2013 WJTA-IMCA Conference and Expo
September 9-11, 2013 ● Houston, Texas

Paper

TECHNICAL AND ECONOMICAL COMPARISON OF WATERJET AND ABRASIVE BLAST METHODS TO BE USED IN DE-COATING AND CLEANING PROCESSES

Hamid Teimourian
Purdue University, IN, USA

H.V. Tamaddoni, B. Mutabi and A. Soleimanzadeh
Tabriz Petrochemical Company
Tabriz, Iran

ABSTRACT

This paper presents a research that has been done in order to make a comparison between the waterjet and abrasive blast techniques, two popular de-coating and cleaning methods. This study addresses both technical and economic concerns. Technical part includes surface cleanliness, substrate surface roughness and environmental issues. Economic comparison investigates the equipment, operational, utilities, waste disposal and maintenance costs. The results show that both methods have their own advantages and disadvantages. However, the waterjet has more advantages in terms of capability of the performance, less operational cost, less environmental and health issues and causes no damage to the substrate surface profile.

Organized and Sponsored by WJTA®-IMCA®

1. INTRODUCTION

Surface preparation is the most important stage in the success of any coating project. Studies show that the performance of any protective coating is largely influenced by the coatings ability to adhere to the substrate surface [1]. There have been many studies regarding the appropriate surface preparation methods and their applicability in different areas of industry. According to the type of coating, substrate, equipment, and service environment several techniques such as chemical, mechanical and thermal have been used and some new methods are emerging.

Surface preparation is not just applied on new raw substrate surfaces before application of the first coating but it is also needed in the de-coating process. Over a period of time, coatings lose their effectiveness and should be removed for maintenance or repair purposes. During recent years coating removal has been a major concern worldwide especially in oil field industry, shipyards, etc.

Among the mentioned approaches, ***sand blasting*** and ***high pressure waterjetting*** are the most popular methods used in de-coating and cleaning. Each of these methods has its own advantages and disadvantages. However, recently high pressure waterjet technology has gained significant progress in surface preparation industry. “Some of the benefits associated with water jetting are: no damage on substrate original profile, no grit residues, less health problems, lower disposal costs and improved surface cleanness of the substrate” [2].

Much research has been conducted in this area as well as established standards prepared by ***SSPC*** (*Society for Protective Coatings*) and ***NACE*** (National Association of Corrosion Engineers). New powerful waterjet machines, robotic systems, water recycling equipment and more efficient nozzles have been developed by manufacturers to respond to the market needs. Dr. L. Frenzel and Dr. A. Momber have done many research projects in this area and have had a great influence on our current understanding of these two methods [2,3,4,5].

However, despite all these facts, some customers are hesitant to change their old traditional sandblasting equipment to waterjetting systems. One reason might be the resistance of the system to the change. However, in most cases the main reason is customers’ lack of knowledge and information. Why do they need to change a method that they have used for many years? Why should they invest money on buying waterjet systems, training personnel, etc? What advantages (technical, economic, environmental, etc) does the waterjet have on sandblast?

In this study, a research has been done in order to make a comparison between the waterjet and abrasive blast techniques, two popular de-coating methods. The paper intends to address both technical and economic concerns regarding these two methods.

2. TECHNICAL COMPARISON

According to IS0 8502 (1995), the performance of a protective coating is significantly affected by the state of the steel surface immediately prior to painting. The main factors that influence this performance are:

(i) Presence of rust and mill scale:
(ii) Surface contaminants, including salts, dust, oil and greases:
(iii) Substrate surface profile [6]

Correct surface preparation will remove all the contaminants to reduce the possibility of initiating corrosion. Another important factor is to create a surface profile to guarantee adhesion of the coating to the substrate surface [7].

