The Treatment of the Surfaces of Mg-Al-Zn-Mn and Ti-Al-Zr-Nb Alloys by Shot Peening

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Abstract: The influence of shot peening on the surfaces of Mg-Al-Zn-Mn and Ti-Al-Zr-Nb alloys is described by the authors. There are the estimates focusing on roughness of the shot peened surfaces and on a size of selected shot peened material - the corundum. Based on the results of measurements, the evaluation was oriented to the curve of roughness, the functionality of surface roughness R_a and the necessary quantity of the shot peening material q_{nR} of estimated material depending on the grain size d_z.

Keywords: shot peening; functional surface; surface roughness

1 Introduction

Surface strengthening by shot peening can make use of shot peening to increase the fatigue resistance of engineering components. Some alloys (on the basis of the magnesium) are inclined to the initiation and propagation of fatigue cracks. Defects like grains and systemless structures begin and accelerate these cracks – the stress concentration.

With high frequency cyclic loading, for a smaller number of cycles to failure the locations of cracks start appearing on the surface [1, 2]. For a higher number of cycles to failure, the location of cracks begins to appear in the thermal area of the experimental sample [3]. Some alloys after thermal treatment obtain structures with compound of balanced polyedric grains with concrete phases. It involves mechanical properties growth and resistance to fatigue as well [4, 13] and resistance to oxidation by high temperature [14].

Nowadays, there are enough developed imaginations of deposition process of thermal spraying coatings on the surfaces of magnesium [5] and steel engineering accessories [14].

There are a lot of methods for the research of the microgeometry of shot peened surfaces [15]. However, the following experimental method is adequate for the determination of the necessary quantity of abrasive material q_{nR}.

The determination of the necessary quantity of abrasive material q_{nR} is important. If the necessary quantity is less than q_{nR} (Fig. 2), the coverage of the shot peened surface and the adhesion of the deposited thermal layer will be inadequate. If the necessary quantity is equal q_{nR} (Fig. 2), the surface of the shot peened surface and the adhesion of deposited thermal layer will be appropriate. If the necessary quantity is more than q_{nR} (Fig. 2), the roughness, R_a, of the shot peened surface and the adhesion of deposited thermal layer will be sufficient as well. There are the cracks on the surface which create the stress concentration. This causes the decrease of limit of the material as well as the lifetime shrinkage of the machine [17].

The lifetime of coatings depends on the ideal adhesion of functional coatings [6, 7, 8]. Adhesion is conditioned by ideal pretreatment of the functional surface. Shot peening is one of the most frequently used technologies of mechanical pretreatment of surfaces under thermal spraying coatings. The surface is cleaned and the necessary microgeometry of the surface is created by shot peening.

It is known that the activation energy of surfaces made from the deformation of surface layers during shot peening definitely affects the coating adhesion [9]. The value of the activation energy is reduced exponentially by the material surface and background influence. Therefore the coating must be deposited till 1-3 hours after shot peening. The coating adhesion to the basic material can be evaluated by the mechanism of adhesion. The mechanical adhesion of coating on the surface relief of sample occupies between 50-80%. The Van der Walls forces make about 5% and power of chemical compounds make up 15-45%. In comparison with surface pretreatment by cauterization, shot peening is more convenient than cauterization. The technology of surface shot peening can be used for surface strengthening and the formation of good surface roughness. The experiment was focused on the influence of shot peening on the presented Mg alloy surface. The influence of the particular parameter on the formation of good, strong coating and on the substance was investigated.

The utilization of thermal spraying is an up-to-date technology for the renovation of aviation components made from light alloys on the base Al, Mg, Ti. The experiment was focused on the research impact of the sorts and dimensions of the shot peening material grain and the shot peening parameters on the necessary surface quality under thermal spraying coatings.

2   Experiment Methodology

This experimental research was directed towards the determination of the curve of roughness, the functionality of the surface roughness, R_a, and the necessary quantity of the shot peening material, q_{nR}, of the evaluated material depending on the grain size, d_z.

