ADVANCED SURFACE SUBSTRATE ANALYSIS AFTER ABRASIVE BLAST-CLEANING

OCHODEK Vladislav[1], SIOSTRZONEK René[1]

[1]*VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU*

Abstract

Blast-cleaning is one of the often-used technologies of surface pre-treatment. Its main use is in the area of anticorrosive protection of materials, as the last technological operation prior to the creation of protective coating. The basic principle of abrasive blast-cleaning is the hurling with high kinetic energy of blast-cleaning abrasive against the surface of a material. The results are the cleaning of the surface of a material from drosses, rust and other impurities, the creation of a characteristic microgeometry of the surface and also the significant effect on the surface layer of a material. All these parameters have a significant impact on the resulting adhesiveness of protective coating of a material to the base material. The following paper presents a complex analysis and evaluation of the surface of a material after abrasive blast-cleaning. A cylindrical intermediate product was blasted with four different types of media. The analysis of individual surfaces included, for instance: the assessment of purity of a surface according to EN ISO 8501-1, Surface tension measurement of the substrate using test inks, a metallographic analysis, assessment of surface roughness, assessment of microhardness and the analysis of residual stress using the magnetoelastic method. On the basis of these analyses, it is possible to clearly set the optimal parameters of surface abrasive blast-cleaning prior to the creation of protective coating.

Keywords: Abrasive blast-cleaning, surface pre-treatment, Barkhausen noise

1. INTRODUCTION

The successful application of final surface layers is directly dependent on the quality of preparation of the anchor surface. Complex assessment of the surface's quality is, however, relatively time-demanding and can be carried out only in a limited extent in operating conditions [1]. The used procedure of analysis enables to unambiguously evaluate the quality of the preparation of the surface by blast-cleaning abrasive [2]; [3].

2. EXPERIMENTAL MATERIAL AND PROCEDURES

For experimental measurements were used five steel cylindrical intermediate products P235TR1 acc. to EN 10217-1 with dimensions T76.1 x 2.9/235 mm. Each sample was blasted following blast-cleaning abrasive: sample S1 - stainless steel shot (average hardness 42 HRC, grain size 0.3 mm), sample S2 - steel shot (average hardness in the range from 46 to 51 HRC, grain size 0.3 mm), sample S3 - steel shot (average hardness in the range from 56 to 52 HRC, grain size 0.3 mm), sample S4 - steel grit G18 (average hardness 59 HRC, grain size in the range from 0.71 to 1.18 mm).

Complex surface analysis of material was carried out the following experimental measurements:

Visual assessment of surface cleanliness acc. to EN ISO 8501-1

Surface tension measurement of the substrate using test inks

- The test ink is applied by brush onto the substrate. If the line of ink will remain "unchanged" on surface of the material for about 2 seconds, then the surface is suitable for application of the coating system. For example if the drops were not formed. The surface suitable for application of the coating has a value of surface tension in the range from 35 to 40 $mN \cdot m^{-1}$. The larger value of surface tension means the rigorous measurement. For this particular measurement the test ink with a value 38 $mN \cdot m^{-1}$ was used.

Surface roughness measurement acc. to EN ISO 4287, where was used a measuring equipment Mitutoyo Surftest SJ-301.

Microhardness measurement and metallography

- Microhardness was determined by the Vickers method. Microhardness tester with a diamond pyramid indenter with the apex angle of 136° was used for this measurement. Load force was 100 g ($HV_{0.1}$).

3. METODOLOGY SURFACE ANALYSIS

3.1. Visual assessment of surface cleanliness

Surface preparation grades of abrasive-blast cleaning surface are divided into four categories: Sa1, Sa2, Sa2½, Sa3. Corrosion protection of steel structures by using coatings recommends a minimum degree of surface preparation grade Sa2½. Results of visual assessment of surface cleanliness are shown in **Table 1**.

Table 1 Visual assessment of surface cleanliness

Sample	S1	S2	S3	S4
Surface preparation grade	Sa3	Sa3	Sa3	Sa3

Surface preparation grade Sa2½ means: very thorough blast-cleaning - when viewed without magnification, the surface shall be free from visible oil, grease and dirt, and form mill scale, rust, paint coatings and foreign matter. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.