2.1. Surface Cleanliness

The life and performance of any protective coating depends on the degree of substrate surface cleanliness prior to application. The desired standards of surface cleanliness for previously painted surfaces are defined in ISO 8501-2. “The presence of even a very thin layer of oil or grease can destroy or seriously impair adhesion of paint. Commercial chemical cleaners such as water rinsable detergents are available but before they are used it must be determined that they will not adversely attack the painted surface”.[7] Although oil or grease can be removed by both methods during surface preparation process, contaminants will still be present as a thin layer and will affect the adhesion of subsequent coating. Removing oil and grease is an independent stage that must be done separately in most cases.

Abrasive blasting produces large quantities of dust and residues which must be removed from the substrate surface before re-coating. In contrast, waterjetting does not make any dust and has the ability to remove high percentages of soluble salts from the steel surface. Table 1 and table 2 show the level of surface contaminants on the substrate surface in different conditions [6]. The results indicate that salt levels and soluble substances are higher in value ($\mu g/cm^2$) in grit blasting compared to waterjetting. The removal of a high proportion of soluble salts from the steel surface is an advantage of ultra-high pressure waterjetting. These high levels of contaminants on the substrate after abrasive blasting adversely affect the adhesion and life of the coating.

Table 1. Surface contaminants and their levels on the substrate in different conditions [6]

Substrate	**Contaminant**	**Salt level (µg/cm2)**		
		Uncleaned	**Grit-Blasted**	**Hydroblasted**
A-36 steel with mill scale	Sulphates	40	3	0
	Phosphates	0	0	0
	Chlorides	2	2	1
	Nitrates	0	6	0
A-285 Grade 3 steel with mill scale	Sulphates	5	5	0
	Phosphates	0	1	0
	Chlorides	4	3	1
	Nitrates	0	11	1
Rusted water Service piper	Sulphates	5	2	1
	Phosphates	1	2	0
	Chlorides	28	32	1
	Nitrates	6	1	1
Intact Coating on water service pipe	Sulphates	8	4	0
	Phosphates	0	2	0
	Chlorides	6	1	1
	Nitrates	4	2	1
Heat exchanger shell	Sulphates	7	4	0
	Phosphates	0	0	0
	Chlorides	17	31	0
	Nitrates	0	3	0

Table 2. Soluble substances levels after waterjetting and abrasive blasting [6]

Element	Soluble substance in µg/cm2	
	waterjetting	**Abrasive blasting**
Nickel	0.006	0.057
Zinc	0.063	1.512
Manganese	0.003	0.031
Magnesium	0.021	0.672
Calcium	0.121	1.989
Copper	0.033	0.25
Aluminum	0.003	0.352
Lead	0.015	0.045
Iron	0.018	9.45
Potassium	0.414	0.513
Sodium	0.855	42.03
Chloride	0.846	62.55
Sulphate	0.211	1.26

2.2. Surface Roughness

One of the basic requirements of a coating is the ability to adhere to the substrate. Studies show that adhesion of a coating is improved by increasing the substrate surface roughness (Figure 1) [8].

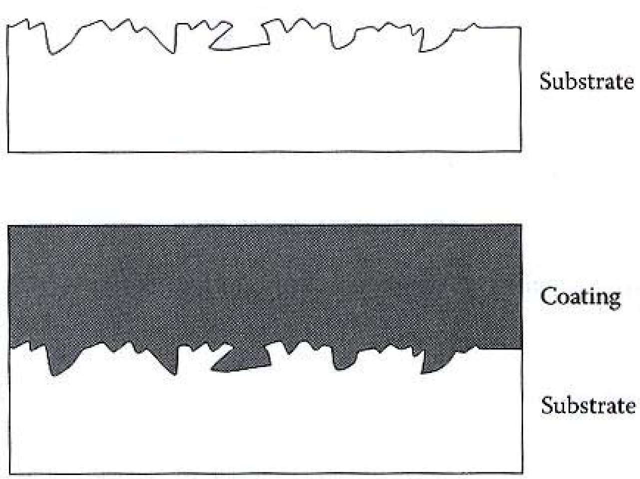

Figure 1. Effect of substrate surface roughness on coating adhesion [8].

