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Paper

EFFECT OF PRESSURE AND STAND-OFF DISTANCE ON MASS REMOVAL AND SURFACE ROUGHNESS IN PAINT STRIPPING WITH THE WATERJET

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ABSTRACT

In this paper, the authors investigated the capability of the waterjet for paint stripping from metallic surfaces. Some experiments were performed on low carbon steel samples (with Zinc Riche primer, Epoxy Polyamide and Aliphatic Polyurethane paints), and the influence of water pressure and stand-off distance on mass removal and surface roughness were studied. The tests results show that the waterjet is an excellent method for coating removal process, and in comparison to other methods, e.g. grit blasting, it is much safer and there are no environmental issues with it. It was also observed that after paint stripping, the samples surface has an acceptable roughness for recoating and waterjet does not decrease roughness compared to the decrease made in overblasting.

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1. INTRODUCTION

Paints are applied to surface to enhance corrosion resistance, improve appearance, or both. Often the coatings need to be removed either as part of the manufacturing operation, or, later in the life of the equipment, to enable maintenance or repair. It appears that removal of paints is a major concern worldwide. The major goal of the investigations reported in the literature is to replace toxic chemical and other environmentally unfriendly removal techniques with the safe and ecologically friendly systems. Moreover in some situations for example in petrochemical industries there is explosion risk (because of presence of explosive gases), so we could not use usual methods such as dry sand blasting. In recent years, waterjets have become quite popular for the removal of coatings [1]. Some of the benefits associated with fluid jetting are: no grit residues, less health problems, lower disposal costs and improved surface cleanness of the substrate [3]. In the plain waterjet process, the critical operating parameters are jet structure, orifice (nozzle) size, pressure, traverse speed and stand-off distance [4]. Mechanisms of material removal and impact by a high pressure waterjet depend on selection of operating parameters [4]. Many authors (for example; Samuel S. Wu & Thomas J. Kim, 1995, P. Meng and et al., 1997, Momber, 2003, Gao Daoming & Chen Jie, 2006) have published papers concerning the relation between the operating parameters and their influence on response variables in waterjet stripping process.

According to ISO 8502 (1995) “The performance of protective coatings of paint and related products applied to steel is significantly affected by the state of the steel surface immediately prior to painting”. One of the principal factors to influence this performance is the surface profile [2]. Grit blasting is the primary method used to prepare structural steel surfaces prior to coating because grit blasting has the capability to create a profile at the surface which guarantees a physical bond between the substrate and applied coating system [5]; So the adhesion of a coating is improved by surface roughness [6]. It is also a very important method for the removal of deteriorated coatings from surfaces [5].

Momber [5] investigated the overblasting effects on surface properties of low-carbon steel. This author [2] noticed that, primary grit blasting increased any roughness parameter, whereas the second grit blasting (as performed during the stripping of worn coatings) again decreased the roughness [2]. This, in turn, affects the properties of the original substrate surface formed during primary grit blasting [5]. In this study, this affect called “overblasting”.

In this paper, paint stripping with the waterjet is investigated. The study focuses on the influence of water pressure and stand-off distance on mass removal and the effect of paint stripping with the waterjet on substrate surface roughness.

2. Experimental procedure

2.1. Experimental Setup for Investigate the Influence of Operating Parameters on Mass Loss

All tests were run on painted low-carbon steel. The specimens were cut away from a standard plate by mechanical sawing; the dimensions were 500 mm×70 mm×5 mm. Grit blasting of samples were performed by a commercial blasting unit with air pressure of 5 bar and nozzle diameter of 8 mm. Copper slag with a mean particle size of 1mm was used as the blasting grit.

All of the specimens were keep together and blasted at an exposure time of 400 s, at an angle of 90° and with a stand-off distance between nozzle exit and specimen surface of 200 mm. the samples after grit blasting are shown in Fig. 1.