Surface preparation grade Sa3 means: blast-cleaning to visually clean steel - when viewed without magnification, the surface shall be free from visible oil, grease and dirt, and shall be free from mill scale, rust, paint coatings and foreign matter. It shall have a uniform metallic color.

3.2. Surface tension measurement of the substrate using test inks

Table 2 Surface tension measurement - test ink 38 $mN \cdot m^{-1}$

Sample	Result	Photographs
S0	Surface unsuitable for coating application	
S1	Surface suitable for coating application	
S2	Surface suitable for coating application	
S3	Surface suitable for coating application	
S4	Surface suitable for coating application	

Note: S0 - initial state of sample

3.3. Surface roughness measurement

For surface roughness measurement was used an equipment Mitutoyo Surftest SJ-301. It was necessary to set measurement conditions before measuring. The measurement conditions are shown in **Table 3**. The results of surface roughness measurement are shown in **Table 4** and **Figure 1**.

Table 3 Surface roughness measurement conditions

Sample	Standard measurement of equipment	λ_C (mm)	*L* (mm)
S0	ISO 1997	0.8	4.0
S1		2.5	12.5
S2			
S3			
S4			

λ_C = filter defining interfaces between the components of roughness and waviness; *L* = measuring distance.

Table 4 Results of surface roughness measurement

Sample	*Ra* (μm)	*Rz* (μm)
S0	0.36	2.60
S1	5.39	33.71
S2	4.94	31.58
S3	4.39	28.15
S4	6.38	39.05

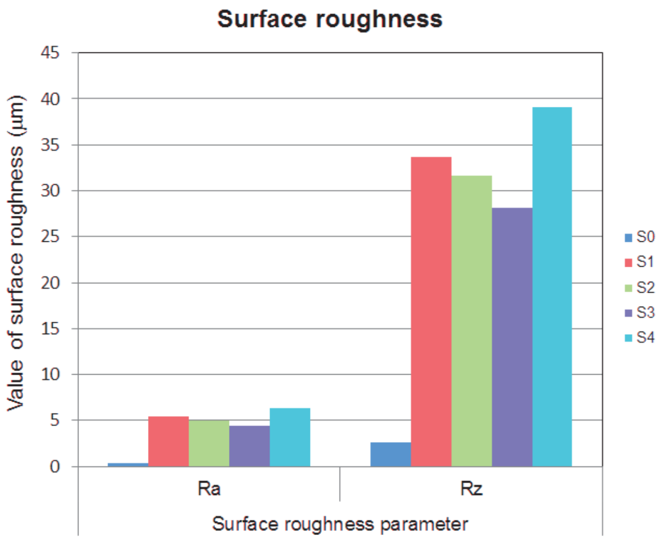

Figure 1 Results of surface roughness measurement

3.4. Analysis of residual stress by magnetoelastic method

Surface pre-treatment technologies significantly affect the stress state in material's surface layers. In order to analyse residual stresses, we used the magnetoelastic method based on the analysis of Barkhausen noise, which enables to non-invasively characterise the surface of ferromagnetic materials [4]; [5], [6]. The relationship between Barkhausen noise and residual stress is depicted in **Figure 2**. With respect to the shape of the analysed sample, we conducted an analysis of residual stresses in the cylindrical part of the semi-finished product outside the weld in a single line in five points 10 mm from each other in the direction of principal residual stresses - see **Figure 3**. The resulting MBN (Magnetic Barkhausen Noise) value is the average of values obtained from measurement in the given five points. **Figure 4** shows the MBN values, which show tensile stress on the surface of components prior to abrasive blast-cleaning. The boundary of the transition from tensile stress to pressure stress is, in the given material and with given parameters of measurement, the value of MBN = 450. Higher residual stress values are in the longitudinal rather than transverse direction, which corresponds to the production method of the semi-finished product [6]. The blasting itself brings compression stress into surface layers in all cases of the used medium [7]; [8]. Blasting leads to a significant compensation of residual stress values in both directions of principal residual stress [9]; [10]. Slightly higher values were found in the transverse direction due to the direction of blasting medium. The highest residual stress values were detected with sample S3, where stainless steel blasting medium with the lowest hardness was used.