Capability of the abrasive blasting method to create a profile at the substrate can guarantee a physical bond between the coating and surface and increases the life and performance of the coating. Figure 2 shows the effect of abrasive blast on the substrate surface after first blasting. Furthermore, it is used as a tool to remove deteriorated coatings from surfaces. Studies have shown that grit blasting is capable of removing coatings, but it always removes substrate material as well [5]. Therefore, any coating removal process that involves grit blasting is accompanied by substrate damage. Figure 2 shows the results of the roughness measurements for different surface preparation conditions. All the results for untreated conditions (0) were taken to 1. Figures 4 to 6 show three-dimensional topography images of the prepared substrates in different condition. As expected, primary blast cleaning (I) increased substrate surface roughness compared to the untreated substrate (0). However, secondary abrasive blasting (II), as a result of the removal of the previous coating from the substrate, deteriorated the roughness values. This phenomenon is frequently referred to as “overblasting” in the manufacturing literature [5, 9].

Comparison between the surface roughness results and topography images, show that surface preparation (de-coating) with the waterjet does not have any effect on the substrate surface original profile formed during primary abrasive blasting. However, abrasive blasting deteriorates the substrate original surface profile during de-coating process. This means that the adhesion of subsequent coating systems, are deteriorated due to overblasting effect. The background of this phenomenon is discussed in more detail by Dr. Momber [10].

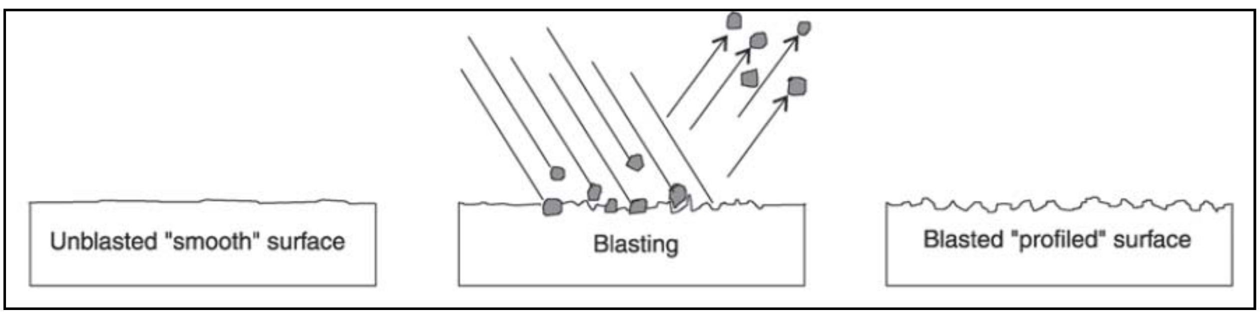

Figure 2. Effect of primary abrasive blast on substrate surface profile [11].

