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MECHANICAL PROPERTIES OF BLASTED STEEL SHEET

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Blasting results in a change of properties of the substrate surface; among others, the strain hardening, the formation of residual stress and a change in the surface morphology take place in the surface layer. The paper deals with the influence of the blasted layer on the resulting mechanical properties of blasted steel sheet RSt 37.2 (11 523.1) with the thickness from 1,5 to 3 mm. While the sheet thickness decreases, the yield point exponentially increases and the deformation properties of blasted sheet decrease. The paper analyses the nature of these changes.

Key words: *steel sheet, blasting, mechanical properties*

Mehanička svojstva pjeskarenog čeličnog lima. Rezultati pjeskarenja u promjeni svojstava površine temeljnog sloja i između ostalog očituju se u otvrdnjavanju deformiranjem, stvaranju preostalog naprezanja, te promjeni morfologije površine. Rad se bavi utjecajem pjeskarenog sloja na rezultate mehaničkih svojstava pjeskarenog čeličnog lima RSt 37.2 (11 523.1) koji ima debljinu od 1,5 do 3 mm. Kad debljina lima opada, granica razvlačenja raste eksponencijalno a opadaju deformacijska svojstva pjeskarenog lima. Ovaj rad analizira prirodu ovih promjena.

Ključne riječi: *čelični lim, pjeskarenje, mehanička svojstva*

INTRODUCTION

The properties of the surface, or the surface layer, have a significant effect on parts and later equipment. Blasting is one of mechanical ways by the use of which we achieve a change of properties of the substrate surface layer. Blasting results in the strain hardening, the formation of residual stress, a change in the surface morphology take place, etc. in the surface layer [1 - 3], which usually increases the strength properties of the layer, but decreases its plasticity and toughness [4 - 6]. The properties of the blasted layer depend on the blasting conditions and the blasted material. The layer obtained by blasting also influences the mechanical properties of the blasted part. From technical literature we know that blasting has a positive effect mainly on fatigue properties [5, 7 - 9], while its effect on the basic mechanical properties is less significant [10 - 12]. A surface strain hardened steel sheet can be considered as a two-layer material and therefore its resulting properties will be a function of the volume share of the hardened surface, the mechanical properties of the surface, its morphology (roughness, defects), the loading method (tension, bending, etc.), etc.

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The purpose of the paper is to evaluate the effect of the volume share of the blasted layer on the mechanical properties of steel sheet RSt 37.2.

EXPERIMENTAL MATERIAL AND METHODS

Experiments were made on steel sheet grade RSt 37.2 with the thickness of 3 mm, whose basic mechanical properties were R_e = 280 MPa, R_m = 400 MPa, A_5 = 32 % and Z = 66 %.

The sheet microstructure is ferrite-pearlitic, with a low pearlite content and the ferrite grain size d_{st} = 0,012 mm (Figure 1.). The structure was homogeneous across the whole sheet thickness.

Test samples were taken from the tested sheet in the rolling direction and flat test bars were made with the measured length L_0 = 50 mm and the cross-section 6 × 3 mm.

The test bars were ground on both sides to the thickness of ca 3; 2,34 and 1,54 mm and some of these bars were blasted on all sides by the use of a pneumatic blasting device with steel granulate with the hardness of 500 HV. At blasting with the pressure p = 0,5 MPa, the steel granulate impact angle α = 30; 45 and 75° and the steel granulate diameter d = 0,56; 0,71 and 0,9 mm were applied to test bars with the thickness of 3 mm. On test bars with the other thicknesses, blasting was only applied at p = 0,5 MPa, α = 75° and d = 0,9 mm.

On as-ground and as-blasted test bars, the surface roughness and the micro-hardness across the thickness of the blasted layer were measured and then a tensile test was made and complete mechanical properties were evaluated.

EXPERIMENTAL RESULTS AND THEIR ANALYSIS

As documented by Figure 1., blasting resulted in an increase of the surface unevenness (roughness) and in the strain hardening of the surface layer.

