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# INFLUENCE OF BLASTING ON MECHANICAL PROPERTIES OF STEEL SHEET

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*Preliminary Note - Prethodno priopćenje*

The paper analyses the influence of blasting conditions on the properties of steel sheet RSt 37-2 having the gauge of 3 mm. Due to blasting, the surface roughness increases by an order and the surface strain hardening takes place to the depth of ca 0.06 mm, which results in compressive stress on the sheet surface. The above-mentioned changes, among others, increase the yield point and decrease the fatigue life in the tension-zero cycle. The increase of the yield point and the decrease of the fatigue life are more significant if the diameter of the blasting medium (within the tested interval from 0,56 to 0,9 mm) and the impact angle (30 to 75°) are greater at the air pressure of 0,4 to 0,5 MPa.

***Key words:*** *blasting, hardness, roughness, yield point, ultimate strength, fatigue*

**Utjecaj pjeskarenja na mehanička svojstva čeličnog lima.** U radu se analizira utjecaj pjeskarenja na svojstva čeličnog lima RSt 37-2 debljine 3 mm. Zbog pjeskarenja hrapavost površine se povećava za neki red veličine, a hladno otvrdnjavanje površine se proteže do 0,06 mm dubine, posljedica toga je tlačno naprezanje na površini lima. Gore spomenute promjene, između ostalog, povećavaju granicu razvlačenja a smanjuju vrijeme umora materijala pri cikličkom naprezanju. Povećanje granice razvlačenja smanjenje vremena umora materijala su značajniji ako su promjer medija pjeskarenja (unutar ispitivanog intervala od 0,56 do 0,9 mm) i udarni kut (30 do 75°) veći pri zračnom tlaku od 0,4 do 0,5 MPa.

***Ključne riječi:*** *pjeskarenje, tvrdoća, hrapavost, granica razvlačenja, maksimalna čvrstoća, umor*

## INTRODUCTION

Blasting is one of basic technologies of surface pre-treatment of metal structures and parts to achieve a suitable surface for a future coating, so that it can have the required properties and durability [1]. The main goal of blasting is to remove any impurities from the metal surface, to create a clean metal surface with a suitable micro-geometry and physical and mechanical properties [2]. Blasted parts and structures are often dynamically or fatigue-loaded and in this connection the influence of blasting on their fatigue life is relevant issue.

The fatigue process is initiated, as a rule, on the surface of a part [3] and therefore the surface quality and the properties of the surface layer have a significant effect on the fatigue properties. The main effect on the fatigue process has the surface roughness, which depends on the blasting conditions.

The basic blasting conditions include: shape, dimensions and size of blasting particles, energy, total quantity and impact angle of particles. Blasting also causes intensive plastic deformation of a thin surface layer, which consequently creates residual compressive stress in this layer and residual tensile stress underneath [4]. Residual compressive stress results in an increase of the fatigue life of parts, especially during bending loading [5, 6]. This positive effect of residual compressive stress will mainly depend on the surface quality, mainly on its roughness. Since in case of surface blasting two opposite tendencies of its effect are shown, the paper is aimed at the investigation of the influence of blasting conditions, such as the particle size, the air pressure and the impact angle on the basic mechanical properties and on the fatigue life.

## MATERIAL AND EXPERIMENTAL METHODS

The influence of blasting conditions on the mechanical properties was investigated on steel sheet grade RSt 37-2 having the gauge of 3 mm and the chemical composition shown in Table 1.

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The basic mechanical properties are: $R_e$ = 279 MPa, $R_m$ = 395 MPa, $A_5$ = 33 %, $Z$ = 71 %. The steel has a fine-grained ferrite-pearlitic structure with the grain size $d_{str.}$ = 0,012 mm.