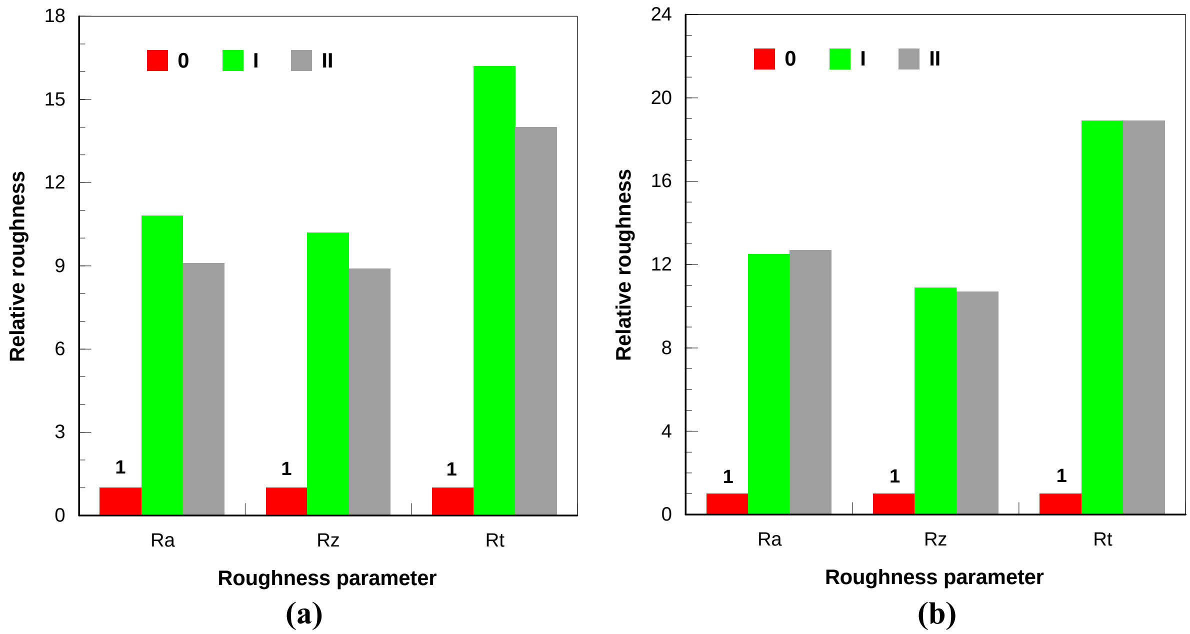

Figure 3. Substrate surface roughness measurements. [9]

a – Untreated (0); primary abrasive blast (I); De-coating with the abrasive blast (II)

b – Untreated (0); primary abrasive blast (I); De-coating with the water jetting (II)

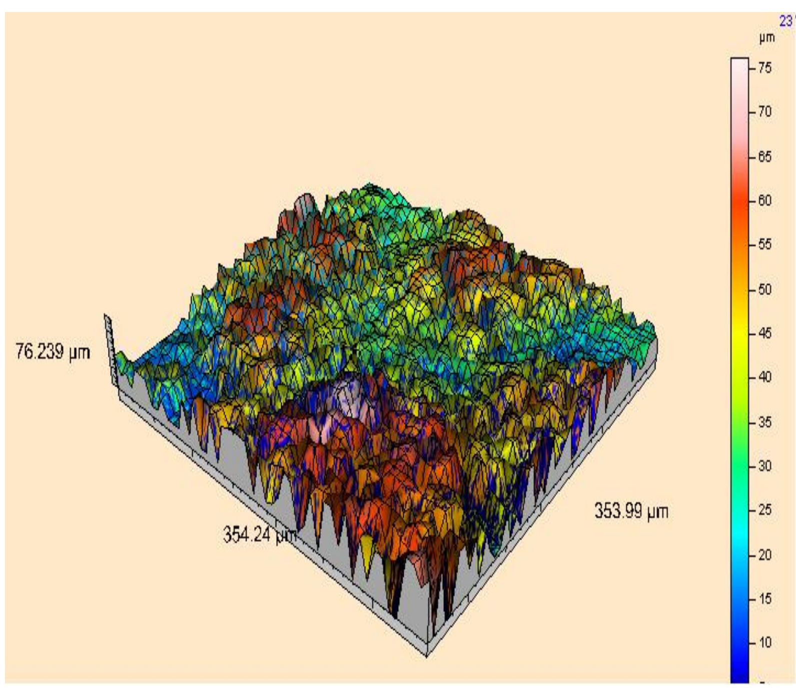

Figure 4. Substrate surface roughness after primary abrasive blast [9]