All specimens were cleaned with dry compressed air to remove any rust, grease, or dust from the surfaces to be evaluated. Then, Zinc Riche Epoxy primer was applied to samples with approximate thickness of 60 µm. The thickness of paint was measured with a coating thickness gauge, Electromatic, CECK-LINE 2000 series. Two layers of Epoxy Polyamide and one layer of Aliphatic Polyurethane paint were applied on samples with a thickness of about 80 µm for each layer. The samples weight was measured before and after paint stripping. The mass balance used was a 'METELER PM16-N' with a precision of ±0.1g. For control and adjust the stand-off distance and nozzle traverse rate, a mechanism was made with use a cross- table, an electro-gearbox and an invertor [Fig. 2]. The waterjet stripping experiments were carried out by using a WOMA Z-225 high pressure system. The following rang of parameters were evaluated:

- Pressure: 400, 500, 600, 700 bars
- Stand-off distance: 60, 70, 80,90 mm
- Nozzle traverse rate: 1, 1.5, 2 mm/s
- Traverse length: 47 mm
- Impact angel: 90°
- Nozzle: Fanjet
- Nozzle diameter: 1.5 mm

2.2. Experimental Setup for Investigate the Surface Profile

All tests were run on painted low-carbon steel. Nine specimens were cut away from a standard plate with dimension of 150 mm× 150 mm× 5 mm. Grit blasting of samples were performed by a commercial blasting unit with air pressure of 5 bar and nozzle diameter of 8 mm. Copper slag with a mean particle size of 1 mm was used as the blasting grit. Specimens were keep together and blasted at an exposure time of 100 s, at an angle of 90° and with a stand-off distance between nozzle exit and specimen surface of 200 mm. Three samples reserve for evaluation of the primary gritblasting and six samples were painted at the condition of the same as the specimens prepared for mass loss evaluation. For investigate the influence of paint stripping with the waterjet and gritblasting on the substrate surface profile, three specimens stripped by waterjet and three of them stripped by gritblasting. Test condition of the secondary gritblasting was the same as the primary gritblasting with exposure time of 40s. Paint stripping with the waterjet was performed on the following condition:

- Pressure: 1000 bar
- Stand-off distance: 90 mm
- Traverse rate: 1 mm/s
- Nozzle: Fanjet
- Nozzle diameter: 1.5 mm
- Impact angel: 90°

For surface profile examinations, a mechanical profilometer type Taylor Hobson with a cut-off length of 0.8 mm was used. The traverse length of the measured profile was 40 mm and the roughness was measured at three different location each specimen. The following roughness parameters were measured: average roughness (R_a), maximum roughness (R_t) and average maximum roughness (R_z).

3. RESULTS AND DISCUTION

3.1. Effect of Pressure on Mass Loss

Water pressure is important parameter influencing the stripping performance. Pressure determines the jet velocity, Reynolds number, turbulent properties and loading of the jet. Figures 3, 4, 5 and 6 show the water pressure influence on mass loss. Experiment results show that the mass removal increase as the operating pressure increase. This trend is most probably caused by the higher waterjet velocity obtained at a higher pressure. The velocity of a waterjet escaping from a orifice can be calculated according to Bernoulli's law [2]:

$$v_J = \varphi\sqrt{\frac{2.p}{\rho_w}} \qquad (1)$$

The kinetic energy of a high speed waterjet is estimated according to the following eq. (2):

$$E_J = \frac{m_w}{2}.v_J^2 \qquad (2)$$

With $m_w = \dot{m}_w.t_E$; $\dot{m}_w = \alpha.\pi/4.d_N^2.v_J$; $t_E = d_N/v_T$, one obtains:

$$E_J = \frac{\alpha.\pi}{8}.d_N^3.v_J^3.\frac{\rho_w}{v_T} \qquad (3)$$

Equations (1) and (3) show that, any increase in water pressure will increase the velocity of the jet, and higher jet velocity leads to higher kinetic energy of impacting jet. Therefore increase in water pressure led to increase the mass loss as seen as in experimental results.