Table 1. **Chemical composition of steel Grade RSt 37-2 / %**
Tablica 1. **Kemijski sastav čelika kvalitete RSt 37-2 / %**

| C | Mn | Si | P | S | Al | Cu |
|---|---|---|---|---|---|---|
| 0,15 | 0,57 | 0,22 | 0,011 | 0,011 | 0,017 | 0,229 |

For experiments, test specimens were used as shown in Figure l. The as-ground test bars were blasted from both the sides. Blasting was made using a pneumatic blasting device from Wonisch company, which makes it possible to regulate the air pressure in the range from 0,4 to 0,7 MPa. The nozzle diameter is 8,8 mm. Blasting was made under the following conditions: air pressure: $p$ = 0,4 and 0,5 MPa, blasting medium grain size: $d_z$ = 0,56, 0,71 and 0,9 mm and the impact angle $\alpha$ = 30°, 45° and 75°. On as-ground and as-blasted specimens, the surface roughness was measured and the mean arithmetical deviation $R_a$ was evaluated using a contact profile meter Hommel Tester, type T, and the micro-hardness HV 0,01 was measured across the thickness of the blasted sheet using a micro-hardness testing machine HANEMAN. The test specimens shown in Figure 1.a. were used to determine basic mechanical properties. Tensile tests were made on a tensile testing machine INSTRON 1185. Fatigue tests were made on a fatigue testing machine INSTRON 8511 by applying a tension-zero cycle with the frequency of 20 Hz on test specimens shown in Figure l.b.

## OBTAINED RESULTS AND ANALYSIS

The roughness results are show in Table 2. The results show that the surface roughness of the as-blasted specimens is higher by an order, which is represented by the mean arithmetical deviation $R_a$. The $R_a$ value is influenced by all the observed blasting parameters.

Table 2. **Mean values of roughness surface $R_a$**
Tablica 2. **Srednje vrijednosti hrapavosti površine $R_a$**

| Blasting mode $\alpha$ / ° | 75° | 75° | 75° | 45° | 30° | 75° | As-ground surface |
|---|---|---|---|---|---|---|---|
| $d_z$ / mm | 0,56 | 0,71 | 0,9 | 0,71 | 0,71 | 0,71 | |
| $p$ / MPa | 0,5 | 0,5 | 0,5 | 0,5 | 0,4 | 0,4 | |
| $R_a$ / µm | 8,31 | 10,6 | 11,2 | 8,52 | 8,2 | 10,5 | 0,394 |

With the change of the air pressure from 0,4 to 0,5 MPa, $R_a$ value increases by 0,1 µm; with the change of the grain diameter from 0,56 to 0,9 mm, $R_a$ value increases by 2,79 µm and with the change of the impact angle from 30 to 75, $R_a$ value increases by 2,4 µm. The highest $R_a$ value was achieved under the following blasting conditions: $\alpha$ = 75°, $d_z$ = 0.9 mm and $p$ = 0.5. The grain size has the most significant effect on the surface hardness of the as-blasted sheet (Figure 2.).

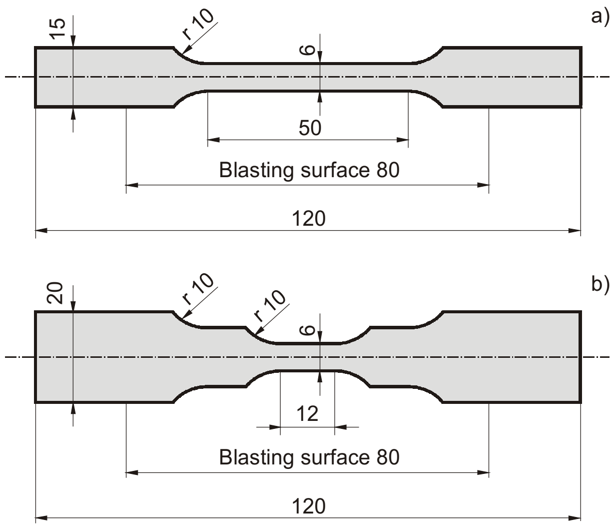


Figure 1. **Test specimens: a) for the tensile test, b) for the fatigue test**
Slika 1. **Ispitni uzorci: a) za ispitivanje na vlak, b) za ispitivanje na zamor**

