EFFECT OF BLASTING MATERIAL ON SURFACE MORPHOLOGY OF STEEL SHEETS

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Abstract
The contribution deals with pre-treated blasting surfaces of steel sheets of grade S235JRG2. Four types of blasting materials were used: steel shot and steel grit, as representatives of metal blasting materials, and brown corundum and demetalized steel slag, as representatives of non-metal blasting materials. Used materials had two shapes: globular and irregular-sharp shape. The quantitative roughness measurement by means of standardized (EN ISO 4287) roughness parameters with contact profilometer was realized. The particular character of blasted surfaces was analyzed by light microscopy and scanning electron microscopy (SEM). Special attention was paid to the comparison of selected methods of blasted surfaces evaluation.

Keywords: cold working, surface structure, SEM, steels

1 Introduction

Blasting as a type of mechanical surface pre-treatment has a universal application in practice and it is the most widely used method for preparing a steel substrate before protective coating. Surface quality of each product is a necessary requirement to ensure an optimal future coating with suitable rheological properties, adhesion, ductility, deformation resistance, porosity, visual appearance of coating and corrosion resistance in all types of stress, too. The surfaces pre-treated by blasting are a good basis for further processing. The aim of blasting process is to remove all impurities from the metal surface, to create a suitable microgeometry and physical and mechanical properties [1 - 4].

One of the main conditions for obtaining required character of blasted surface is the selection of an appropriate kind, shape and size of blasting materials. The constitutive criteria in choosing a blasting media is the purpose of blasting (cleaning, surface treatment, hardening, etc.) [5 - 7]. The blasting media is thrown onto a metal surface at high speed and is accelerated mechanically by blasting wheels, flowing gas or air.

The research in blasting reacts on economy and ecology requirements by developing of new types of blasting materials, which can potentially replace those traditionally used [8 - 10]. On the other hand, the development of surface evaluation after blasting process constantly comes with new possibilities of surface morphology measurement. In the present time it is developed and used several classical and new methods of evaluation and visualization of blasting surface, which are described in the works of domestic and foreign authors [11 - 17].

The aim of the present paper is to analyze surface changes induced by blasting process using various blasting materials. The article compares several methods of surface evaluation - conventional methods are supported by microscopic analysis.

2 Materials and Experimental Methods

As a substrate material the steel sheets of grade S235JRG2 were used. Samples for experiments were taken from the tested sheet in the rolling direction. Sample dimensions were as follows: 100 x 50 x 2 mm. Chemical composition and main mechanical properties of substrate material are shown in **Table 1**. Surface pre-treatment was realized on pneumatic blasting laboratory machine of type TJVP-320 Škoda Plzeň, at air of pressure of 0.4 MPa and a constant distance of blasting gun nozzle from substrate material of 200 mm. Basic characteristics of used blasting materials are given in **Tables 2** and **3**. **Figure 1** shows the appearance of metal and non-metal blasting materials. The first two images of blasting metal materials are taken from the source [18].

Table 1 Chemical composition and mechanical properties of substrate material S235JRG2

Material	Chemical composition [wt %]						Mechanical properties		
	C_{max}	**Mn_{max}**	**P_{max}**	**S_{max}**	**Al_{min}**	**N_{max}**	**UTS [MPa]**	**YS [MPa]**	**A5 [%]**
S235JRG2	0.17	1.40	0.045	0.045	0.020	0.009	383	245	26

