RESEARCH ON ABRASIVENESS OF MATERIALS USED ON FINISHING METAL ALLOYS. PART II

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Abstract: *The article aims to model data which predicts the abrasiveness depending on the working parameters (type of abrasive material, abrasive material grain size, speed and time) using a multivariable second-degree polynomial model, developed using the Software Design Expert 6.0. The real values and the predicted ones were compared in order to observe the validity of the proposed model. The regression coefficients for the models obtained regarding the level of abrasion are greater than 0.955 and all models are significant in terms of the analysis of variance (P <0.05).*

Keywords: *abrasiveness, granite, electrocorundum, siliceous sand, mixture, modeling.*

1. Introduction

In the article *„Research on abrasiveness of materials used on finishing metal alloys. Part I"* the logistics used to obtain the materials necessary for magneto-abrasive finishing (metal and abrasive materials) were presented. Also, data on the abrasiveness of different materials and mixture powders (granite and siliceous sand, granite and electrocorundum, electrocorundum and siliceous sand and a mixture from all three) were collected, and the final roughness of the samples used on tests was determined [1], [2], [3].

Taking into consideration that certain practical values of answers were followed, it was appropriate to establish interdependencies able to describe both the nature and the extent of the considered influences, therefore a mathematical model was determined [3], [4].

2. Characterizing the abrasiveness of materials

2.1. Characterizing the granite abrasiveness

For the mathematical model of the granite abrasiveness, the data were collected in accordance with Table 3 from the article *„Research on abrasiveness of materials used on finishing metal alloys. Part I*".

The mathematical model that defines the quantity of material removed from the sample in case of granite – the material abrasiveness- (dependent variable), depending on the parameters (independent variables), is shown in the equation 1.

$$m = 0,009297 + 0,001859 \times A + 0,005239 \times B + 0,004476 \times C - 0,0006714 \times A^2 - 0,002022 \times B^2 + 0,0009357 \times C^2 + 0,001381 \times A \times B + 0,0008429 \times A \times C + 0,002726 \times B \times C$$

In order to confirm the validity of the mathematical model proposed, an operational validity through comparative graphical representation has been made -*the obtained value vs. predicted value* (figure 1).

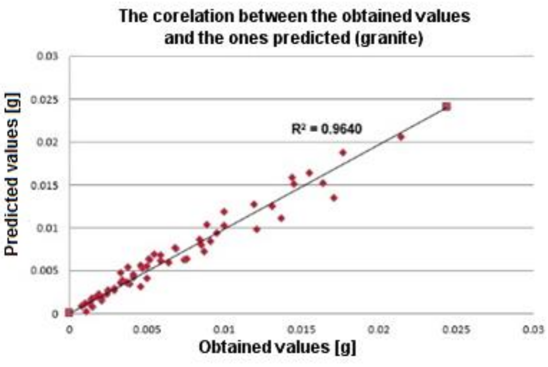

Figure 1. *The correlation between the measured values and those predicted (granite)*

In figure 2 the variation of abrasiveness for granite is shown, depending on grain size and time.

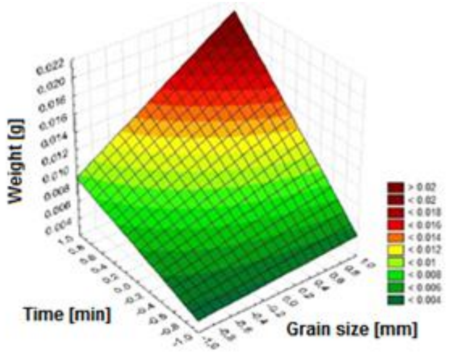

Figure 2 - *The influence of grain size and time on abrasiveness for granite*

The 3D graph was obtained after changing the grain's size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.3, the highest value) and the time between -1 (30 minutes, the smallest value) and +1 (90 minutes, the highest value). The maximum value of the abrasiveness for granite according to the mathematical model is obtained at the maximum grain size (0.3 mm) and at the maximum time (90 minutes). The minimum value of abrasiveness is obtained at minimum grain size (0.04 mm) and the shortest time (30 minutes).

The figure 3 represent the variation of abrasiveness for granite, depending on the speed and the grain size. The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the grain size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.03, the highest value).

