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Dry Ice Blasting Method as a Descaling

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Abstract
The scale removing process with acid, generally called as the pickling process, is accepted by the steel producers and applied satisfactorily. However, most of the producers tend to develop scale removing process without acid due to the environmental regulations. In the related literature, some methods were studied for finding eco-friendly solutions. Although these studies seem to be promising, pickling process is still dominant as a descaling process before cold rolling applications. In this study, efficient surface cleaning method which is called as dry ice blasting method was used under different parameters on the carbon steel surface as it might be used instead of pickling process. Results of the experiments were studied by observing cross-sectional microstructure of samples. In addition, before destroying samples for hot mounting application, the surface topographies were measured by non-contact device. Finally, surface roughness values of the samples were showed on figures.

1. Introduction

The formation of the scale is a natural process in which surface of the hot steel alloy is faced with air. While the magnetite and hematite are formed in steel below temperature of 570 °C, at above this temperature, wustite, magnetite and hematite appear on the surface of metal alloy [1]. The chemical composition of the material is less effective in the formation of scale, but the temperature and cooling rate of the material are more effective [2].

The scale layer on the steel is an undesired sh ell because of the quality requirements. Therefore, it should be cleared before cold rolling and coating pro cesses. The scale removal process is called as picklin g process and it needs to use acid for cleaning of carb on steels [3]. Pickling process is the chemical or elec trochemical reaction process that cleans surface of m etal by etching [4]. The HCl and H2SO4 acid is used for carbon steel pickling process while HF and HNO 3 acid is used for stainless steel [5]. However, HCl ac id is widely used by steel producers located in Europ e generally [2]. HCI acid is preferred due to three ma in reasons: its low cost, swift pickling process and ge tting better surface quality after pickling [5].

The most important problem in pickling process with acid is waste of liquor. The waste of this media is hazardous for the environment. Therefore, most of the countries have limit values for discharge of waste [6]. Although the pickling process has been accepted by iron-steel producers, the environmental regulations as well as the operation and maintenance costs of this process urge steel producers to find eco-friendly solutions. For this purpose, gas reduction and slurry blast methods have been developed [7].

Gas reduction method is a chemical process reducing iron oxide under heated atmosphere. There are many studies in the related literature about iron oxide reduction. However, there is limited research on the scale surface on hot rolled steel sheet. The first experiment on hot rolled sample was conducted by Robert M. Hudson. He kept the samples in stainless steel box under the H_2 or H_2-N_2 mixture atmosphere whose temperature was 635 °C throughout 24 hours. Due to the beneficial results of gas reduction method which is published in academic papers, some patents

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have been released related to this method. One of them is construction named Acid-Free Scale Removal (AFSR) line and belongs to Danieli Wean United [8].

AFSR line consists of three main components. The first section of this line is heating section that heats sheet metal up to 400 ˚C. After that, sheet metal is moved by the table roller to the reduction section. In reduction section, reductive atmosphere is supplied by nozzles to the sheet metal surface. Thanks to turbulence effect of reduction atmosphere, most of the oxide is reduced in this area. Finally, sheet metal surface is cooled down in cooling section to prevent oxide layer emergence again [9].

The other method which is alternative to the pickling is slurry blast method. This method uses water-iron pellets mixture as a blasting media and this media is applied to the steel surface by the pressure which comes from rotational movement of dispersion head. Although, one of the challenging conditions of this method is non-homogenous scale distribution on steel surface, it is solved with mounting combination of dispersion head which is developed by The Material Works Company. After blasting process, sheet metal surface is cleaned form residual scale and blasting media with water and blasting mixture can be filtered to use again [7].

In a test report comparing the slurry blasted samples and the pickled samples, different tests are applied to the slurry blasted samples. According to the result, it was decided that the slurry blasting method can be applied instead of pickling process [10].

Although these methods seem to be environment-friendly, slurry blast method has high energy and operation costs [11]. The gas reduction method, on the other hand, has poor descaling properties and requires additional mechanical brushing [12].

In this research, dry ice blasting method, one of the eco-friendly and efficient cleaning methods was used for scale removing. Although there is only one study of the dry ice blasting method on hot rolled carbon steel slab, it is thought that this method can be used for scale removal due to its surface cleaning performance.