Table 2 Characteristics of blasting materials

Steel Shot (OG 0.9)	*Structure:* fine homogeneous structure of tempered martenzite and bainite mixture with an optimal flexibility and fatigue resistance of material. *Chemical composition*: C ≥ 0.75 %, P ≤ 0.04 %, S ≤0.04 %, Mn ≥ 0.40 %, Si ≥ 0.70%.
Steel Grit (OD 0.71)	*Structure*: partially tempered martenzite. *Chemical composition*: C ≥ 0.75 %, P ≤ 0.04 %, S ≤ 0.04 %, Mn ≥ 0.40 %, Si ≥0.70%.
Brown Corundum (K 0.9)	Synthetic crystalline material produced by melting in electric arc furnace from calcined bauxite, coke and Fe particles. *Chemical composition*: min. 95.50 % Al_2O_3, max. 1.40 % SiO_2, max. 0.60% Fe_2O_3, max. 0.20 % CaO, 1.5 – 3.0 % TiO_2.
Demetalized Steel Slag (DOT 0.9)	Secondary product in the manufacture of steel in company U.S.STEEL s.r.o Košice. *Chemical composition*: 43.53 % CaO, 13.5 % SiO_2, 1.68 % Al_2O_3, 28.15 % Fe_2O_3, 6.15% MgO, 3.84 % MnO, 0.94 % SO_3, 1.95 % pig iron. Chemical composition is variable due to weather effects and staying in a dump in the slag heaps. The slag for investigation was in slacked and selected form.

Table 3 Used types, shapes and particle sizes of blasting materials

Symbol of blasting materials	Type	Shape	Particle Size [mm]
OG 0.9	Metal	Globular	0.9
OD 0.71		Irregular -sharp	0.71
K 0.9	Non-metal		0.9
DOT 0.9			

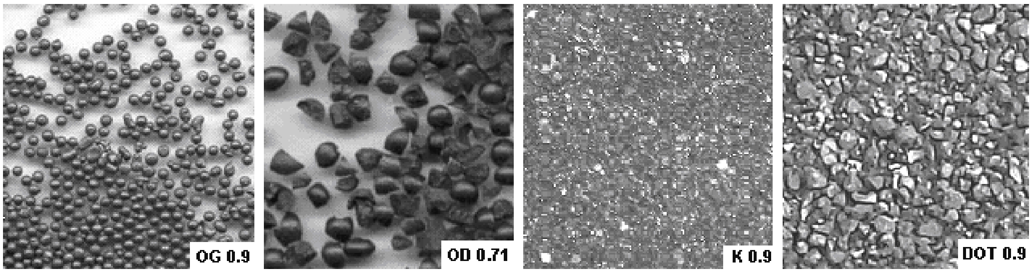

Fig.1 Appearance of metal and non - metal blasting materials

The surface roughness was measured with contact profilometer Surftest SJ-301 Mitutoyo, Japan, with a diamond tip of curvature radius of 5 μm. Output measurements were presented in the form of selected values of roughness parameters by norm EN ISO 4287: Ra - arithmetic mean deviation of profile, Rz - maximum height of profile, Rt - total height of profile, Rp - maximum profile peak height, Rv - maximum profile valley depth, RSm - mean width of profile elements [19]. Measurement parameters: base length l (λc) = 2.5 mm, the number of basic lengths (N) = 5, measured profile: R (a system of central line), filter: Gauss, the evaluation length ln = 12.5 mm, number of measurements: 20.
For metallographic analysis, the light microscope NEOPHOT 32 and SEM JEOL JSM-35 CF was used. Samples for analysis were prepared by standard metallographic method and observed in cross-section.

3 Results and Discussion

3.1 The roughness of blasting surfaces

The final blasting surfaces are formed by surface transformation mainly due to mechanical effects and may interfere with macro, micro and submicroscopic volumes of blasting surface layers. The value of surface roughness refers to the rate of marks in the substrate material after using of a certain size and shape of the blasting materials [5,6]. Arithmetic averages of the measured roughness parameters are summarized in **Table 4.**

Table 4 Arithmetic averages of the measured roughness parameters

Symbols of blasting materials	Ra [μm]	Rz [μm]	Rt [μm]	Rp [μm]	Rv [μm]	RSm [μm]
OG 0.9	11.22	60.79	71.26	32.61	28.18	642.70
OD 0.71	10.91	68.7	84.41	33.84	34.86	355.05
K 0.9	11.43	70.29	86.13	31.96	38.34	339.45
DOT 0.9	10.59	64.31	76.09	26.84	37.46	401.40