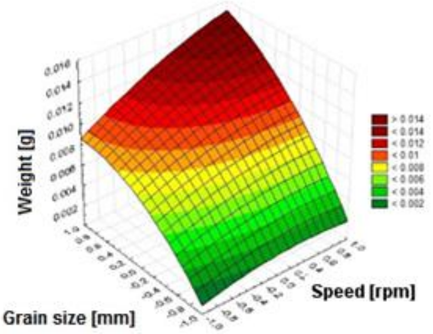

Figure 3. *The influence of speed and the grain size on the abrasiveness of granite*

The maximum value of the abrasiveness for granite according to the mathematical model is obtained at the maximum speed (1000 rpm) and the maximum grain size (0.3 mm). The minimum value of abrasiveness is obtained at minimum speed (700 rpm) and the smallest grain size (0.04 mm).

The figure 4 represent the abrasiveness variation for granite, depending on the speed and time. The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the time between -1 (30 minutes, the smallest value of the field studied) and +1 (90 minutes, the highest value).

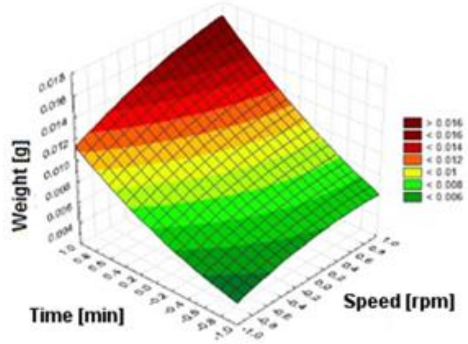

Figure 4. *The influence of speed and time on the abrasiveness of granite*

The maximum value of the abrasiveness for granite according to the mathematical model is obtained at the maximum speed (1000 rpm) and the maximum time (90 minutes). The minimum value of abrasiveness is obtained at minimum speed (700 rpm) and the shortest time for processing (30 minutes).

2.2. Characterizing the siliceous sand abrasiveness

For the mathematical model of the siliceous sand abrasiveness, the data were collected in accordance with Table 4 from the article „*Research on abrasiveness of materials used on finishing metal alloys. Part I*”..

The mathematical model that defines the quantity of material removed from the sample in case of siliceous sand – the material abrasiveness - (dependent variable), depending on the parameters (independent variables), is shown in the equation 2.

$$m = 0{,}006242 + 0{,}001315\times A + 0{,}003680\times B + 0{,}003110\times C - 0.0004643\times A^2 - 0{,}001369\times B^2 + 0{,}0006143\times C^2 + 0{,}001021\times A\times B + 0{,}0005857\times A\times C + 0{,}001919\times B\times C$$

In order to confirm the validity of the proposed mathematical model, an operational validity through comparative graphical representation has been made -*the obtained value vs. predicted value* (figure 5).

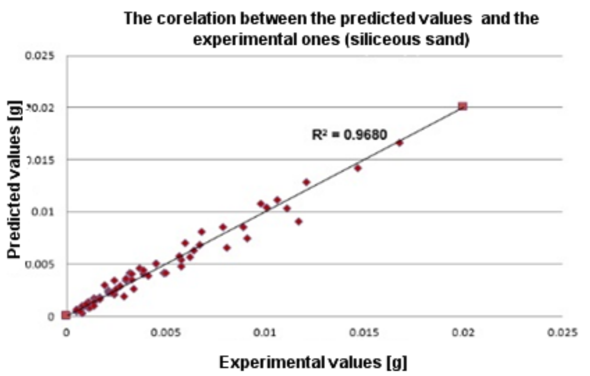

Figure 5. *The correlation between the measured values and those predicted (siliceous sand)*

In figure 6 the variation of abrasiveness for siliceous sand is shown, depending on grain size and time.

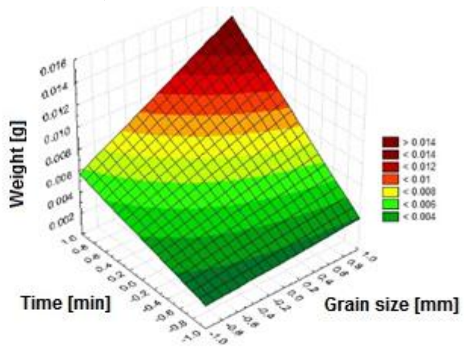

Figure 6 - *The influence of grain size and time on abrasiveness for siliceous sand*

The 3D graph was obtained after changing the grain's size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.3, the highest value) and the time between -1 (30 minutes, the smallest value) and +1 (90 minutes, the highest value).The maximum value of the abrasiveness for siliceous sand according to the mathematical model is obtained at the maximum grain size (0.3 mm) and at the maximum time (90 minutes). The minimum value of abrasiveness is obtained at minimum grain size (0.04 mm) and the shortest time (30 minutes).

The figure 7 represent the variation of abrasiveness for siliceous sand, depending on the speed and the grain size. The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the grain size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.03, the highest value).