Dry ice blasting process is a simple, environment-friendly, low cost and abrasive-free surface cleaning method. Dry ice pellets transmit their kinetic energy to the surface when they blast with air. After pellets bump into surface, their solid phase changes to the gaseous and this is called as sublimation. In this way, dry ice blasting method reduces second waste ratio up to 95% [13]. The most important advantage of cleaning with dry ice blasting method is eco-friendly. After application, the CO_2 gas formation occurs besides contamination leaving of the surface. The CO_2 is not harmful for the environment. However, after dry ice blasting it should not be exceeded the allowed concentration [14].

The temperature of dry ice is -78.5 ˚C under normal conditions. The temperature difference with dry ice pellets and surface creates a thermal shock effect. Due to this effect, contamination of the steel surface is more brittle and bonds between contamination and surface are weaker [15]. The difference between dry ice blasting and other blasting-based cleaning methods is that dry ice blasting method has thermal, mechanical and expansion effects [16].

The application of dry ice blasting on to the steel surface for removal of scale surface was patented in 1994 by Sumitomo Metal Industries Ltd. In this research, inventors applied five different blasting methods to the surface of slab which is 235 mm thickness and 1140 ˚C surface temperatures.

- Method A: Water spraying at 60 ˚C temperature and 150 bar pressure.
- Method B: Stainless steel brushing under 100 kg/m pressure
- Method C: Slurry blasting under 150 bar pressure with iron pellets, which constitute 20% of the total weight, and water at 60 ˚C.
- Method D: Water ice blasting under 20 bar pressure in which the ice dimension is 5 mm.
- Invention Method: Dry ice blasting under 20 bar pressure and 720 kg/h flow rate in which the diameter of ice pellets is 5 mm.

As a result, invention method has a definite solution for removing scale from slab surface. In addition, it presents better solution compared to Method A and Method D, especially Method D [17].

2. Material and Method

The samples were chosen from commercial products of Ereğli Iron-Steel Production Company, widely known as Erdemir. The pseudonym of the samples indicates which properties would have been gained after cold rolling operations. Each sample group has different quality that includes different chemical composition. All samples were taken from coil tail and/or head. The mechanical descaling such as tension leveling were not applied to these samples.

Dry ice blasting was applied to the samples which are shown in Table 1 with fixed pressure of 10 bar. Diameter of dry ice pellet was 3 mm. Dry ice blasting nozzle was approximately at the same distance to all samples and angle between nozzle and sample was about 90°. The experimental mechanism is shown in Figure 1.

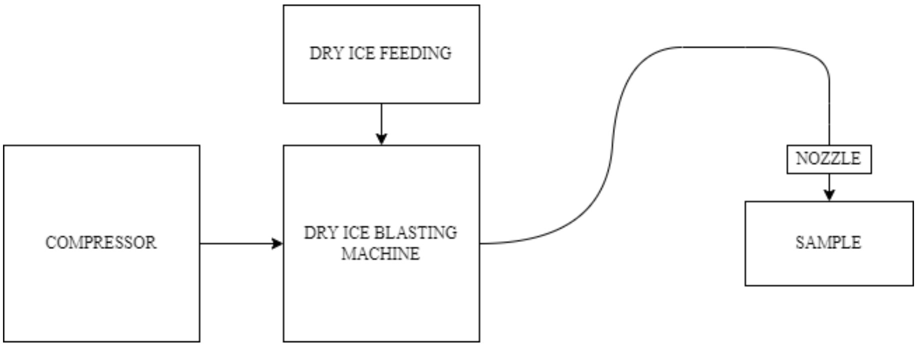

Figure 1. Schematic drawing of the dry ice blasting experiment

Table 1. Dry ice blasting parameters

Samples	Flow Rate (m^3/h)	Time (min)
TNR1	0.5	1
TNR2	2.0	2
TNR3	3.5	3
ICCR1	0.5	1
ICCR2	2.0	2
ICCR3	3.5	3
RP1	0.5	1
RP2	2.0	2
RP3	3.5	3