All studied blasted surfaces have approximately comparable values of roughness parameter Ra (from 10.59 μm - measured at DOT 0.9 to 11.43 μm - measured at K 0.9). It is interesting that all blasted surfaces are similar according to the measured values of roughness parameter Ra, although it isn't true. Till now, arithmetic mean deviation (Ra) is the primary and the most common evaluated parameter of roughness but it is often insufficient. It seems that two surfaces having the same Ra value may behave differently in principle as was demonstrated by measuring of other characteristics of roughness and by microscopic analysis discussed in next chapters of this paper too. Used type and shape of blasting particles is fully reflected in other measured values of roughness parameters. Measured values of amplitude parameters (Rz, Rt) show a minimal removal of substrate material (Rz = 60.79 μm, Rt = 71.26 μm) after blasting with globular particles. In contrast, surfaces blasted with irregular-sharp particles are more roughened - measured parameters have the higher values, see Table 4.

Measured geometrical parameter Rp - maximum profile peak height vary from 26.84 μm at surface blasted with DOT 0.9 to 33.84 μm at surface blasted with OD 0.71. Potentially higher value of parameter Rp was measured at surface blasted with OG 0.9 (Rp = 32.61 μm). This fact can be explained by behavior of edges which are created after the shot fall to the substrate material. Parameter Rv - maximum profile valley depth was measured in the range from 28.18 μm at surface blasted with OG 0.9 to 38.34 μm at surface blasted with brown corundum (K 0.9). Parameter named as mean spacing of profile irregularities (RSm) characterize blasted surfaces in terms of its roughness. The roughest surface was measured at surface blasted with K 0.9 where RSm was the smallest (339.45 μm). The surface blasted with OG 0.9 had the smallest roughness, where RSm acquired the highest value (642.70 μm).

3.2 Optical microscopy

The first method of surface morphology evaluation was the macroscopic analysis. The fundamental differences in characteristics of surfaces blasted with round and irregular-sharp blasting materials are shown in **Fig. 2**. After blasting with steel shots (OG 0.9) we can see the amount of uniform distributed and overlapping spherical craters on the surface. The average size of the craters is about 1.2 mm. Surfaces, blasted with irregular - sharp particles don't showed expected more substantial changes in the surface quality and integrity. It is necessary to underline that all surfaces has a stochastic and rough character.

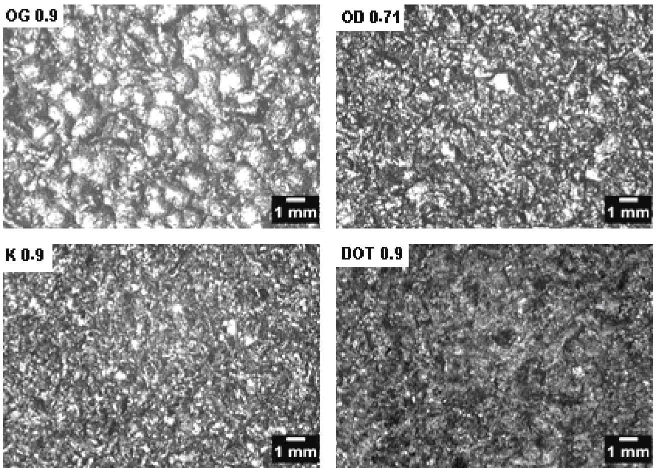

Fig.2 Images of surfaces induced by blasting and evaluated by optical microscope

The surface profile was observed on the cross-sections of blasted substrates. Blasted surfaces of all four samples are shown on **Fig. 3**. Steel surface blasted with steel granulate (OG 0.9) has more uniform profile. Macroscopically observed spherical craters are shallow without sharp lips in contrast to the surfaces blasted with irregular-sharp blasting materials (OD 0.71; K 0.9; DOT 0.9). An irregular profile with amount of sharp peaks and hollows are clearly visible.