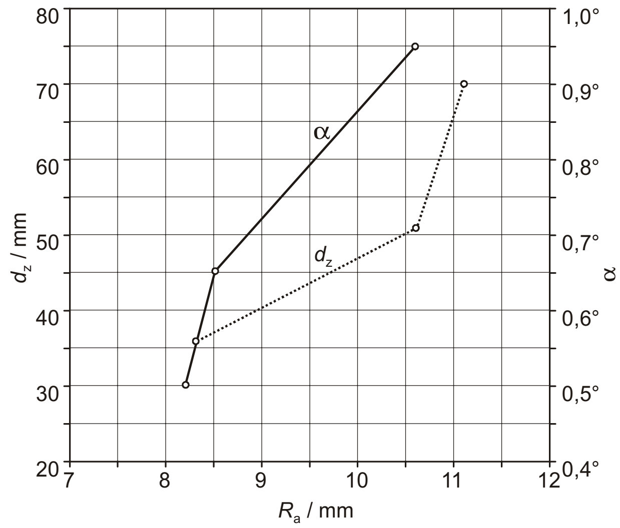


Figure 2. **Influence of the grain diameter $d_z$ and the impact angle $\alpha$ of the blasting medium on the roughness $R_a$ of the tested sheet at the air pressure $p$ = 0.5 MPa**
Slika 2. **Utjecaj promjera zrna $d_z$ i udarnog kuta $\alpha$ pjeskarenog medija na hrapavost $R_a$ ispitivanog lima pri tlaku zraka od $p$ = 0,5 MPa**

The results of measuring the micro-hardness HV 0,01 across the sheet thickness $h$ under selected blasting conditions are shown in Table 3. and Figure 3.

It results from the micro-hardness values that the surface of as-blasted sheet is hardened to a maximum depth of 0,06 mm. The impact angle of the blasting medium influences the strain hardening only slightly. The mean value of HV 0,01 of the strain-hardened layer at the impact angle

$\alpha = 30°$ is 161, at $\alpha = 45°$ is 162 and at $\alpha = 75°$ is 165. It results from the above-mentioned that the mean strength value of the strain-hardened layer increases by ca 62 MPa (at $\alpha = 30°$) up to 75 MPa (at $\alpha = 75°$) when compared with the basic material.

Table 3. **Micro-hardness HV = 0.01 from the surface of as-blasted specimens under the following conditions: $p$ = 0.5 MPa, $d_z$ = 0.9 mm, $\alpha$ = 30, 45 and 75°**

Tablica 3. **Mikro tvrdoća HV = 0,01 površine pjeskarenih uzoraka pod slijedećim uvjetima: $p$ = 0,5 MPa, $d_z$ = 0,9 mm, $\alpha$ = 30, 45 i 75°**

| HV 0.01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $h$ / mm | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 |
| $\alpha$ = 30 ° | 181 | 163 | 160 | 153 | 149 | 145 | 145 | 145 |
| $\alpha$ = 45 ° | 180 | 165 | 160 | 157 | 149 | 145 | 145 | 145 |
| $\alpha$ = 75 ° | 180 | 170 | 165 | 160 | 151 | 145 | 145 | 145 |

The experimental results show that the roughness of the as-blasted specimens is higher by an order when compared with the original state and that the surface layer is strain-hardened and its mean hardness increases by 16-20 HV 0,01. The mentioned facts will influence the resulting mechanical and fatigue properties.

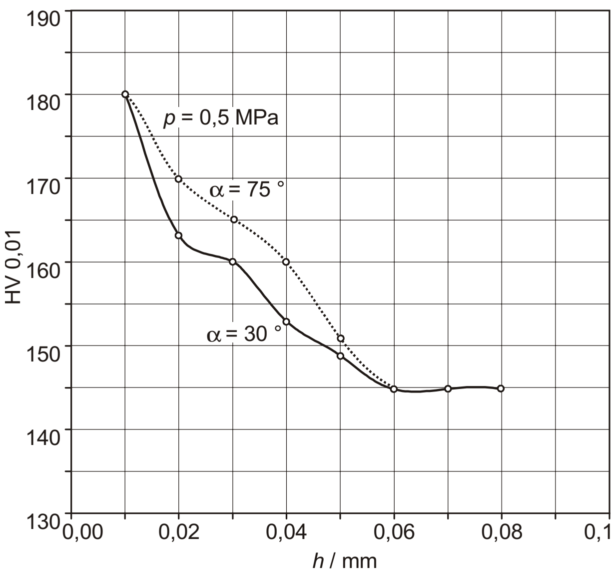


Figure 3. **Course of the micro-hardness HV = 0,01 from the specimen surface $h$ at various impact angles of the blasting medium**