3.2. Effect of Stand-off Distance on Mass Loss

Any coating removal target parameter is very sensitive to variations in stand-off distance. Stand-off distance determines the type of jet impacting on the coating either continues or impact or mixed [4]. The influence of the stand-off distance is shown in Fig.7, 8 and 9. The results show that there exit an optimal stand-off distance at which the volume of material removal is the greatest. The results obtained for the different stand-off distances are a clear indication that the jet structure dominates the process at lower pressures. At the lower pressure, the stagnation pressure in the jet core is too low to effectively remove the material. The much higher impact pressure of the droplets from the droplet zone is required to remove additional material.

3.3. Surface Roughness

The results of the roughness measurements were listed in table 1. The corresponding relative roughness values are plotted in Figure 10; all results obtained for condition (0) were taken to 100%. It can be seen that primary grit blasting increased any roughness parameter, whereas the second grit blasting (overblasting) has decreased the roughness. This, in turn, the second grit blasting (overblasting) affects the properties of the original substrate surface formed during primary grit blasting. The reason of this phenomenon is not completely clear. However, the secondary electron mode images were taken by Momber [5] shown that topographical details may be determined by the number of flat regions at the surface. This author noted that this number is considerably higher after overblasting and erosion made in overblasting may have caused the surface to have a higher number of flat regions. By comparison the results of roughness measurements after waterjet stripping and primary gritblasting, it could be seen that the paint stripping with the waterjet dose not affect the surface original profile formed during the primary gritblasting. The higher the roughness the better the adhesion between substrate and coating. This means that the adhesion of subsequent coating systems, deteriorated due to overblasting but further paint will applied on surface that stripped by the waterjet, will have a appropriate adhesion.

4. CONCLUSIONS

A series of tests was conducted for study the effect of water pressure and stand-off distance on mass loss in paint stripping with the waterjet. Also the effect of paint stripping with the waterjet and gritblasting on the substrate surface roughness was investigated. Conclusions from these results are:

- High speed waterjetting is a safe and environmentally method for paint stripping in comparison to other methods, e.g. solvent stripping and gritblasting.
- Experiments on water pressure show that the mass loss will increase with the increase of water pressure.
- It is shown that the mass loss will increase with the increase of the stand-off distance until it reaches the optimal stand-off distance.
- The results obtained for the different stand-off distances show that the jet structure dominates the paint stripping process.
- It is also observed that in paint stripping process, waterjet does not decrease roughness compared to the decrease made in overblasting.

5. AKNOWLEDGMENTS

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6. NOMENCLATURE

v_J	jet velocity
p	pump pressure
ρ_w	water density
φ	nozzle efficiency parameter
E_J	kinetic energy waterjet
$\dot{m}_W$	water mass flow rate
t_E	exposure time
α	water nozzle out flow parameter (considers the reduction in the volumetric flow rate due to the sudden changes in the fluid conditions in a nozzle with a sharp orifice. For diamond orifices, its value is about $0.65 < \alpha < 0.75$)
d_N	nozzle diameter
v_T	nozzle traverse rate

7. REFERENCES

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Table 1. Experimental results of surface roughness measurements**.**

Test number	Untreated (0)			Grit blasted (I)			Overblasted (II)			waterjetting		
	R_a	R_z	R_t	R_a	R_z	R_t	R_a	R_z	R_t	R_a	R_z	R_t
1	0.94	5.32	6.66	10.23	54.65	107.4	____	____	____	____	____	____
2	0.83	4.7	5.88	10.4	55.56	109.2	____	____	____	____	____	____
3	0.86	4.87	6.09	10.28	54.92	107.92	____	____	____	____	____	____
4	0.96	5.43	6.8	10.31	55.08	108.24	8.68	47.66	93.65	____	____	____
5	0.91	5.15	6.45	10.22	54.6	107.3	8.64	47.44	90.71	____	____	____
6	0.95	5.38	6.73	10.18	54.38	106.87	8.6	47.22	92.79	____	____	____
7	0.78	4.41	5.53	10.11	54.01	106.14	____	____	____	10.15	54.22	106.56
8	0.88	4.98	6.23	10.3	55.02	108.13	____	____	____	10.27	54.86	107.82
9	0.77	4.36	5.45	10.34	55.24	108.55	____	____	____	10.36	55.34	108.76

Figure 1. The specimens after gritblasting.