2.1   Evaluation of Shot Peened Surface Roughness R_a

Shot peening is a specific form of surface pretreatment of components. The character of the shot peened surface is typical for this technology. In the shot peening process the component surface is consequently roughened. The roughness is evaluated by a touch-profimeter. These appliances have bigger scale of measured parameters of surface roughness, for example R_a=30 µm. The average roughness, R_a, was selected for surface evaluation. A Profimeter HOMMEL Tester T2000 was used for the measured values and for the profile formation of the shot peened surfaces.

To obtain relevant results, the following conditions have been used [8, 9]:

- measured length L= 6,3 mm,
- terminal undulation (cut-off) l = 1,25 mm
- number of measurements n = 10.

Profiles were taken out following next conditions:

- measured length L= 6,3 mm,
- terminal undulation pinch l=∞.

The mean arithmetic value as a statistic value has been calculated from the measured values of roughness. Each surface was evaluated by two profilegrams.

2.2   Experimental Samples Preparation

Mg-Al-Zn-Mn and Ti-Al-Zr-Nb alloy samples [10] were used in the experiment. Sample dimensions were chosen in such a way as to eliminate the unwanted influence of the shot peening device on the shot peening process (e.g. the heterogeneous consistency of the grain touches in the entire field of shot peening beam). The samples' dimensions enabled us to realize the adhesion test after thermal spraying coatings on surfaces of the shot peened samples. The samples were made by turning into the form of a roll with a diameter of 30 mm and a thickness of 3 mm (Fig. 1). The functional surface of the samples before shot peening had the roughness of $R_a=0,6$ µm.
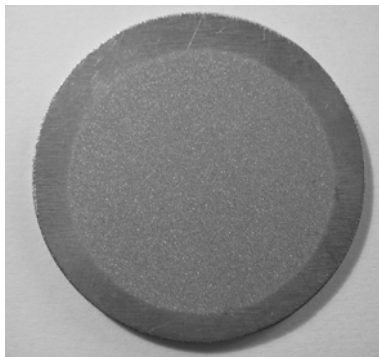

Figure 1
The sample of the Mg-Al-Zn-Mn alloy after shot peening

2.3   The Material Used for Shot Peening

There are not uniform selected criteria for shot peening material by now. Selection of the shot peening material was based on the basic material properties.

For the surfaces' shot peening process, corundum granular was used (STN EN 22 40 12). This material is produced in all granularities and the shot peening material is a polydisperse. To explain the influence of the grain size on the surface roughness, the shot peening material was selected via a wire screen with a specific grain diameter. The chosen gain diameter was according to STN 15 3105.

2.4   Shot Peening Process

Laboratory equipment [7] was used for the shot peening of the evaluated sample surfaces. The influence of the grain size of the shot peening material on the roughness of the surface of Mg-Al-Zn-Mn and Ti-Al-Zr-Nb alloys was tested during the experiment at speed $v=78.1$ ms^{-1}. The angle of incidence of the shot

peening material grain on the sample surface was α=75°. The sample distance to the shot peening wheel was L=200 mm. According to Matling and Steaffens, one cannot prevent hobbing of the shot peening material onto the shot peened surface [11]. It causes galvanic cells formation [12]. Impresses (by hobbing) can be made by shot peening of the surface with harder materials, too. Consequently, corundum with a minimum grain speed of v_1=78.1 ms^{-1} was used for shot peening of the Mg-Al-Zn-Mn and Ti-Al-Zr-Nb alloys. Corundum with medium grain diameters 0.1; 0.2; 0.315; 0.4; 0.5; 0.63; 0.71; 0.8; 1.0; 1.25 mm was used for the Mg-Al-Zn-Mn alloy. Corundum with medium grain diameters 0.36; 0.56; 0.71; 0.9; and 1.12 mm was used for Ti-Al-Zr-Nb alloy.