Slika 3. **Rasprostiranje mikrotvrdoće HV = 0,01 površine uzorka $h$ pri različitim upadnim kutovima pjeskarenog medija**

Experimental results of basic mechanical properties determined by a static tensile test are shown in Table 4.

It results from the analysis of the above-mentioned results that blasting does not influence the tensile strength, but increases the yield point $R_e$ and decreases the elongation ($A_5$) and the - reduction of area ($Z$) of blasted sheet in the dependence on the blasting conditions. The air pressure ranging from 0,4 to 0,5 MPa does not influence the above-mentioned properties in, fact. With an increasing grain diameter and impact angle of the blasting medium, the yield point increases (Figure 4.) and the deformation properties change slightly. The most significant changes of the as-blasted surface when compared with the as-ground surface were measured under the following blasting conditions: $\alpha = 75°$ and $d_z$ = 0.9 mm. The yield point increased by 30 MPa (i.e. ca 10 %) and the deformation properties decreased by 5 % ($A_5$) and 2 % ($Z$) when compared with the as-gro und surface.

Table 4. **Basic mechanical properties of as-blasted specimens under various blasting conditions**

Tablica 4. **Osnovna mehanička svojstva pjeskarenih uzoraka pri raznim uvjetima pjeskarenja**

| | Blasting mode $\alpha$ / °, $d_z$ / mm, $p$ / MPa | | | | | | |
|---|---|---|---|---|---|---|---|
| Measuring parameters | 75°<br>0,56 mm<br>0,5 MPa | 75°<br>0,71 mm<br>0,5 MPa | 75°<br>0,90 mm<br>0,5 MPa | 45°<br>0,71 mm<br>0,5 MPa | 30°<br>0,71 mm<br>0,5 MPa | 75°<br>0,71 mm<br>0,4 MPa | Ground surface |
| $R_m$ / MPa | 394 | 395 | 395 | 394 | 395 | 395 | 395 |
| $R_e$ / MPa | 297 | 302 | 309 | 298 | 290 | 298 | 279 |
| $A_5$ / % | 32 | 29 | 28 | 28 | 27 | 30 | 33 |
| $Z$ / % | 71 | 70 | 69 | 71 | 69 | 69 | 71 |

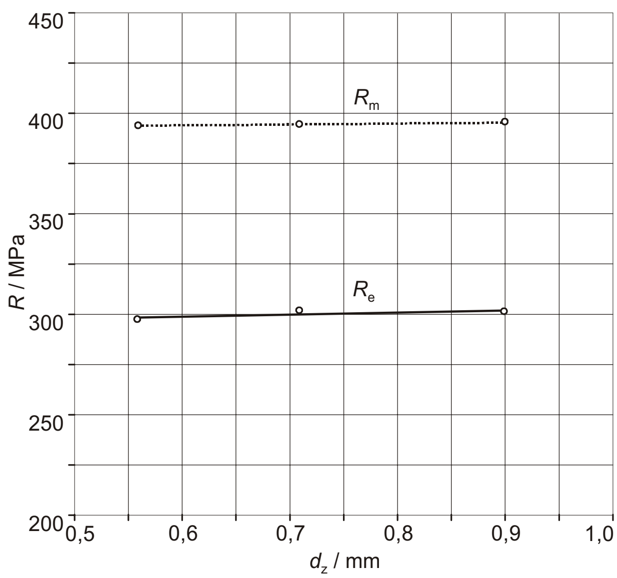


Figure 4. **Influence of the grain diameter $d_z$ of the blasting medium on the strength limit $R_m$ and the yield point $R_e$ under the following blasting conditions: $\alpha$ = 75°, $p$ = 0.5 MPa**