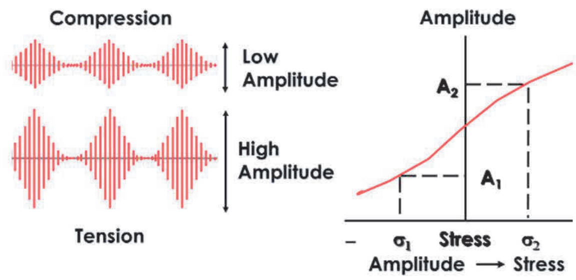

Figure 2 Barkhausen noise responses to tensile and compressive stress [4]

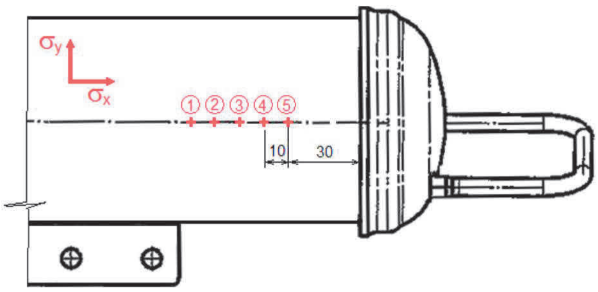

Figure 3 Residual stress analysis location

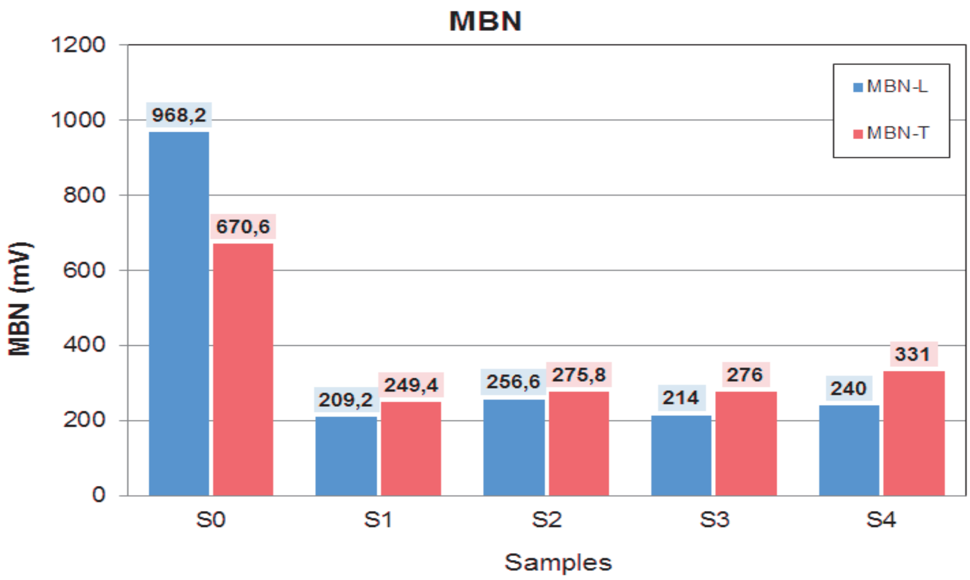

Figure 4 Average value MBN samples

3.5. Microhardness measurement and metallography

Influence of abrasive blast-cleaning to material properties - microhardness and metallography, was evaluated in four areas of cross-section: weld joint - the surface layer, weld joint - half the thickness of the material, the surface layer of the base material, base material - half the thickness of the material. The purpose of the measurement was to evaluate the change in microhardness of the surface layer and half the thickness of the pressure vessel material after abrasive blast-cleaning. Results of microhardness measurement are shown in **Figure 5**.