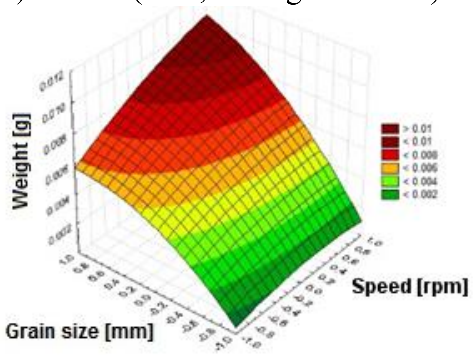

Figure 7. *The influence of speed and the grain size on the abrasiveness of siliceous sand*

The maximum value of the abrasiveness for siliceous sand according to the mathematical model is obtained at the maximum speed (1000 rpm) and the maximum grain size (0.3 mm). The minimum value of abrasiveness is obtained at minimum speed (700 rpm) and the smallest grain size (0.04 mm).

The figure 8 represent the abrasiveness variation for siliceous sand, depending on the speed and time. The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the time between -1 (30 minutes, the smallest value of the field studied) and +1 (90 minutes, the highest value).

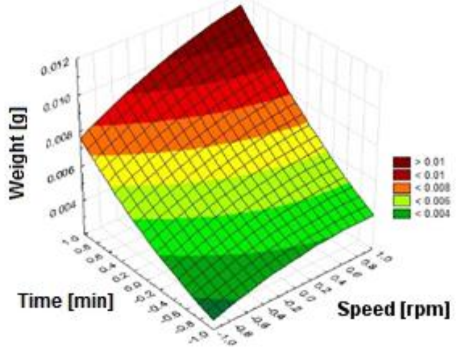

Figure 8. *The influence of speed and time on the abrasiveness of siliceous sand*

2.3 Characterizing the electrocorundum abrasiveness

For the mathematical model of the electrocorundum abrasiveness, the data were collected in accordance with Table 5 from the article „*Research on abrasiveness of materials used on finishing metal alloys. Part I*"..

The mathematical model that defines the quantity of material removed from the sample in case of electrocorundum - the material abrasiveness - (dependent variable), depending on the parameters (independent variables), is shown in the equation 3.

$$m = 0,0023 + 0,004793 \times A + 0,0013 \times B + 0,0011 \times C - 0.001664 \times A^2 - 0,005178 \times B^2 + 0,002536 \times C^2 + 0,003639 \times A \times B + 0,002089 \times A \times C + 0,006796 \times B \times C$$

In order to confirm the validity of the proposed mathematical model, an operational validity through comparative graphical representation has been made -*the obtained value vs. predicted value* (figure 9).

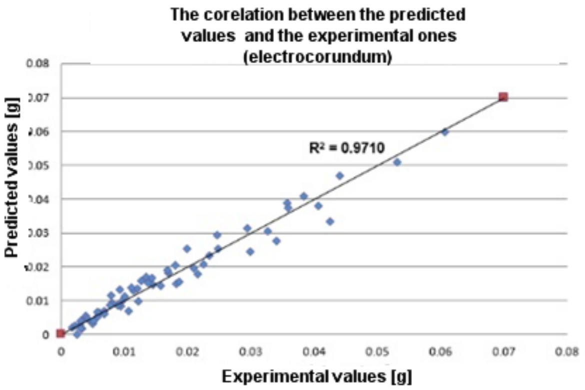

Figure 9. *The correlation between the measured values and those predicted (electrocorundum)*

In figure 10 the variation of abrasiveness for electrocorundum is shown, depending on grain size and time.

The 3D graph was obtained after changing the grain's size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.3, the highest value) and the time between -1 (30 minutes, the smallest value) and +1 (90 minutes, the highest value).The maximum value of the abrasiveness for electrocorundum according to the mathematical model is obtained at the maximum grain size (0.3 mm) and at the maximum time (90 minutes). The minimum value of abrasiveness is obtained at minimum grain size (0.04 mm) and the shortest time (30 minutes).

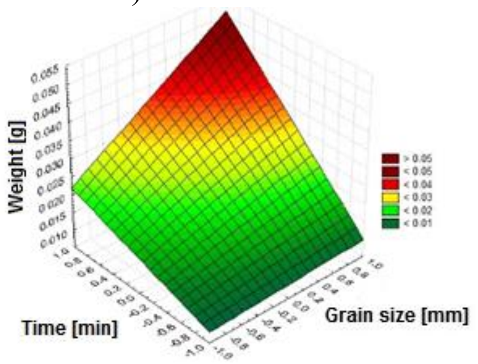

Figure 10. *The influence of grain size and time on abrasiveness for eletrocorundum*

The figure 11 represent the variation of abrasiveness for electrocorundum, depending on the speed and the grain size. The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the grain size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.03, the highest value).