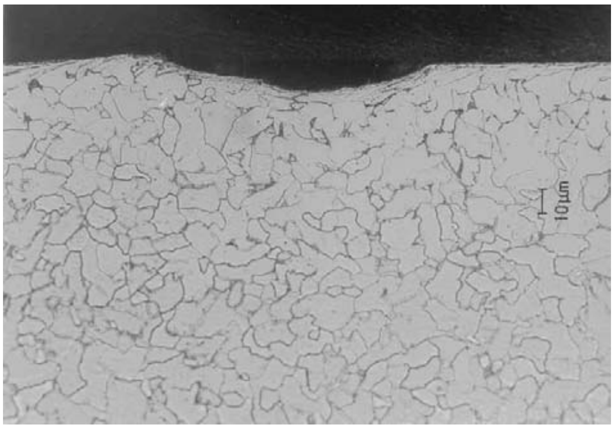

Figure 1. **Microstructure of the tested sheet with the blasted surface at p = 0,4 MPa, d = 0,9 mm, α = 30 °**

Slika 1. **Mikrostruktura ispitivanog lima s pjeskarenom površinom pod tlakom od p = 0,4 MPa, d = 0,9 mm, α = 30 °**

The surface roughness was evaluated through the mean arithmetic deviation Ra and the highest profile height R_z. Figure 2. documents the measured surface roughness values; it results from them that the roughness characteristics increase with the growing grain diameter d and the impact angle α of steel granulate. Important is a finding that the blasted surface roughness is higher by an order than that of the sheet with the ground surface, where R_a = 0,27 μm and R_z = 1,56 μm.

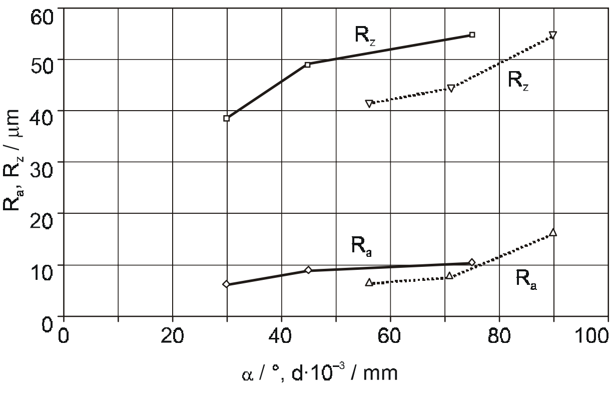

Figure 2. **Effect of the impact angle α and the blasting granulate diameter d on the roughness characteristics R_a, R_z**

Slika 2. **Utjecaj kuta udara α i promjera pjeskarene granule d na hrapavost R_a, R_z**

The quantitative determination of strain hardening of the surface layer was made by measuring micro-hardness HVM 0,01. Figure 3. shows the course of micro-hardness in the blasted surface layer. Because of the surface layer thickness, the HVM 0,01 measurements did not make it pos-

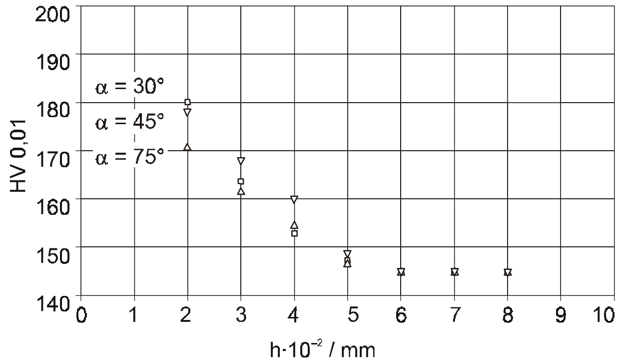

Figure 3. **Course of micro-hardness HVM 0,01 across the thickness of the blasted test sheet h**

Slika 3. **Tijek mikro-tvrdoće HVM 0,01 preko debljine pjeskarenog ispitnog lima h**

sible to precisely assess the effect of the blasting parameters on the course of HV 0,01 in the surface layer, and the HVM 0,01 values measured under various blasting conditions ranged within the interval marked in Figure 3. It resulted from the micro-hardness measurements that the thickness of the strain hardened layer was ca 0,055 mm. The surface shows the highest micro-hardness (the greatest hardening) (180 HVM 0,01), while the mean micro-hardness value of the blasted layer is 163 HVM 0,01.