Figure 2. The mechanism was made for performing the tests.

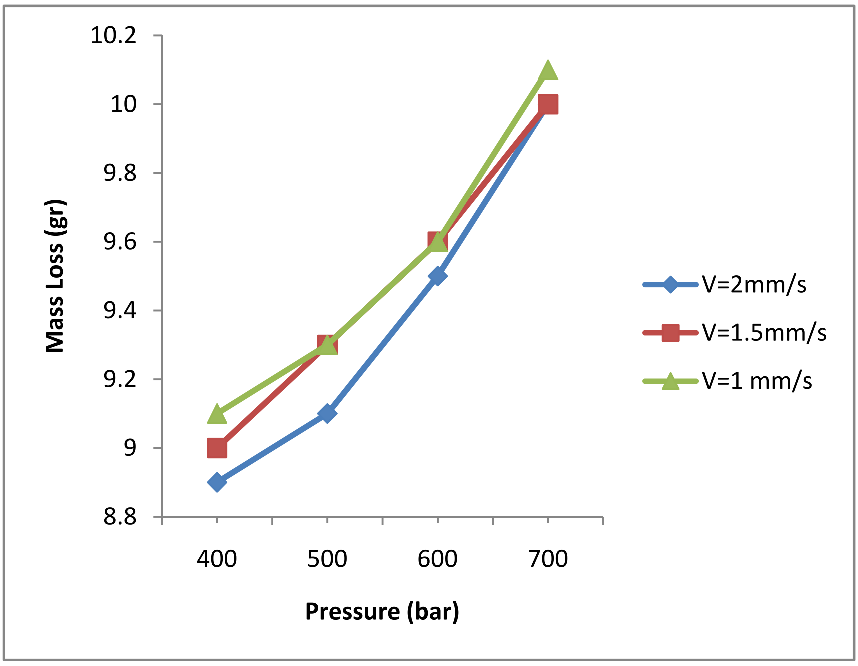

Figure 3. Influence of operating pressure on mass loss (Stand-off distance 60 mm).

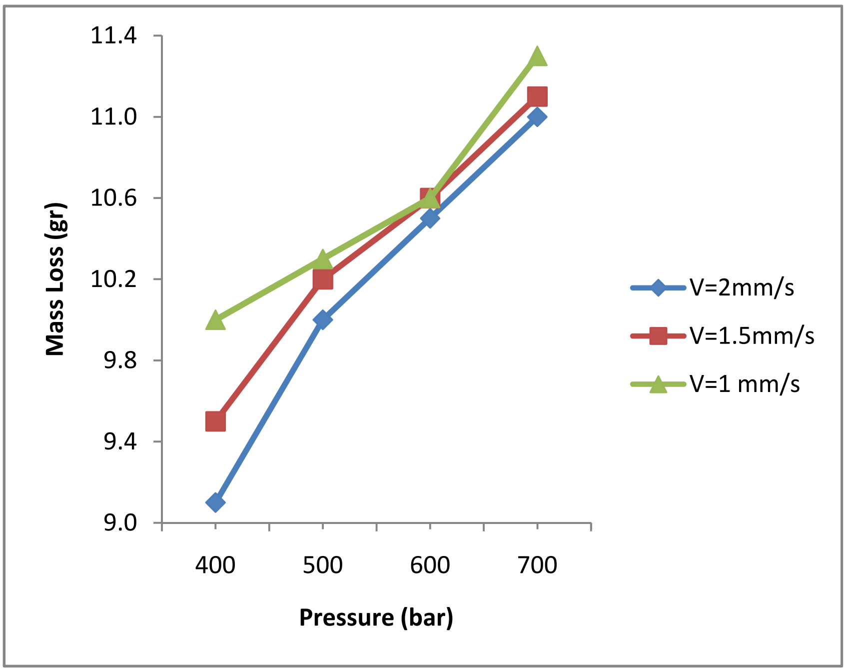

Figure 4. Influence of operating pressure on mass loss (Stand-off distance 70 mm).