3   Methods for Determining the Roughening Curve of the Shot Peened Surface

The experiment was aimed at determining the necessary quantity of abrasive material, q_{nR}, which is needed to cover the shot peened surface completely. The initial ration was determined from the characteristic roughening curves. The roughening curve technique specifies the functional dependancy of the shot peened surface roughness on the quantity of the abrasive material which shapes the measured surface (Fig. 2). The area from the first to the second section is important for the determination of the covering grade of the shot peened surface by roughening curves (Fig. 2) [8].
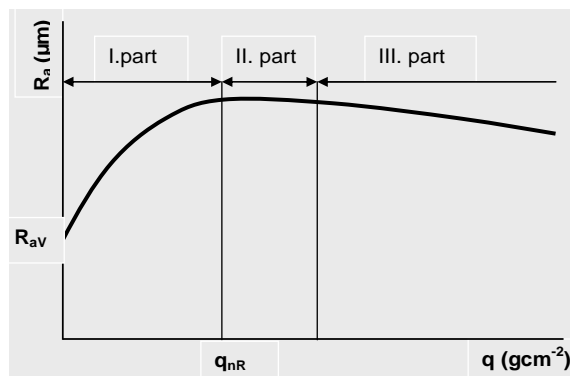

Figure 2
The roughening curve

3.1   Determining the Roughening Curves of the Mg-Al-Zn-Mn Alloy

Samples from the Mg-Al-Zn-Mn alloy were gradually shot peened with a ration of 1000 g of corundum, with covering grade $q=0.5$ gcm^{-2}, and with the number of rations 10. Next samples were shot peened by 1000 g of corundum with the fraction diameter $d_z=0.1$; 0.2; 0.315; 0.4; 0.5; 0.63; 0.71; 0.8; 1.0 and 1.25 mm. After each shot peening the roughness R_a was measured. Each R_a is the arithmetic average of 10 measured tests. After each shot peening the surface was evaluated by means of optical microscope. After each shot peening another material was selected. The number of rations in the experiment was selected so that the roughening curve could capture the first and second part, and partially the third one (Fig. 2). The roughening curves are in Fig. 3.
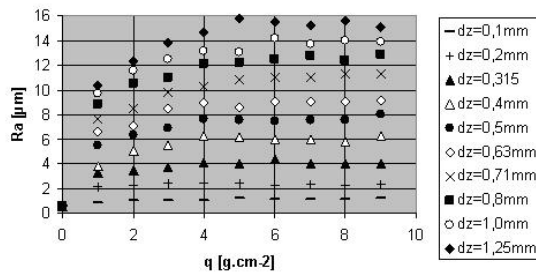

Figure 3

Roughening curves of the Mg-Al-Zn-Mn alloy with corundum fractions of the diameters d_z

3.2   Determining the Roughening Curves of the Ti-Al-Zr-Nb Alloy

Samples from the Ti-Al-Zr-Nb alloy were shot peened gradually with a ration of 2000 g of corundum, with covering grade $q=1.0$ gcm^{-2}, and the number of rations 10. Next samples were shot peened with six rations of 2000 g, fraction diameter $d_z=0.36$ mm; by seven rations of 2000 g, fraction diameter $d_z=0.56$ mm; by three rations of 2000 g, fraction diameter $d_z=0.71$ mm; by three rations of 4000 g, fraction diameter $d_z=0.9$ mm and by six rations of 4000 g, fraction diameter $d_z=1.12$ mm. After each shot peening the roughness R_a was measured. Each of R_a is the arithmetic average of 10 measured accounts. After each shot peening the surface was evaluated by means of optical microscope. After each shot peening another material was selected. The number of rations in the experiment was selected so that the roughening curve could capture the first and second part and partially the third one (Fig. 2). The roughening curves are in Fig. 4.
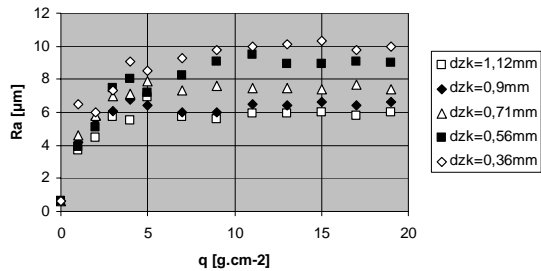
Figure 4

Roughening curves of the Ti-Al-Zr-Nb alloy with corundum fractions of the diameters d_{zK}

3.3   Determining the Necessary Quantity of Abrasive Material

To cover the shot peened surface with touches by shot peening, it is necessary to know the microgeometry of the shot peened surface. The grade of covering of this surface is to be n=1. Now, the necessary quantity of abrasive material for surface covering is on the roughening curve q_{nR}. It is expected that the linear and planar covering grade is 1 (Fig. 2).