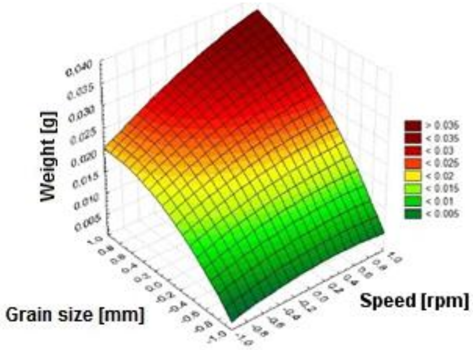

Figure 11. *The influence of speed and the grain size on the abrasiveness of electrocorundum*

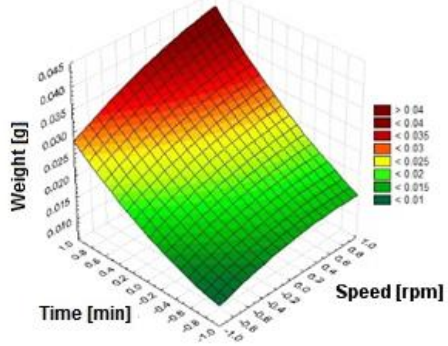

Figure 12. *The influence of speed and time on the abrasiveness of electrocorundum*

The maximum value of the abrasiveness for electrocorundum, according to the mathematical model, is obtained at the maximum speed (1000 rpm) and the maximum grain size (0.3 mm). The minimum value of abrasiveness is obtained at minimum speed (700 rpm) and the smallest grain size (0.04 mm).

The figure 12 represent the abrasiveness variation for electrocorundum, depending on the speed and time.

The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the time between -1 (30 minutes, the smallest value of the field studied) and +1 (90 minutes, the highest value)

2.4 Characterizing the abrasiveness of the mixture of siliceous sand and electrocorondum

For the mathematical model of the mixture of siliceous sand and electrocorondum abrasiveness, the data were collected in accordance with Table 6 from the article „*Research on abrasiveness of materials used on finishing metal alloys. Part I*"..

The mathematical model that defines the quantity of material removed from the sample in case of electrocorundum - the material abrasiveness - (dependent variable), depending on the parameters (independent variables), is shown in the equation 4.

$$m = 0{,}009949 + 0{,}001474 \times A + 0{,}006403 \times B + 0{,}004858 \times C - 0.0008074 \times A^2 - 0{,}001193 \times B^2 + 0{,}001023 \times C^2 + 0{,}001640 \times A \times B + 0{,}000206 \times A \times C + 0{,}003625 \times B \times C$$

In order to confirm the validity of the proposed mathematical model, an operational validity through comparative graphical representation has been made -*the obtained value vs. predicted value* (figure 13).

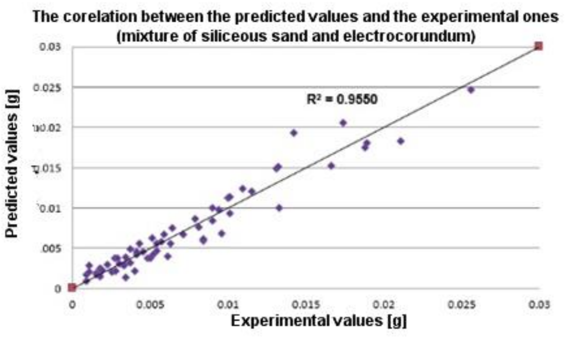

Figure 13. *The correlation between the predicted values and the experimental ones (mixture of electrocorundum and siliceous sand)*

In figure 14 the variation of abrasiveness for the mixture of electrocorundum and siliceous sand is shown, depending on grain size and time.

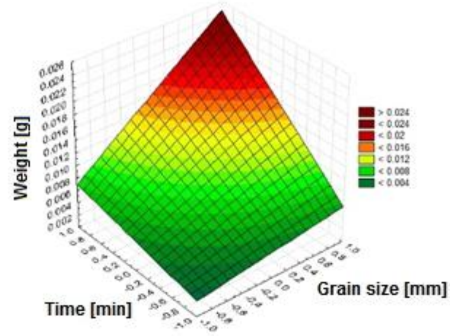

Figure 14. *The influence of grain size and time on abrasiveness for mixture of siliceous sand and eletrocorundum*

The 3D graph was obtained after changing the grain's size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.3, the highest value) and the time between -1 (30 minutes, the smallest value) and +1 (90 minutes, the highest value). The maximum value of the abrasiveness for the mixture of electrocorundum and siliceous sand, according to the mathematical model, is obtained at the maximum grain size (0.3 mm) and at the maximum time (90 minutes). The minimum value of abrasiveness is obtained at minimum grain size (0.04 mm) and the shortest time (30 minutes).