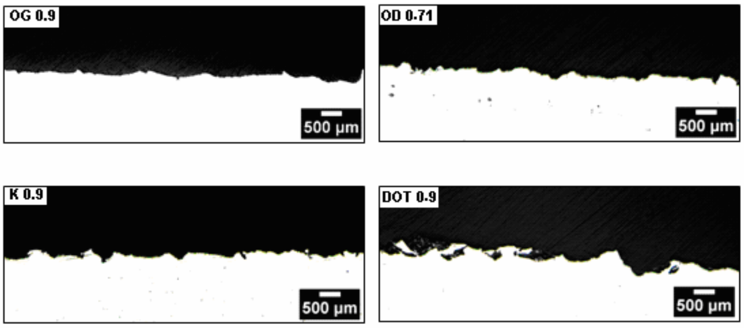

Fig.3 Cross-sections of blasted surfaces

3.3 Scanning microscopy

Surface craters after blasting with OG 0.9 perfectly correspond with used shape and especially with type of used globular grain of blasting material. Surfaces are well-defined by intersecting globular contour (**Fig. 4 a, b**). The surface detail shows that globular particles don't create deep craters (**Fig. 4 c**).

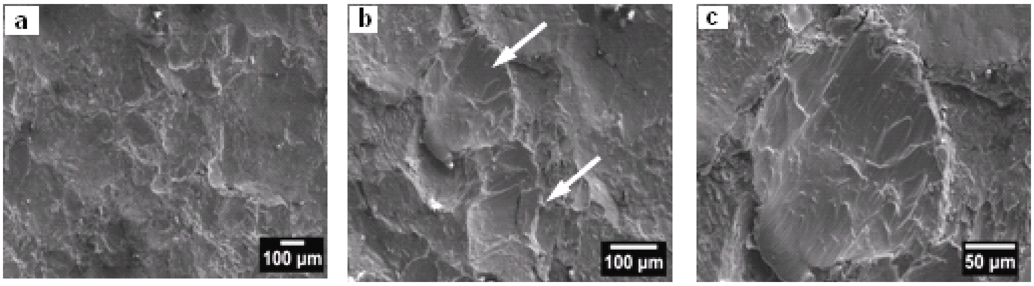

Fig.4 SEM images of surface morphology induced by blasting with OG 0.9 a), b) general view, c) detail view

Steel grit (OD 0.71) as a representative of irregular - sharp blasting materials caused non-oriented, intersecting sharp lips (**Fig. 5 a, b**). A detailed look at the areas with different orientation of surface scratches is on **Fig. 5 c**. The surface morphology shows considerably different view in contrast to the surface blasted with OG 0.9.

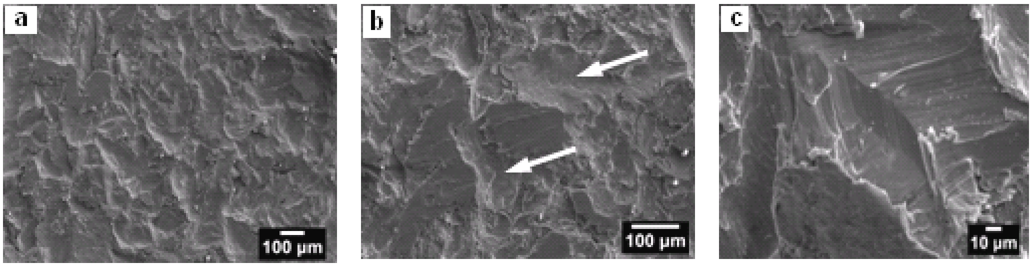

Fig.5 SEM images of surface morphology induced by blasting with OD 0.71 a), b) general view, c) detail view

Surface blasted with brown corundum (K 0.9) is characterized by strong heterogeneity and surface roughness (**Fig. 6 b, c**). The typical feature of this surface is presence of residues of corundum grains (**Fig. 6 a**) with negative influence on the properties.

