waves were rolled at temperatures in the range from 900 to 925 ^{o}C, whereas the sheets with good quality were rolled on temperatures between 925 and 950^{o}C.

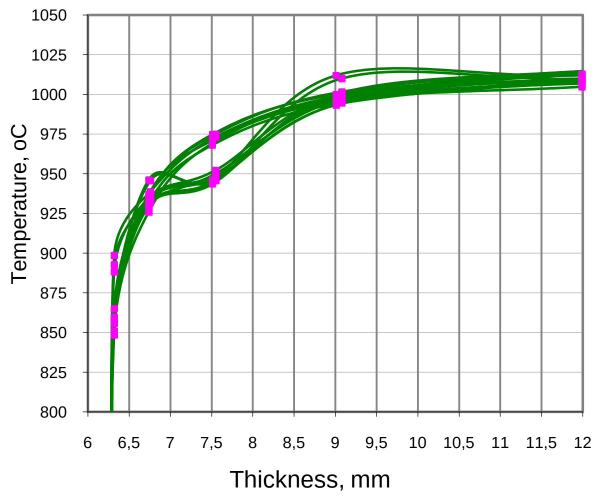

Figure 3. Temperature change during the rolling of steel sheets without edge waves.

For better comprehension of the data, the temperature change in the course of rolling of all steel sheets is presented on Fig.4: the sheets without edge waves are highlighted with green and the sheets with edge waves – with red.

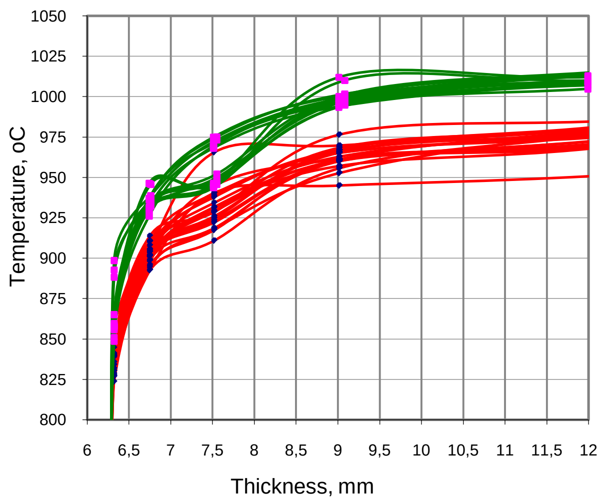

Figure 4. Temperature change during the rolling of all steel sheets.

The data regarding the rolling force are monitored in each pass, predicted and realized. The beggining of the rolling is characterized with force between 1500 and 2500 t. After that, the force is increased and maintained in the range from 2500 and 3500 t. The force values in can, on occasion, be lower than the given range and, rarely, slightly above it. In the two last passes, the force is reduced, with values below 2500 t.

The rolling forces applied in the production of steel sheet with appearance of edge waves are shown od Fig.5. For a specific pass, the rolling force can differ for a maximum of 500 t.

The rolling forces for steel sheets with good quality and without edge waves are given on Fig. 6.

The values of the rolling forces applied on these sheets are lower in comparison to the forces observed on sheets with appearance of edge waves.

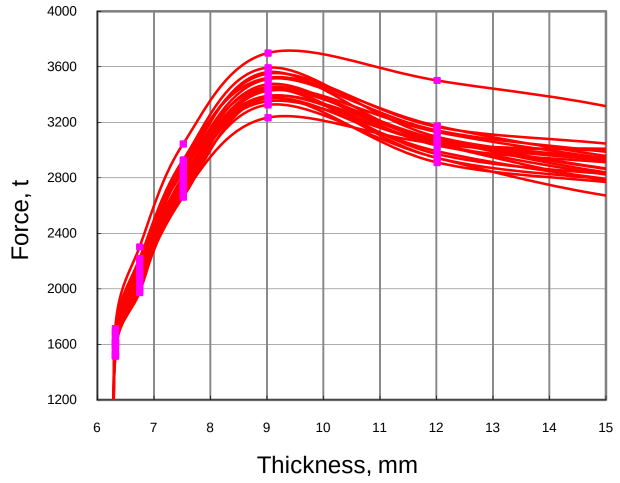

Figure 5. Rolling forces for steel sheets with edge waves.