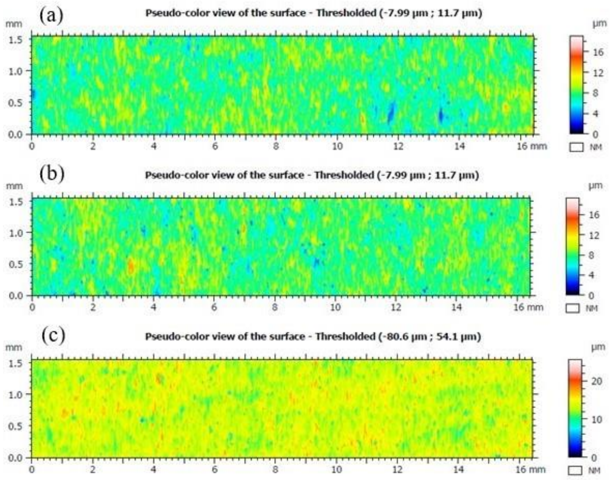

Figure 2. Topography of metal surface a) TNR1, b) TNR2, c) TNR3

3. Results and Discussion

After dry ice blasting process, surface roughness of samples was measured to observe blasting effect on scale layer by Nanofocus MarSurf CM Mobile. The surface topographies are shown in Figure 2, Figure 3 and Figure 4. The surface roughness values with standard deviations after dry ice blasting are listed in Table 2. The same threshold values were chosen in each sample. The top and valley points of surface could be obtained by automatic topography measurement system. Similar morphological features such as depth profile and distribution of points were observed according to the colored scale next to the figures.

The roughness of the surface was decreased by decreasing flow rate value under 2.0 m3/h. It should here be noted that, the critical flow rate value could be higher than 0.5 m3/h. As shown in the Figure 2, Figure 3 and Figure 4, there are no crucial differences between 2.0 and 3.5 m3/h. According to the roughness values which are shown in Table 2, IC CR samples are more stable than TNR and RP sa mples with respect to the Ra values. Since some scale remains on the surface after the dry ice pro cess, the roughness values may be affected.

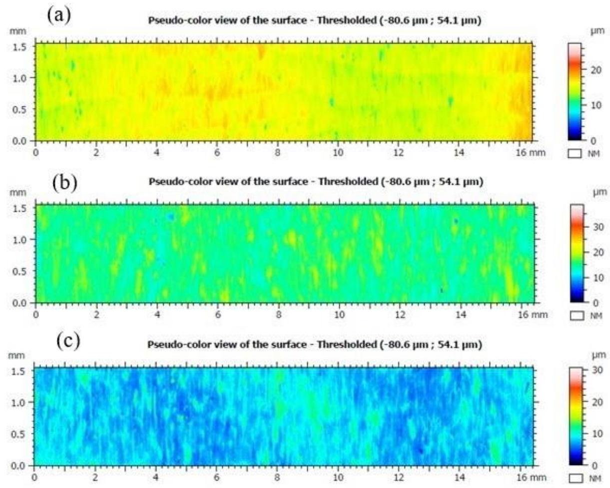

Figure 3. Topography of metal surface a) ICCR1, b) ICCR2, c) ICCR3

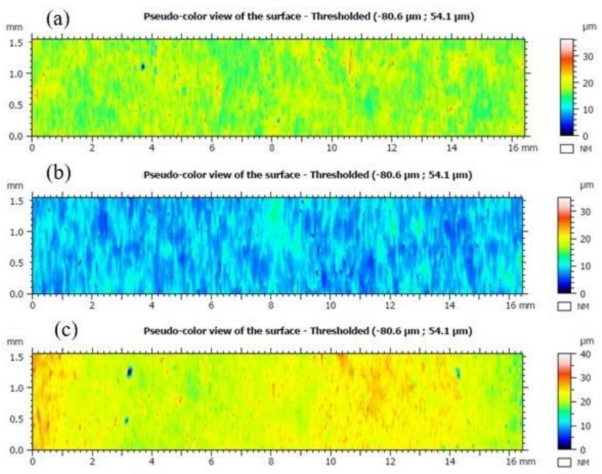

Figure 4. Topography of metal surface a) RP1, b) RP2, c) RP3

Table 2. Surface roughness values and standard deviations after dry ice blasting

Samples	Ra (µm)	Std Deviation
TNR1	0.931	0.055
TNR2	0.948	0.061
TNR3	0.902	0.051
ICCR1	0.454	0.027
ICCR2	0.921	0.071
ICCR3	0.836	0.057
RP1	0.971	0.083
RP2	1.030	0.061
RP3	0.922	0.068

After surface roughness measurement, samples were prepared according to the ASTM E3 [18]. The samples were hot mounted with Struers Citopres-20 machine. Struers Tegra Pol-21 and Struers Tegra Force-5 devices were used for grinding and polishing, respectively. Then, they were etched according to the ASTM E407 with 2% nitrile solution [19].