The figure 15 represent the variation of abrasiveness for the mixture of electrocorundum and siliceous sand, depending on the speed and the grain size.

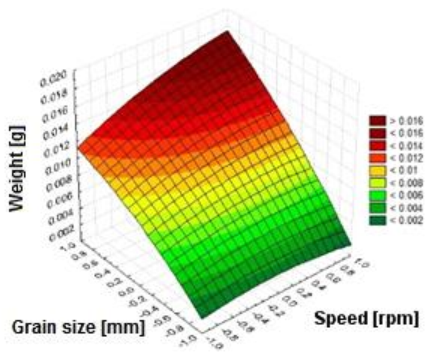

Figure 15. *The influence of speed and the grain size on the abrasiveness for mixture of electrocorundum and siliceous sand*

The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the grain size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.03, the highest value).

The maximum value of the abrasiveness for the mixture of electrocorundum and siliceous sand, according to the mathematical model, is obtained at the maximum speed (1000 rpm) and the maximum grain size (0.3 mm). The minimum value of abrasiveness is obtained at minimum speed (700 rpm) and the smallest grain size (0.04 mm).

The figure 16 represent the abrasiveness variation for the mixture of electrocorundum and siliceous sand, depending on the speed and time.

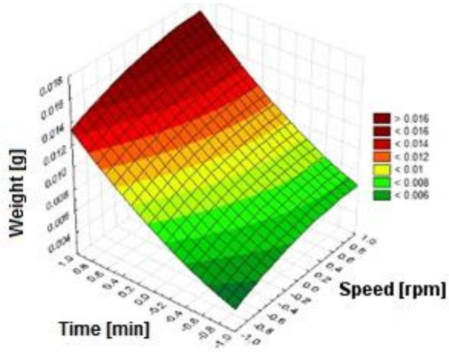

Figure 16. *The influence of speed and time on the abrasiveness for the mixture of electrocorundum and siliceous sand*

The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the time between -1 (30 minutes, the smallest value of the field studied) and +1 (90 minutes, the highest value).

2.5. Characterizing the abrasiveness of the mixture of granite and electrocorundum

For the mathematical model of the mixture of granite and electrocorundum abrasiveness, the data were collected in accordance with Table 7 from the article „*Research on abrasiveness of materials used on finishing metal alloys. Part I*"..

The mathematical model that defines the quantity of material removed from the sample in case of electrocorundum - the material abrasiveness - (dependent variable), depending on the parameters (independent variables), is shown in the equation 5.

$$m = 0{,}009949 + 0{,}001474 \times A + 0{,}006403 \times B + 0{,}004858 \times C - 0.0008074 \times A^2 - 0{,}001193 \times B^2 + 0{,}001023 \times C^2 + 0{,}001640 \times A \times B + 0{,}000206 \times A \times C + 0{,}003625 \times B \times C$$

In order to confirm the validity of the proposed mathematical model, an operational validity through comparative graphical representation has been made -*the obtained value vs. predicted value* (figure 17).

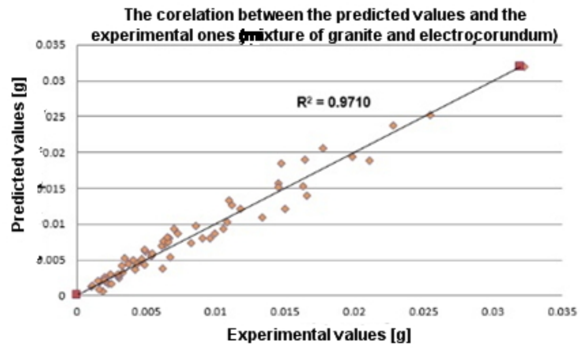

Figure 17. *The correlation between the predicted values and the experimental ones (mixture of electrocorundum and granite)*

In figure 18 the variation of abrasiveness for the mixture of electrocorundum and granite is shown, depending on grain size and time.

The 3D graph was obtained after changing the grain's size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.3, the highest value) and the time between -1 (30 minutes, the smallest value) and +1 (90 minutes, the highest value). The maximum value of the abrasiveness for the mixture of granite and electrocorundum, according to the mathematical model, is obtained at the maximum grain size (0.3 mm) and at the maximum time (90 minutes). The minimum value of abrasiveness is obtained at minimum grain size (0.04 mm) and the shortest time (30 minutes).