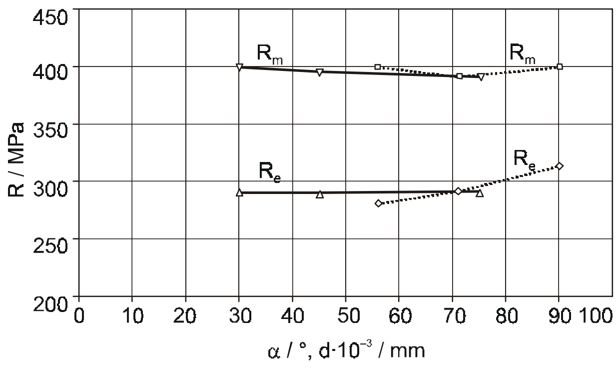

Figure 4. **Effect of the impact angle α and the blasting granulate diameter d on the yield point R_e and the tensile strength R_m**

Slika 4. **Utjecaj upadnog kuta α i dijametra pjeskarene granule d na granicu razvlačenja R_e i vlačnu čvrstoću R_m**

The effect of the blasting conditions on the basic mechanical properties of the blasted sheet with the thickness of 3 mm is documented by Figure 4. and Figure 5. If we consider the internal and external conditions influencing the

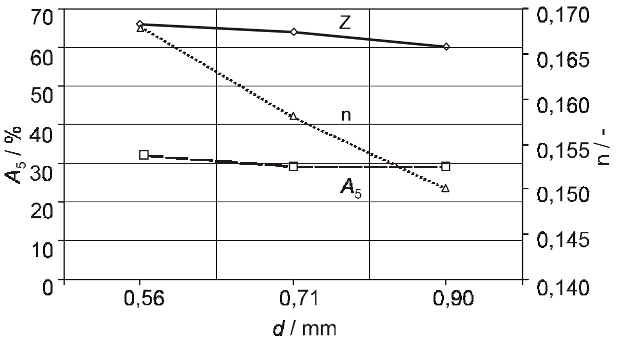

Figure 5. **Effect of the blasting granulate diameter d on the elongation A_5, the reduction of area Z and the strain hardening exponent n (p = 0,5 MPa, α = 75 °)**

Slika 5. **Utjecaj pjeskarene granule d na izduživanje A_5, suženje Z i eksponent deformiranja n (p = 0,5 MPa, α = 75°)**

measured results on a real material, we can state that the basic mechanical properties of the blasted sheet with the thickness of ca 3 mm are only slightly influenced by the blasted layer. The yield point R_e is increased slightly (max. by 5 %), the tensile strength R_m is decreased (max. by 1 %), the elongation A_5 and the reduction of area Z are decreased (by ca 3 % and 5 %, respectively). However, the strain hardening exponent n is decreased significantly, by 21 %.

The surface strain hardened sheet can be considered as a two-layer material. The effect of the surface layer on the mechanical properties of the two-layer material is a function of the mechanical properties, the volume (cross-sectional) share of the surface layer in the total volume (cross-section) of the sheet, but also of other internal and external factors. An increase of the share of the layer in the total cross-section was achieved by reducing its thickness through grinding. Figure 6. graphically presents the effect of the share of the strain hardened layer on the mechanical properties of the blasted sheet. It results from the measurements that an increase of the share of the blasted layer in the total cross-

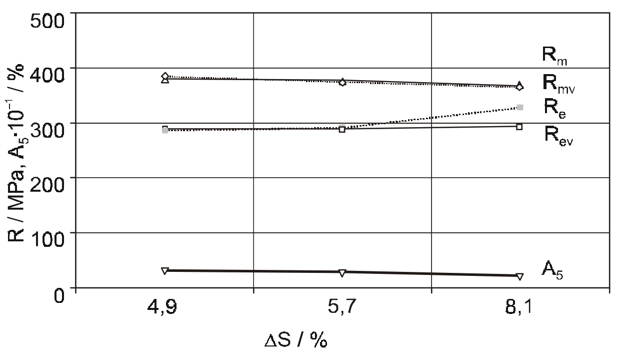

Figure 6. **Effect of the share of the blasting strain hardened layer on the mechanical properties of blasted sheet. R_m, R_e - measured values, R_{ev}, R_{mv} - calculated values for two-layer material**

Slika 6. **Utjecaj udjela pjeskarenog sloja otvrdnutog deformacijom na mehanička svojstva pjeskarenog lima. R_m, R_e - izmjerene vrijednosti, R_{ev}, R_{mv} izračunate vrijednosti za dvoslojni materijal**

section slightly decreases the tensile strength R_m, exponentially increases the yield point R_e and decreases the elongation A_5 and the reduction of area Z (at h = 3 mm, Z = 61 %, at h = 2,34 mm, Z = 59 % and at h = 1,54 mm, Z = 49 %).