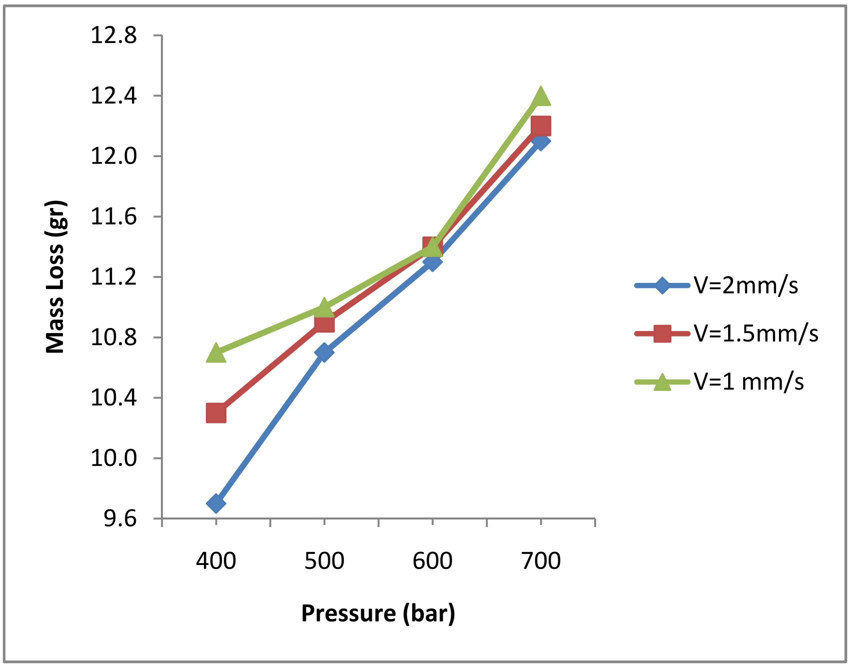

Figure 5. Influence of operating pressure on mass loss (Stand-off distance 80 mm).