Prepared samples were examined with microscope of Nikon Epiphot 200 according to the ASTM E45 and ASTM E112 to observe deformation of scale layer [20-21]. The sectional view of scale layers is shown with x500 scale in Figure 5, Figure 6 and Figure 7. The scale on the surface is crushed by the effect of dry ice blasting deformation.

As there are some porosity and crack on the scale layer, especially in ICCR samples which are shown in Figure 6, it could be seen that dry ice blasting applications which are applied in all different parameters are effective.

In RP named samples whose cross-sectional view is shown in Figure 7, RP1 was more affected one compared to the others even though all three samples were taken from same sheet.

In TNR samples, it could be said that dry ice blasting application had limited effect. Especially small cracking on scale surface of TNR2 samples might have happened while preparing for hot mounting application.

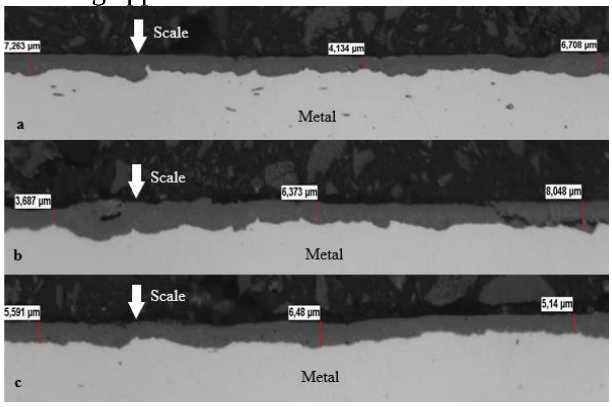

Figure 5. Sectional view of scale layer a) TNR1, b) TNR2, c) TNR3

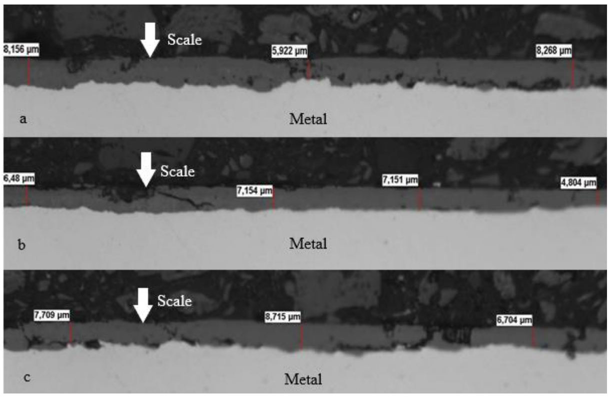

Figure 6. Sectional view of scale layer a) ICCR1, b) ICCR2, c) ICCR3

4. Conclusion and Suggestions

In some samples, dry ice blasting method achieves to break surface layer on carbon steel samples. However, this method is not enough for descaling by itself. According to the surface roughness value, it can be seen that, dry ice blasting method affected scale layer of some samples more than the other samples.

In blasting methods, there are many parameters on method achievement. Some of these parameters are pressure, flow rate, dry ice pellet diameter, nozzle type, angle of nozzle, distance from sample, etc. Therefore, dry ice blasting method should be applied again with different parameters.

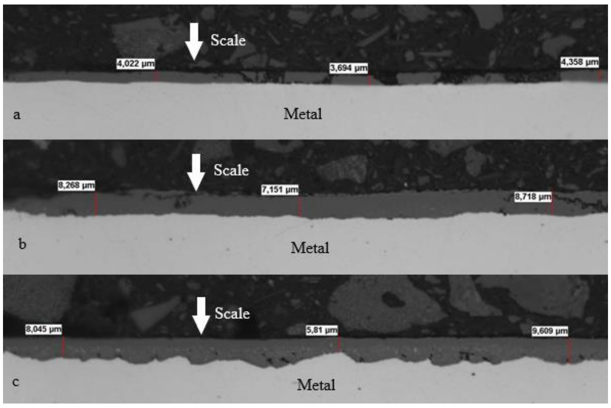

Figure 7. Sectional view of scale layer a) RP1, b) RP2, c) RP3

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Contributions of the Authors

The contributions of each author to the article should be indicated.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

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