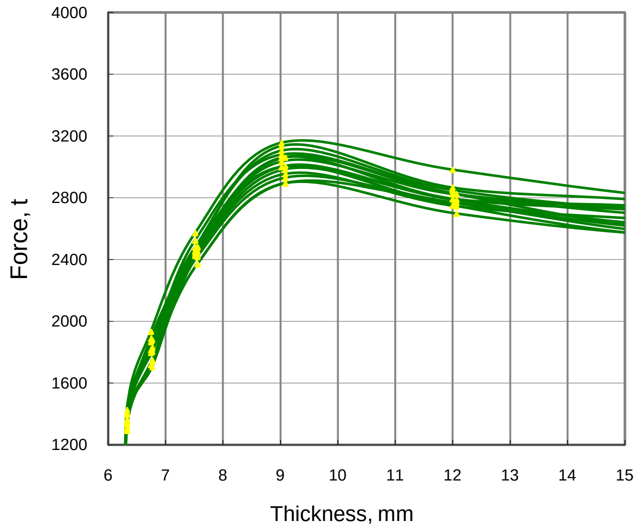

Figure 6. Rolling forces for steel sheets without edge waves.

It is obvious that the sheets rolled with lower force have better surface quality. In almost all of the analyzed runs, the steel sheets with satisfactory surface quality and absence of edge waves were rolled at lower forces. In general, the forces are lower in all passes. The average difference is around 300 t and the maximal is above 400 t. More detailed overview of this can be seen on Fig.7.

The careful observation and analysis regarding the edge waves has shown that a relation between the appearance of edge waves on steel sheets and the applied rolling force for their processing can be established. During the investigation of 34 processes, edge waves have appeared on 20 sheets, produced by rolling with higher force. The remaining 14, obtained at lower rolling forces, are with good surface quality and without appearance of edge waves.

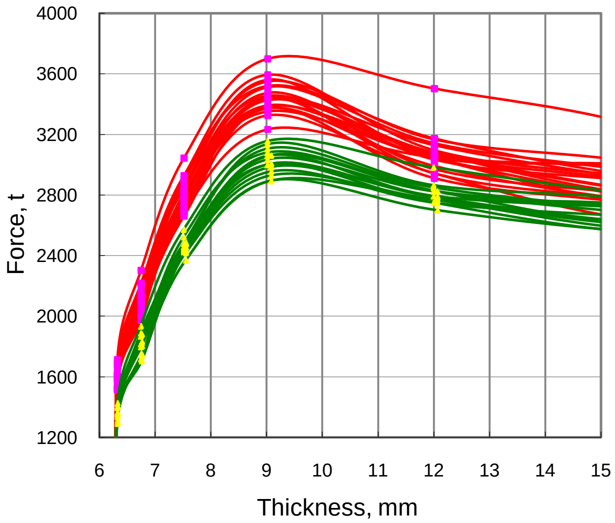

Figure 7. Rolling forces for all steel sheets.

The conducted investigation and analysis on 34 rolling processes with equivalent chemical composition, have shown that edge waves appear more frequently on sheets processed with lower rolling velocities. The study has also shown that edge waves appear on lower rolling temperatures and elevated rolling forces. Certainly, for complete determining of the causes for appearance of edge waves additional analysis of other parameters responsible for this defect is necessary, such as the condition of the rolls, presence of scales, quality of the material, etc. Additional analysis would provide more accurate definition of the optimal sheet processing conditions.

4. Conclusion

The hot rolling processes of manganese steels with final thickness of 6,32 mm were analyzed. In addition, the changes of the most important parameters of the rolling process were followed and especially, their influence on the appearance of edge waves.

From the obtained results, the following can be concluded:

The rolling velocities in the course of the observed processes were in the range from 0,93 m/s to 3,81 m/s. From the total number of steel sheets with edge waves, 90% were processed with generally lower rolling velocities.

The rolling temperatures during the followed processes were between 1170 ^{o}C and 540 ^{o}C. Edge waves were observed on 19 sheets rolled on lower temperatures, which represents 95%, and only on one steel sheet rolled on higher temperature.

It was noted that the increase of the rolling temperature for only 30 ^{o}C results in satisfactory quality of the sheet.

The rolling forces in the course of the processes varied from 1160 t to 3560 t. The edge waves appear on the sheets when higher rolling forces were applied, in 90% of the analyzed runs.

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