Slika 4. **Utjecaj promjera zrna $d_z$ pjeskarenog medija na vlačnu čvrstoću $R_m$ i granicu razvlačenja $R_e$ pri slijedećim uvjetima: $\alpha$ = 75°, $p$ = 0,5 MPa**

The increase of $R_e$ and the decrease of $A_5$ and $Z$ of the as-blasted surface when compared with the as-ground surface is mainly due to the strain hardening of the surface layer. The micro-hardness results showed that the greatest hardening of the surface layer was measured under the following blasting conditions: $\alpha = 75°$ and $d_z = 0,9$ mm (see Table 3.), which corresponds with the results determined using the tensile test. It should he emphasized that the tensile test results apply to a sheet with the gauge of 3 mm. In case of less gauges, the blasting effect would be more significant and vice versa.

Tensile fatigue tests with the tension-zero cycle were made on as-ground and as-blasted specimens under the following blasting conditions: $p = 0.5$ MPa, $\alpha = 75°$ and $d_z = 0,9$ mm. Wöhler fatigue curves are shown in Figure 5. It

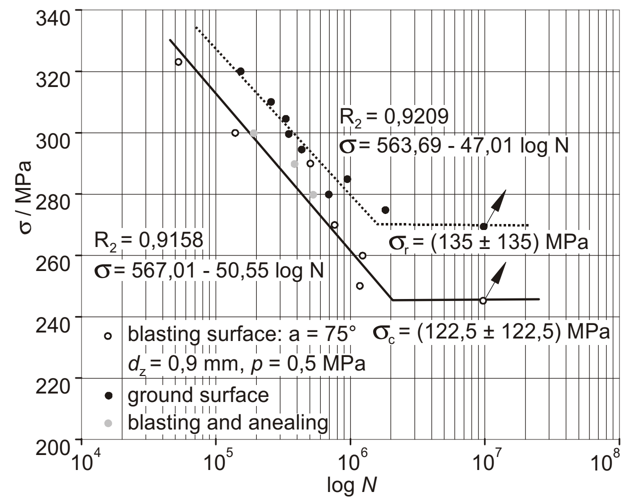


Figure 5. **Wöhler fatigue curves at the tension-zero cycle**
Slika 5. **Wöherove krivulje umora pri cikličnom naprezanju**

results from the fatigue tests that the fatigue limit of the as-blasted specimens is 25 MPa less (ca by 10 %) than that of the as-ground specimens, and the time fatigue limit (shift of the inclined part of Wöhler curve to left) is also decreased, while its slope does not change very much.

The fatigue properties of as-blasted specimens are influenced by two opposite factors. The hardened surface layer of as-blasted specimens causes the formation of compressive stress on the specimen surface (to the depth of ca 0.6 mm), which has a positive effect on the fatigue properties. On the other hand, the increase of roughness of the as-blasted surface by an order has a negative effect on the fatigue properties. During microscopic observations of the cross- sections of the surface layer, significant deformation of grains was found out, but no cracks were observed (see Figure 6. and Figure 7.). To assess the influence of individual factors on the fatigue properties, fatigue tests were also made on as-blasted specimens that were annealed at 600 °C/l h/furnace, which eliminated surface stress due to blasting. The results obtained on the as-annealed specimens are similar to the results obtained on the as-blasted specimens (see Figure 5.). These measurements confirmed

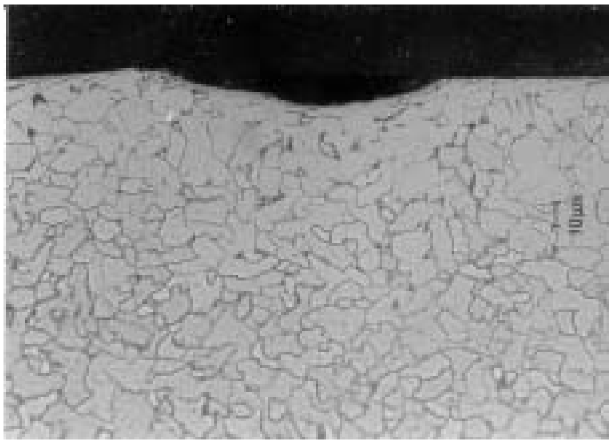

Figure 6. **Microstructure of the as-blasted sheet surface under the following blasting conditions: $d_z = 0,9$ mm, $\alpha = 45°$, $p = 0,5$ MPa**
Slika 6. **Mikrostruktura pjeskarene površine pri slijedećim uvjetima pjeskarenja: $d_z = 0,9$ mm, $\alpha = 45°$, $p = 0,5$ MPa**