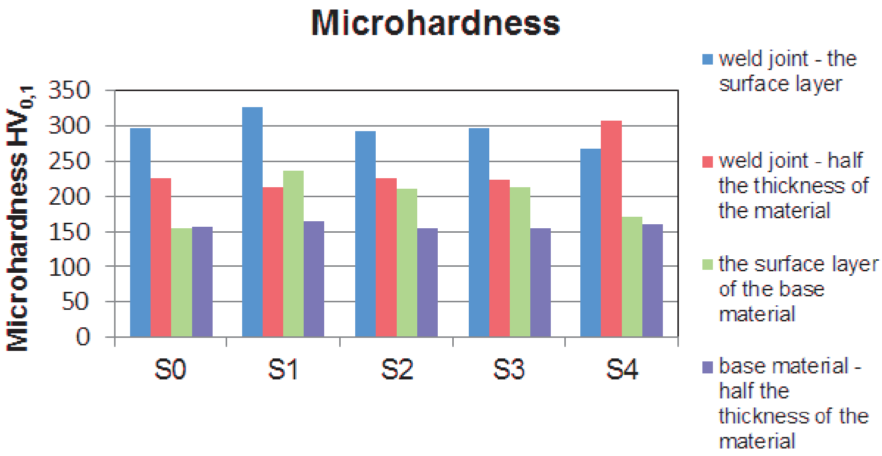

Figure 5 Results of microhardness measurement

Metallography of all samples was carried out on optical microscope NEOPHOT 2 (VŠB - Technical University Ostrava, Faculty of mechanical engineering, Department of mechanical technology). Influence of abrasive blast-cleaning to microstructure the surface layer of base material is showed in **Figure 6**.

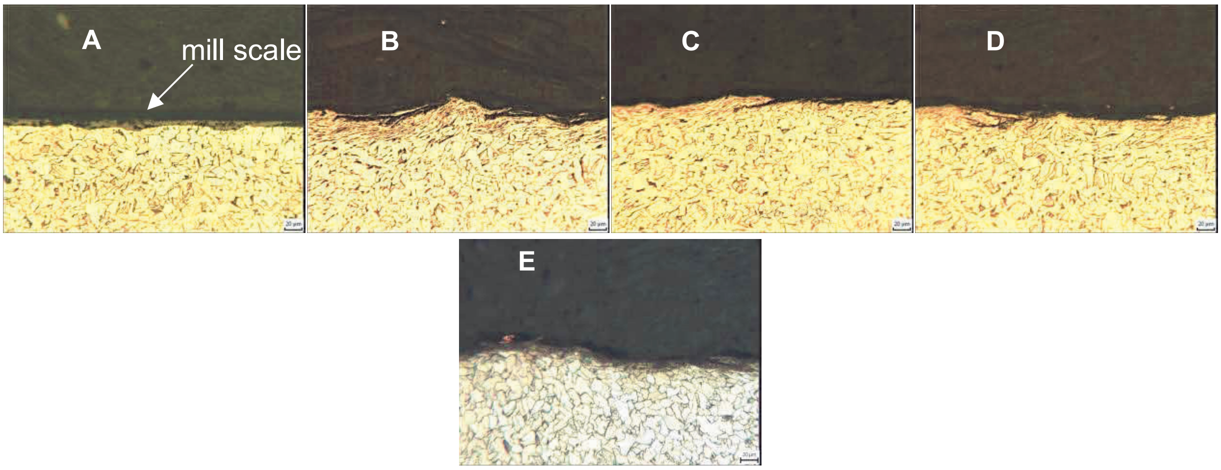

Figure 6 Metallography - surface layer of base material: A) sample without surface preparation-S0; B) sample S1; C) sample S2; D) sample S3; E) sample S4

4. CONCLUSION

The paper provides a complex analysis of surface after abrasive blast-cleaning of the substrate and prior final surface treatment. The analysis of individual surfaces included, for instance: the assessment of purity of a surface according to EN ISO 8501-1, measurement of surface stress in the base material using test inks, a metallographic analysis, assessment of surface asperity, assessment of microhardness and the analysis of residual stress using the magnetoelastic method. Based on the analyses conducted, it is possible to unequivocally set optimal parameters and the medium for surface blasting before creating protective coating. The optimal values of the blasted surface were achieved by using the medium: sharp-edged steel grit G18- everage hardness 59 HRC, grain size: 0.71-1.18 mm. The properties of an ideal surface for anchoring final layers are a compromise between the values of residual stress, hardness, surface rough and surface purity. The application of the magnetoelastic method enables to operatively evaluate the course of blasting process in a non-destructive way. The results obtained are in concordance with traditional methods of surface evaluation.

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