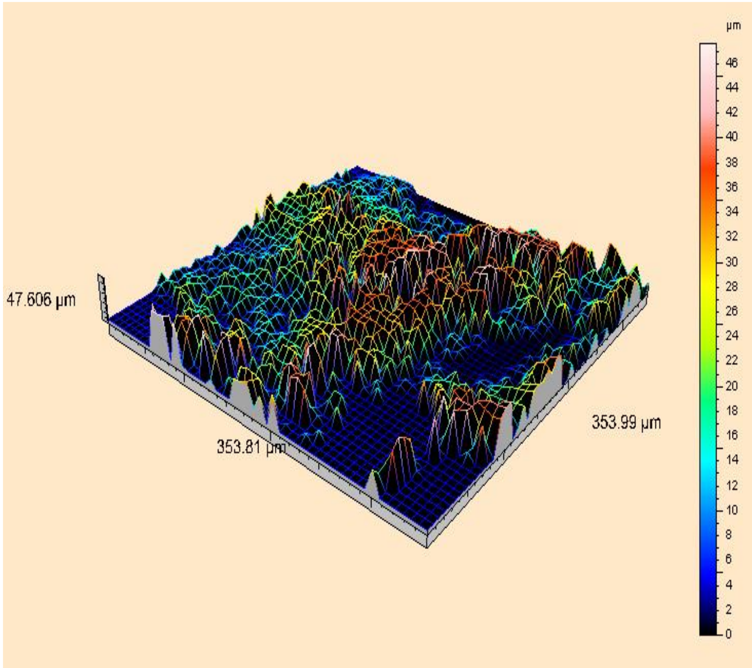

Figure 5. Substrate surface roughness after de-coating with the abrasive blast [9]

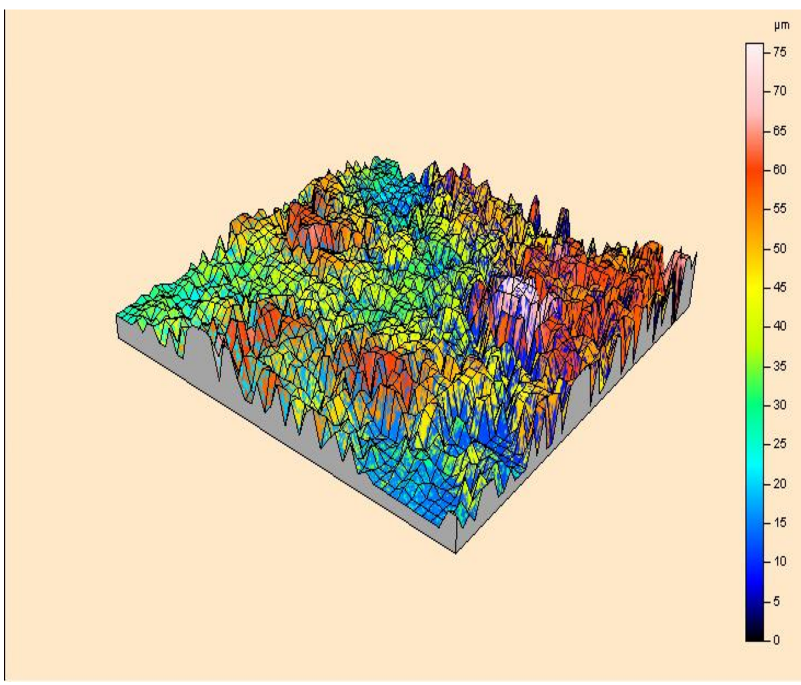

Figure 6. Substrate surface roughness after de-coating with the water jetting [9]

2.3. Environmental Issues

Abrasive blasting has been used for surface preparation and maintenance purposes for many years. However, it has become environmentally unacceptable due to the creation of dust and pollution during the operation [1]. "Abrasive blasting also has a major impact on the environment, health and safety of staff including: Air pollution, Waste disposal, Hazardous waste, and Noise. There are also other impacts on health and safety from inhalation of solvents used to prepare the surface, contaminated material or blast media" [12]. Table 3 shows a summary of the potential health hazards associated with abrasive blasting [13].