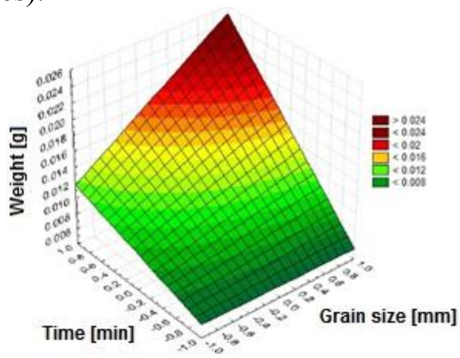

Figure 18. *The influence of grain size and time on abrasiveness for mixture of granite and eletrocorundum*

The figure 19 represent the variation of abrasiveness for the mixture of granite and electrocorundum, depending on the speed and the grain size. The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the grain size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.03, the highest value).

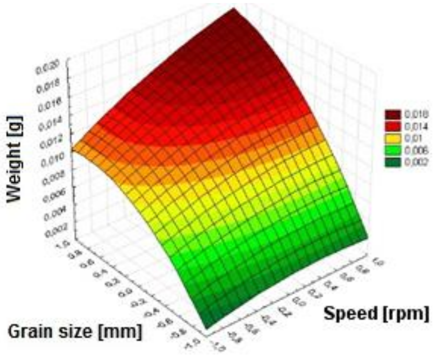

Figure 19. *The influence of speed and the grain size on the abrasiveness for mixture of granite and electrocorundum*

The maximum value of the abrasiveness for the mixture of granite and electrocorundum, according to the mathematical model, is obtained at the maximum speed (1000 rpm) and the maximum grain size (0.3 mm). The minimum value of abrasiveness is obtained at minimum speed (700 rpm) and the smallest grain size (0.04 mm).

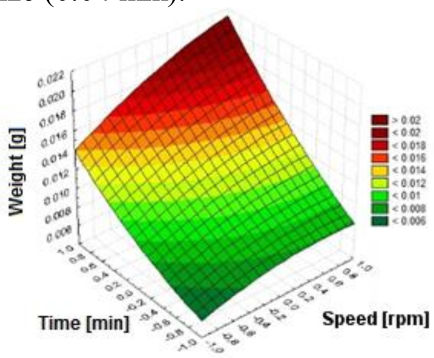

Figure 20. *The influence of speed and time on the abrasiveness for the mixture of granite and electrocorundum*

The figure 20 represent the abrasiveness variation for the mixture of granite and electrocorundum, depending on the speed and time.

The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the time between -1 (30 minutes, the smallest value of the field studied) and +1 (90 minutes, the highest value).

2.6 Characterizing the abrasiveness of the mixture of granite and siliceous sand

For the mathematical model of the mixture of granite and electrocorundum abrasiveness, the data were collected in accordance with Table 8 from the article „*Research on abrasiveness of materials used on finishing metal alloys. Part I*".

The mathematical model that defines the quantity of material removed from the sample in case of electrocorundum - the material abrasiveness - (dependent variable), depending on the parameters (independent variables), is shown in the equation 6.

$$m = 0{,}0012 + 0{,}002308 \times A + 0{,}006507 \times B + 0{,}005405 \times C - 0.0008326 \times A^2 - 0{,}003266 \times B^2 + 0{,}001057 \times C^2 + 0{,}001769 \times A \times B + 0{,}001319 \times A \times C + 0{,}003479 \times B \times C$$

In order to confirm the validity of the proposed mathematical model, an operational validity through comparative graphical representation has been made -*the obtained value vs. predicted value* (figure 21).

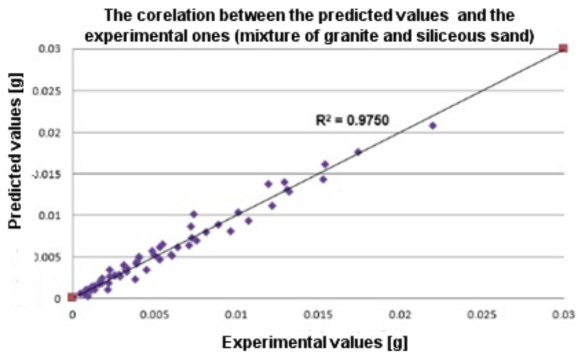

Figure 21. *The correlation between the predicted values and the experimental ones (mixture of siliceous sand and granite)*

In figure 22 the variation of abrasiveness for the mixture of granite and siliceous sand is shown, depending on grain size and time.