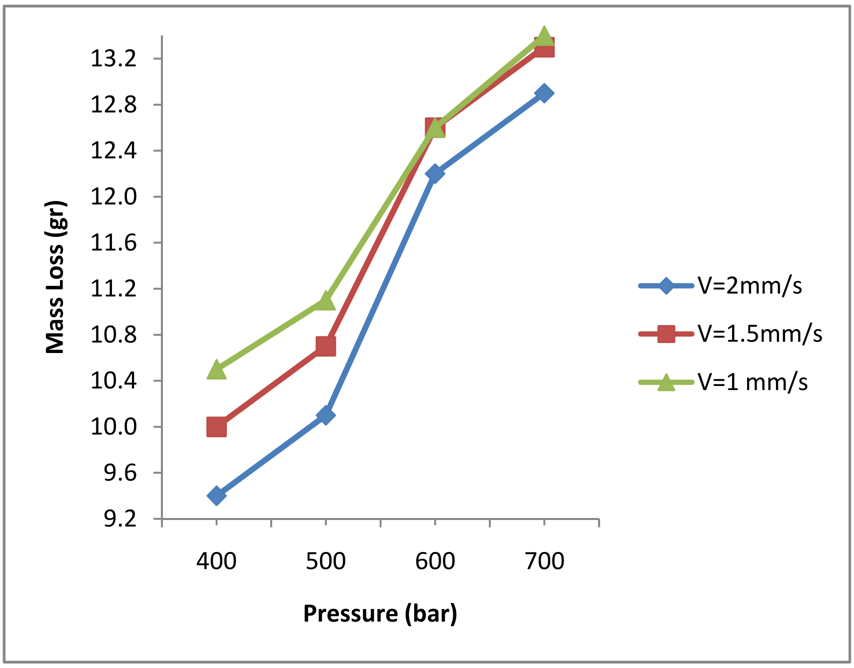

Figure 6. Influence of operating pressure on mass loss (Stand-off distance 90 mm).

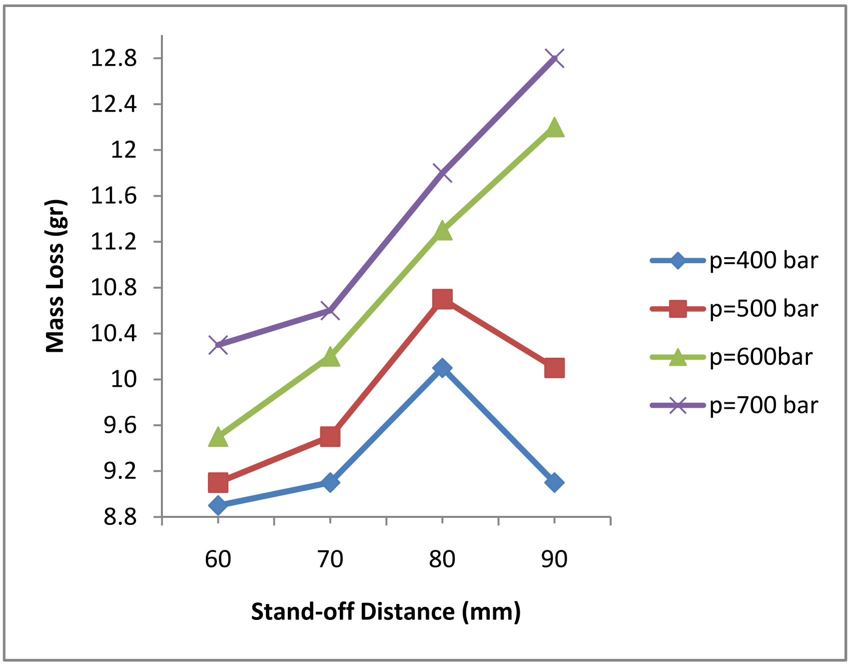

Figure 7. Influence of stand-off distance on mass loss (Traverse Rate 2 mm/s).