Table 3. Hazards of air contaminants associated with abrasive blasting [13].

Contaminant	Potential Health Hazards
Aluminum	Respiratory irritation.
Arsenic (metal)	Occupational overexposure to arsenic can increase the risk of skin, lung and possibly lymphatic cancers and lead to peripheral neuropathy and vascular disease.
Cadmium	Occupational overexposure to cadmium can lead to degeneration of the renal tubules [kidney damage] manifested by increased protein in the urine [proteinuria]; increased blood pressure contributing to hypertension; obstructive lung diseases like chronic bronchitis, pulmonary fibrosis and emphysema; and increase the risk of lung and prostate cancer.
Chromium (metal)	Skin irritation and increase the risk of lung fibrosis.
Chromium (III)	Respiratory irritation and allergic dermatitis upon skin contact.
Chromium (VI)	Risk of lung cancer and occupational asthma, damage nasal tissue and cause allergic dermatitis with skin contact.
Cobaltt	Chronic lung inflammation and pulmonary fibrosis, increase the risk of lung cancer, and cause allergic contact dermatitis with skin contact.
Copper	Respiratory irritation.
Lead	Occupational overexposure to lead can cause subclinical and clinical peripheral neuropathy [muscle weakness, pain, and paralysis of extremities], disruption of hemesynthesis and anemia, loss of kidney function, increased blood pressure, nephropathy, reduced sperm count and male sterility, and increase the risk of cancer.
Nickel	Risk of lung and nasal cancers, and cause occupational asthma and allergic dermatitis with skin contact.

3. ECONOMICAL COMPARISON

Studies show that two-thirds of the cost of a coating job goes for surface preparation and labor [14]. Figure 7 shows the percentage of surface preparation cost (40-55%) on an industrial painting project [15]. Two case studies are presented to compare the cost of abrasive blast and waterjetting methods.

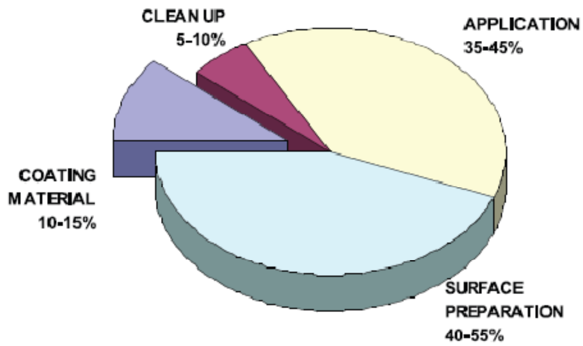

Figure 7. Surface preparation cost [15].

3.1. Case Study 1

In this project a cost comparison has been made between waterjet and abrasive blast methods for de-coating from 100,000 square feet vessel. The results show total direct cost saving of $930,400 (based on 1993 prices) for de-coating process if water jet was used [16].

Table 3. Direct cost savings on 100,000 sq. ft. of surface preparation at the shipyard level [16].

Type	**Cost**		***Total Cost Saving***
	Abrasive Blast	Waterjet	
Non-hazardous material	232,000	30,600	201,400
Hazardous material	765,000	36,000	729,000

3.2. Case study 2

The objective of this project was to compare the High Pressure Water Jet process and conventional abrasive blasting for maintenance activities. Economic analysis for field level maintenance activities revealed that replacing abrasive blasting with a waterjet process would be more financially beneficial. The results are shown in Table 4 and 5 [17].

Table 4. Cost comparison between abrasive blasting and waterjet process [17].