an assumption that the negative effect of the surface roughness is a prevailing effect on the tensile fatigue life of blasted sheets under the investigated blasting conditions. The specimens failed in such away that a crack was initiated on sharp edges of the side and front surfaces, where there was the greatest stress concentration and the greatest hardening. In these places, the notch affect after blasting is also more significant. Therefore it can be assumed that the gauge of the tested sheet does not have a significant effect on the fatigue properties of blasted sheet.

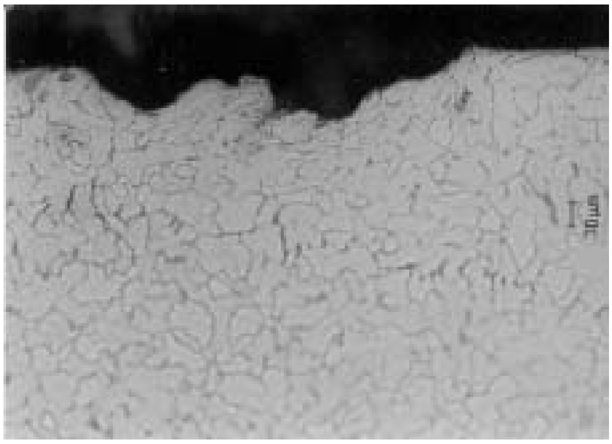

Figure 7. **Microstructure of the as-blasted sheet surface under the following blasting conditions: $d_z = 0,9$ mm, $\alpha = 75°$, $p = 0,5$ MPa**
Slika 7. **Mikrostruktura pjeskarene površine lima pri slijedećim uvjetima pjeskarenja: $d_z = 0,9$ mm, $\alpha = 75°$, $p = 0,5$ MPa**

## CONCLUSION

The paper analyses the influence of blasting conditions on the properties of steel sheet RSt 37-2. During blasting, the air pressure (0,4 and 0,5 MPa), the grain diameter of the blasting medium (0,56; 0,71 and 0,9 mm) and the impact angle (30°, 45° and 75° C) were changed. It results from the experimental results and analysis:

- blasting results in an increase of the surface roughness by an order, the strain hardening of the surface layer to the depth of ca 0,6 mm, an increase of the yield point and a decrease of the fatigue life;
- among the selected blasting conditions, the grain diameter and the impact angle of the blasting medium have the greatest effect on the change of the observed properties;
- the least changes of the yield point and the fatigue life were found out under the following blasting conditions: $p$ = 0,4 MPa, $\alpha$ = 30° and $d_z$ = 0,56 mm and the greatest changes were found out at $p$ = 0,5 MPa, $\alpha$ = 75 and $d_z$ = 0,9 mm;
- the decrease of the tensile fatigue life of as-blasted specimens determined by applying the tension-zero cycle is due to increased roughness of their surface, i.e. a notch effect, which eliminates a positive effect of compressive stress induced by the strain-hardened surface.

## REFERENCES

[1] V. Bačova: Secondary effects of blasting in sheet surface pretreatment, In Eurometal working 96, Bratislava 1996, 178.
[2] D. Kniewald: Blasting surface preparation under coatings, Koroze a ochrana materialu, 32, (1998) 42.
[3] A. Puškár: High-frequency fatigue of materials, DU Žilina, 1997.
[4] V. Sedlaček: Surfaces and coatings of metals, Praha 1992.
[5] M. Klesnil: Cyclic deformation and fatigue ofmetals, VEDA Bratislava, 1987.
[6] R. A. Chemenkoff, I. Mocarski: Increased Fatigue, (1996) 5, 104.