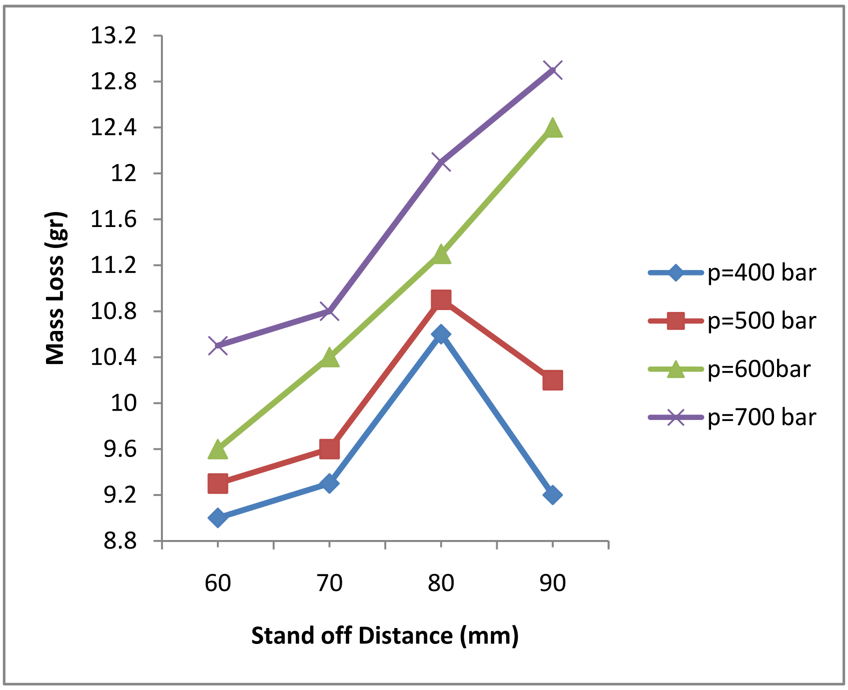

Figure 8. Influence of stand-off distance on mass loss (Traverse Rate 1.5 mm/s).

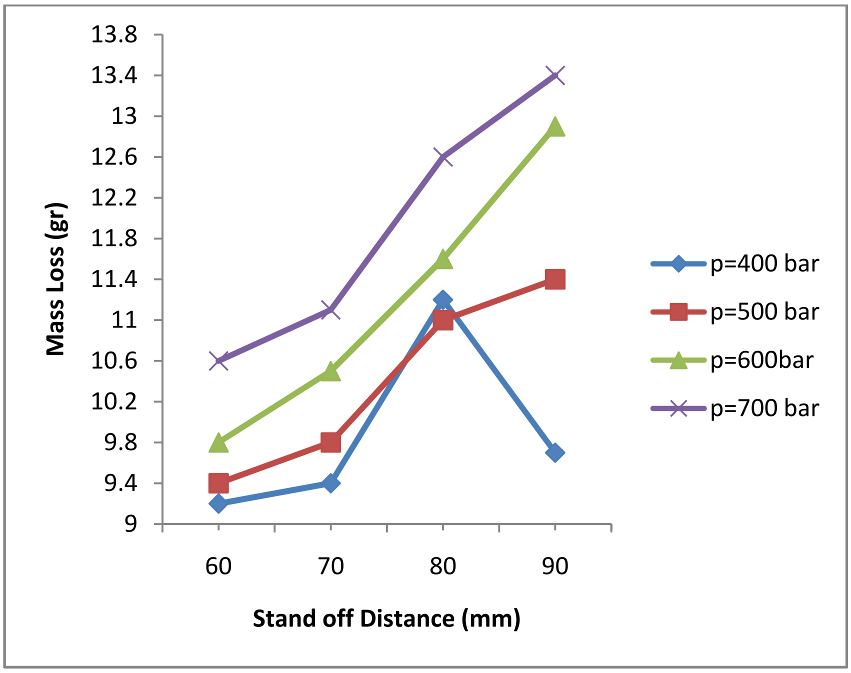

Figure 9. Influence of stand-off distance on mass loss (Traverse Rate 1 mm/s).