COST	Waterjet	Abrasive Blasting
Maintenance	20 hr/yr	240/yr
Total labor costs	$18,744/yr	$25,344/yr
Material costs	$0	$75,330/yr
Utility costs	$262/yr electricity, $125/yr compressed air	3,557/yr electricity, $371/yr water
Waste disposal/management costs	1,570/yr plus $500 water permit every 5 yrs	$7,358/yr plus $615 air permit every 5 yrs
Health and safety costs	$670/yr	$1,680/yr

Table 5. Economic Analysis Summary of Abrasive Blasting and Waterjet Process [17].

Economic Analysis Summary		
Cost	**Waterjet**	**Abrasive Blasting**
Labor	$19,044	$28,944
Material	$0	$75,330
Waste disposal	$1,670.00	$7,461
Utility costs	$387.00	$3,928
Health and safety costs	$670.00	$1,680
Total Operational costs	$21,771.00	$117,343

4. CONCLUSIONS

Water jet and abrasive blasting are the two most popular methods that are used in surface preparation industry. Generally, efficiency of a surface preparation project depends on many parameters. However, studies show that the waterjet is more technically capable in terms of cleanness and no damage to the substrate original profile, cost effective and environmentally friendly method compared to conventional abrasive blasting method.

5. AKNOWLEDGMENTS

The author wishes to thank Dr. M. Hashish, Mr. D. Lafferty, Dr. A. Momber, Dr. Lydia Frenzel, Dr. A. Alavizadeh, Mr. Biglarian and Mr. Jafarnia for their help, guidance and support. Thanks are also addressed to Dr. M. Vijay, Dr. l.halavac, Dr. M. Mahboubkhah, Mr. B. Shojaee, and Mr. S. Ebrahimi Saei.

6. REFERENCES

[1] The National physical laboratory; National corrosion service. “Guides to good practice in corrosion control; surface preparation for coating.”

[2] Momber, A.W., Wong, Y.C., Ij, R., Budidharma, E. “Hydrodynamic profiling and grit blasting of low-carbon steel surfaces.” Tribology International 35 (2002): 271-281.

[3] Frenzel, Lydia M., “A comparison of surface preparation for coatings by water jetting and abrasive blasting.” WJTA Conference; 1999, Houston TX.

[4] Frenzel, Lydia M., “Evaluation of 20,000 psi water jetting for surface preparation of steel prior to coating or recoating.” Coastal science associates, inc.,

[5] Momber, A.W., Wong, Y.C., “Overblasting Effects on Surface Properties of Low-Carbon Steel.” JCT Research Vol.2, No.6 (2005): 453-461.

[6] Momber, A.W. Hydroblasting and coating of steel structures. Elsevier Science, 2001.

[7] Marine paint guide, International marine coatings. www.international-marine.com

[8] Schweitzer, Philip A., P.E. Paint and Coatings: application and corosion resistance. New York: Taylor & Francis Group, 2006.

[9] Teimourian, H., Shabgard, M. R., Momber, A.W. “De-painting with high-speed water jets: Paint removal process and substrate surface roughness”. Progress in organic coatings, 69 (2010) 455–462.

[10] A.W. Momber, Blast Cleaning Technology, Springer-Verlag, Berlin-Heidelberg, Germany, 2008.

[11] Pictorial surface preparation grades of blast cleaned steel. Blast-one international. Technical reference, section 14.

[12] Abrasive blasting; Blast costs away. http://www.ecoefficiency.com.au/

[13] Abrasive blasting hazards in shipyard employment. U.S. department of labor occupational safety and health administration directorate of standards and guidance office of maritime. An OSHA guidance document ,December 2006.

[14] Ozbayoglu, G., Ataman, N., “Evaluation of turkish industrial wastes as blasting abrasives”. Physicochemical Problems of Mineral Processing, 40 (2006), 117-124.

[15] Ponderosa Protective Coatings; Surface Preparation.

[16] McGuire, D., “An evaluation of hydro-blasting surface preparation and independent suitability testing of commercial coatings”. AMCLEAN Inc., Florida USA

[17] Concurrent Technologies Corporation. "Coating Removal: Water Jetting". Technology report. February 1995.