Provided that the basic mechanical properties of the blasted sheet are only a function of the mechanical properties of the basic material and the blasted layer and of their volume share, it is possible to predict them from the tensile test diagrams, which is shown in Figure 7. It re-

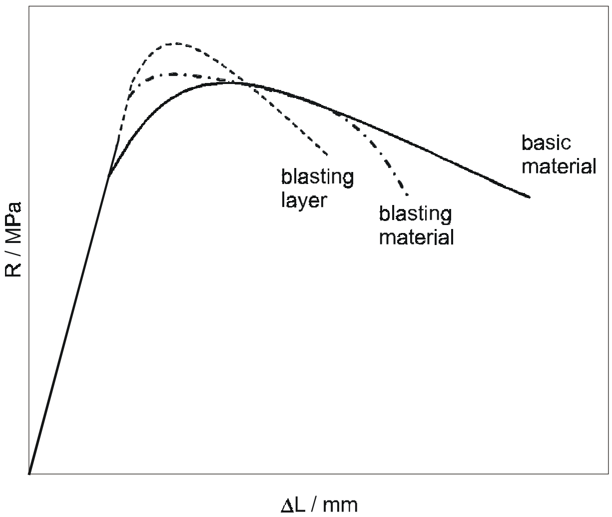

Figure 7. **General tensile test diagram of two-layer material**

Slika 7. **Opći dijagram testa na vlak dvoslojnog materijala**

sulted from the experiments that the mean micro-hardness value of the strain hardened layer (Figure 3.) is, when compared with that of the basic material, higher by 18 HVM 0,01, which is ca 60 MPa, when converted to the strength value. On the other hand, in the blasted layer the whole part of homogeneous plastic deformation, or its significant part, is exhausted, and it will fail before the basic material reaches the plastic stability limit (R_m), which will reduce the functional cross-section of the test bar. Using the formula for the calculation of the strength characteristics of a composite material:

$$R = R_m V_m + R_p V_p$$

where R_m, R_p is the yield point (tensile strength) of the basic material and the layer, respectively, and V_m, V_p are their volume shares, we can predict the strength properties of the blasted sheet. The R_{ev} and R_{mv} values, calculated according to the above-mentioned considerations, are shown in Figure 6. These results show that the tensile strength values of the blasted samples, measured experimentally (R_m) and calculated (R_{mv}), are identical. The measured yield point values (R_e) are higher than the calculated ones (R_{ev}) and this difference increases with the increasing volume share of the blasted layer. A significant increase of the R_e value when compared with R_{ev} ($\Delta R = R_e - R_{ev}$) in samples with a small thickness (1,54 mm) can be attributed to the unevenness (roughness) of the surface blasted sheet (Figure 2.), since this roughness becomes stress concentrators and increases the nominal stress for the plastic deformation initiation [10]. After exceeding the yield point, significant plastic deformation takes place, the effect of the surface roughness is eliminated and therefore the R_m and R_{mv} are identical, in fact.

The unevenness of the blasted surface (micro-notches) and its failure before reaching the plastic stability limit of the basic material are crucial for the decrease of the deformation properties of the blasted samples. The mentioned factors show up more significantly when the sheet thickness decreases.

For the strength calculations, the yield point is usually crucial. In blasted sheets, it is always higher than the basic material (e.g. by as many as 16 % at the tested sheet thickness of 1,54 mm). Since blasted sheet shows sufficient deformation properties (at h = 1,54 mm, A = 23 %, Z = 49 %), it will have higher limit state characteristics.

CONCLUSION

It follows from the experimental results and their analysis that the mechanical properties of the blasted sheet of 11 523,1 grade are, under the same blasting conditions, influenced by the sheet thickness. With a decreasing thickness of the sheet, the following takes place:

- a significant increase of the yield point due to an increasing share of the blasting-hardened volume, but also due to an intensive effect of the unevenness of the blasted sheet and the properties of the interface,
- a linear decrease of the strength value due to a decrease of the cross-section by the blasted cross-section of the surface layer,
- a significant decrease of the deformation properties due to the unevenness of the blasted surface and its strain hardening.

In practice, loading lower than the yield point is permitted and therefore blasting-loaded sheet will be more resistant against plastic deformation, which increases its service properties.

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