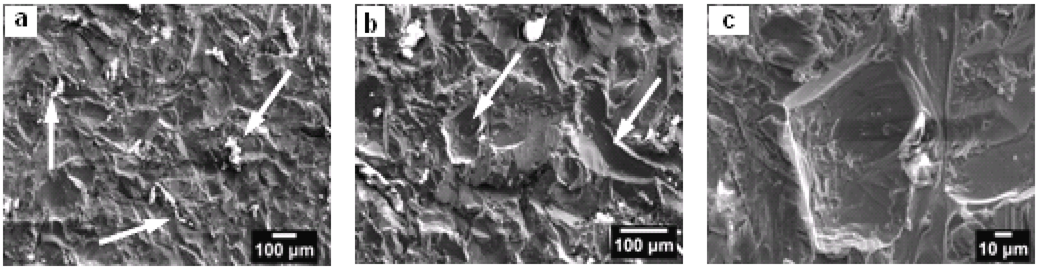

Fig.6 SEM images of surface morphology induced by blasting with K 0.9 a), b) general view, c) detail view

Demetalized steel slag (DOT 0.9) is a potentially new blasting material of non-metal type. The surface pre-treated by this type of blasting material has the smallest surface roughness in contrast to the surfaces blasted with irregular-sharp blasting materials. The reason of this fact we can be found in low weight of slag and low kinetic energy caused by the fall to steel surface. In the moment of particles fall, the slag crumbled into smaller pieces - surface craters were therefore less obvious (**Fig. 7 b, c**). In case of demetalized steel slag, the presence of powder proportion on the surface was confirmed, see **Fig. 7 a.**

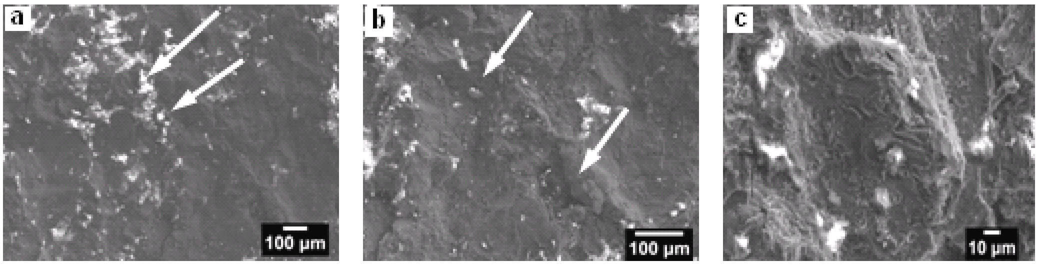

Fig.7 SEM images of surface morphology induced by blasting with DOT 0.9 a),b) general view, c) detail view

4 Conclusions

Based on the results of roughness measurements and microscopic analysis of tested samples the following conclusions can be stated:

1. The shape and type of blasting materials significantly affects the surface morphology of the investigated steel sheets. Globular particles of blasting materials (steel shot) cause more uniform surface morphology that consists of mutually intersecting spherical areas. Removal of the substrate is not significant and measured roughness parameters are minimal. Irregular and sharp particles of blasting materials - (steel grit, brown corundum, demetalized steel slag) create non-oriented relief with amount of sharp lips in substrate material. Surface traces after blasting with different blasting materials differ in cutting intensity, surface quality and content of negative secondary impurities of the surface (brown corundum - residues of blasting material, demetalized steel slag - powder proportion). Steel surface blasted with brown corundum and steel grit shows

the most relevant surface deformation. The peaks and hollows were deep and very sharp. Knowledge about the impact of various types and shapes of blasting materials are very valuable for obtaining the expected state of the surface.

2. For the complex and concise evaluation of blasted surfaces morphology it is necessary to use and combine several methods of evaluation since the evaluation with roughness parameter Ra (arithmetic mean deviation) is insufficient. We propose to use additional amplitude characteristics of roughness and spacing parameters, too.
3. Microscopic analysis is accurate and valuable subsidiary for morphology evaluation of blasted surfaces. The optical microscopy explained the principal differences of surface morphology after blasting with ground and irregular-sharp blasting materials. SEM identified surface changes more closely and revealed the presence of secondary impurities on the blasted surfaces.
4. The 2D form predicates about a little functionality of the surface and can ignore the substantial aspects of measured surface. The 3D evaluation is modern and realistic method of evaluation but at the moment is not normalized in Slovakia.

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