The 3D graph was obtained after changing the grain's size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.3, the highest value) and the time between -1 (30 minutes, the smallest value) and +1 (90 minutes, the highest value). The maximum value of the abrasiveness for the mixture of granite and siliceous sand, according to the mathematical model, is obtained at the maximum grain size (0.3 mm) and at the maximum time (90 minutes). The minimum value of abrasiveness is obtained at minimum grain size (0.04 mm) and the shortest time (30 minutes).

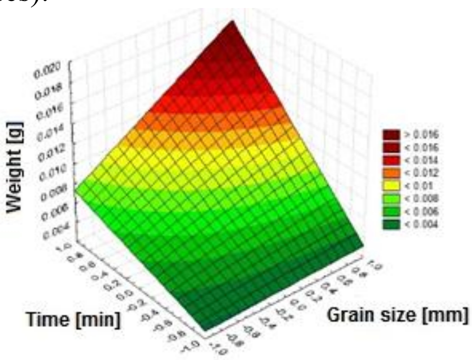

Figure 22. *The influence of grain size and time on abrasiveness for mixture of granite and siliceous sand*

The figure 23 represent the variation of abrasiveness for the mixture of granite and siliceous sand, depending on the speed and the grain size. The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the grain size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.03, the highest value).

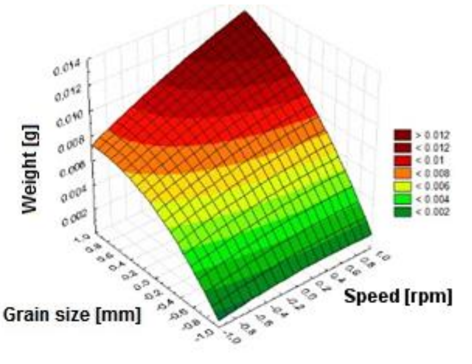

Figure 23. *The influence of speed and the grain size on the abrasiveness for mixture of granite and siliceous sand*

The maximum value of the abrasiveness for the mixture of granite and siliceous sand, according to the mathematical model, is obtained at the maximum speed (1000 rpm) and the maximum grain size (0.3 mm). The minimum value of abrasiveness is obtained at minimum speed (700 rpm) and the smallest grain size (0.04 mm).

The figure 24 represent the abrasiveness variation for the mixture of granite and siliceous sand, depending on the speed and time.

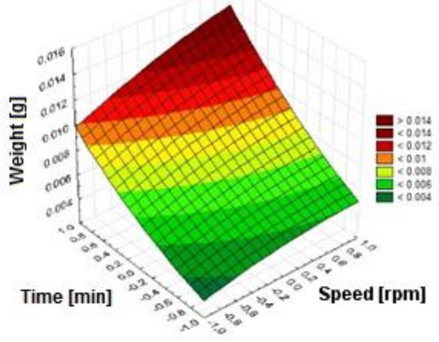

Figure 24. *The influence of speed and time on the abrasiveness for the mixture of granite and siliceous sand*

The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the time between -1 (30 minutes, the smallest value of the field studied) and +1 (90 minutes, the highest value).

2.7 Characterizing the abrasiveness of the mixture of granite, electrocorundum and siliceous sand

For the mathematical model of the mixture of granite, electrocorundum and siliceous sand abrasiveness, the data were collected in accordance with Table 9 from the article „*Research on abrasiveness of materials used on finishing metal alloys. Part I*”.

The mathematical model that defines the quantity of material removed from the sample in case of the mixture of granite, electrocorundum and siliceous sand- the material abrasiveness - (dependent variable), depending on the parameters (independent variables), is shown in the equation 7.

$$m = 0{,}0013 + 0{,}002600 \times A + 0{,}007195 \times B + 0{,}006193 \times C - 0.0009477 \times A^2 - 0{,}002861 \times B^2 + 0{,}001332 \times C^2 + 0{,}001945 \times A \times B + 0{,}001131 \times A \times C + 0{,}003741 \times B \times C$$

In order to confirm the validity of the proposed mathematical model, an operational validity through comparative graphical representation has been made -*the obtained value vs. predicted value* (figure 25).

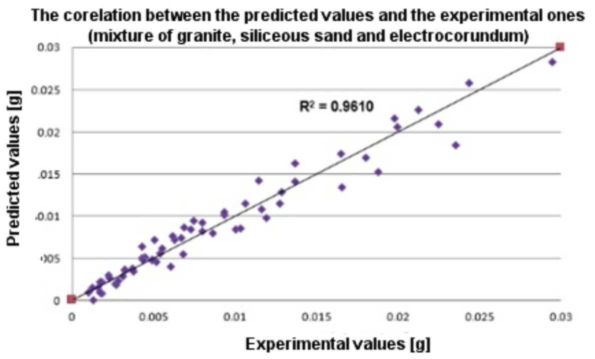

Figure 25. *The correlation between the predicted values and the experimental ones (mixture of granite, electrocorundum and siliceous sand)*

In figure 26 the variation of abrasiveness for the mixture of granite, electrocorundum and siliceous sand is shown, depending on grain size and time.