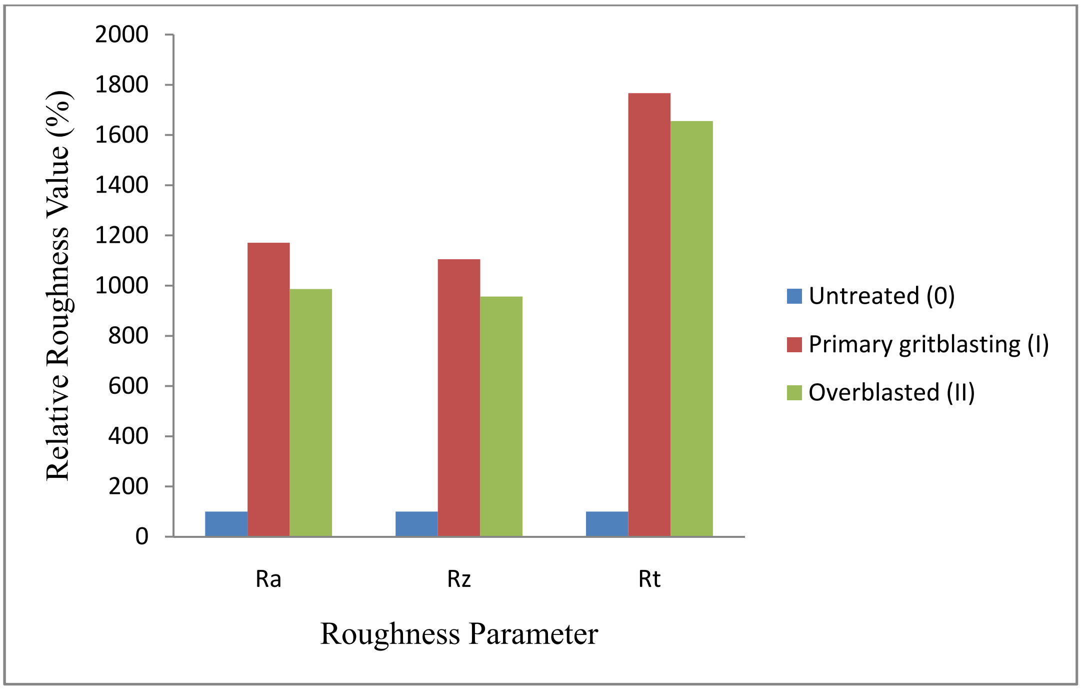

Figure 10. Surface roughness modification due to gritblasting.

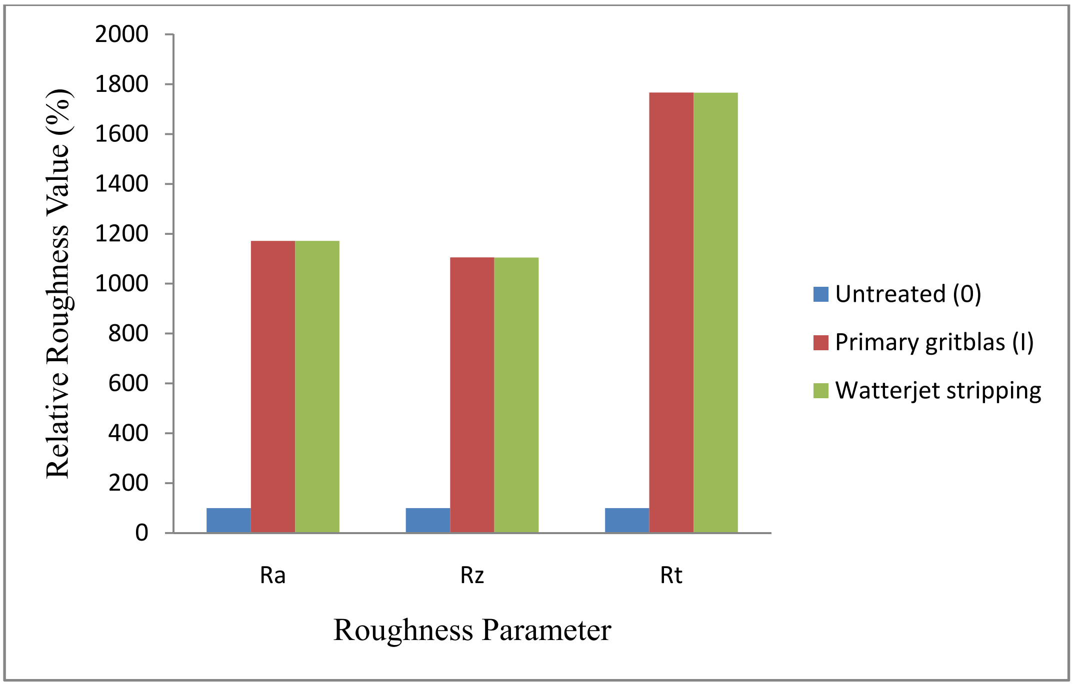

Figure 11. Influence of paint stripping with the waterjet on substrate surface roughness.