The 3D graph was obtained after changing the grain's size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.3, the highest value) and the time between -1 (30 minutes, the smallest value) and +1 (90 minutes, the highest value). The maximum value of the abrasiveness for the mixture of granite, electrocorundum and siliceous sand, according to the mathematical model, is obtained at the maximum grain size (0.3 mm) and at the maximum time (90 minutes). The minimum value of abrasiveness is obtained at minimum grain size (0.04 mm) and the shortest time (30 minutes).

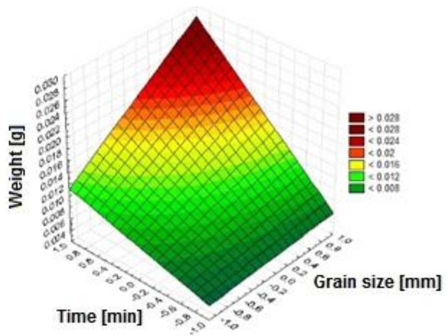

Figure 26. *The influence of grain size and time on abrasiveness for mixture of granite, electrocorundum and siliceous sand*

The figure 27 represent the variation of abrasiveness for the mixture of granite, electrocorundum and siliceous sand, depending on the speed and the grain size. The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the grain size between -1 (0.04 mm, the smallest value of the field studied) and +1 (0.03, the highest value).

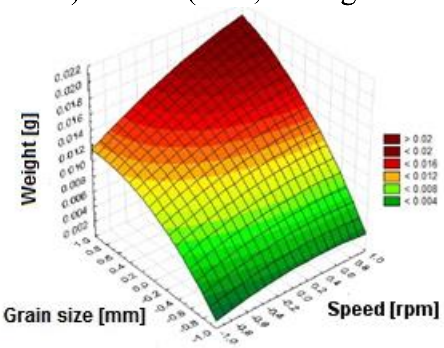

Figure 27. *The influence of speed and the grain size on the abrasiveness for mixture of granite, electrocorundum and siliceous sand*

The maximum value of the abrasiveness for the mixture of granite, electrocorundum and siliceous sand, according to the mathematical model, is obtained at the maximum speed (1000 rpm) and the maximum grain size (0.3 mm). The minimum value of abrasiveness is obtained at minimum speed (700 rpm) and the smallest grain size (0.04 mm).

The figure 28 represent the abrasiveness variation for the mixture of granite, electrocorundum and siliceous sand depending on the speed and time.

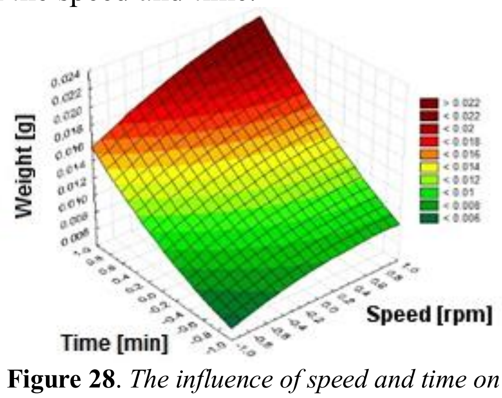

Figure 28. *The influence of speed and time on the abrasiveness for the mixture of granite, electrocorundum and siliceous sand*

The 3D graph was obtained after changing the speed between -1 (700 rpm, the smallest value) and +1 (1000 rpm, the highest value) and the time between -1 (30 minutes, the smallest value of the field studied) and +1 (90 minutes, the highest value).

3 Conclusions

The research carried out and presented here mainly aim to determinate the extent of influence of each technological parameter on the level of final results characteristic (weight of material removed). Secondly, a determination of a mathematical correlation between the influences manifested by these parameters was aimed in such a way as to create a real possibility of control and rapid intervention in the process at the time when the one of parameters cannot be maintained at a preset value.

Following the analysis of the experimental data, respectively of the mathematical models, it appears that the best material removal was done when using powders of abrasive waste (electrocorundum) a maximum quantity of material removed m = 0,0607 grams was registered.

These values were obtained at maximum speed and grain size respectively at 1,000 rpm and a grain size of 0.4mm. In other words, the impact of speed is negligible for small grains.

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