The dependency of the necessary quantity of the abrasive material on the grain dimension can be solved from the roughening curves (Figs. 3, 4). The correlation of grain diameter d_z on the necessary quantity of shot peening material q_{nR} for Mg-Al-Zn-Mn alloy and Ti-Al-Zr-Nb alloy was determined (Figs. 5, 6). This way is valid for shot peening.
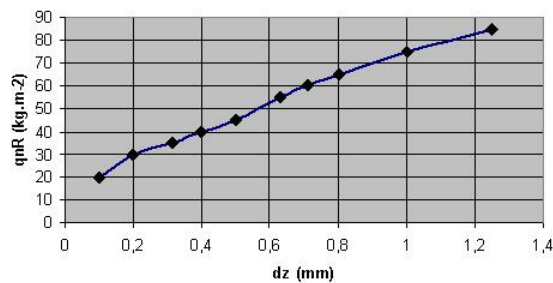

Figure 5

The correlation of grain diameter d_z on the necessary quantity of shot peening material q_{nR} of the Mg-Al-Zn-Mn alloy
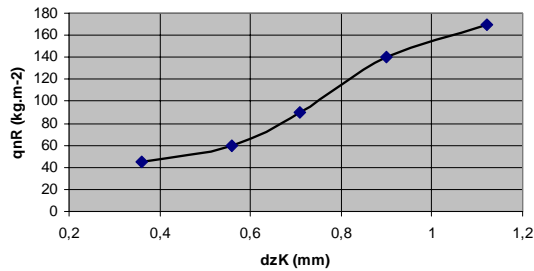
Figure 6

The correlation of grain diameter d_{zK} on the quantity of shot peening material q_{nR} of the Ti-Al-Zr-Nb alloy

3.4   The Influence of Grain Diameter of the Shot Peened Material on the Roughness R_a

The roughness value R_a of the shot peened surface of Mg-Al-Zn-Mn and Ti-Al-Zr-Nb alloys was determined as the arithmetic average from 10 measurements. The final values for particular grain diameters of the shot peening material by speed $v_1=78.1$ ms^{-1} are in diagram (Figs. 7, 8). From function dependency it is obvious that if the grain diameter grows, the roughness of the shot peened material grows, too. It is related directly to the touch size after the grains of the shot peening material fall on the surface.
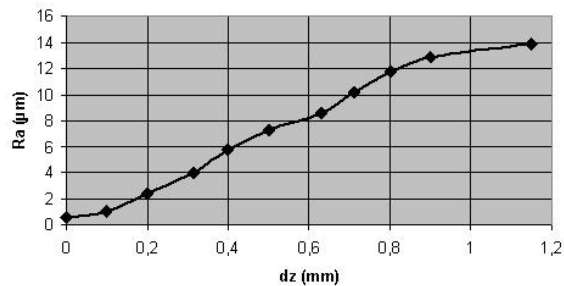

Figure 7

The correlation of grain diameter d_z on the surface roughness R_a of the Mg-Al-Zn-Mn alloy
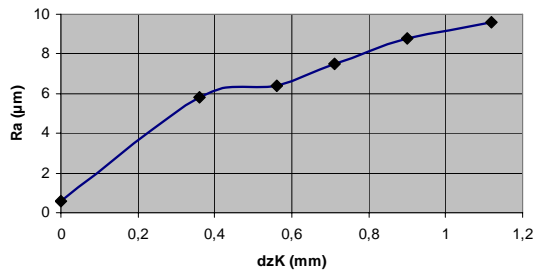
Figure 8

The correlation of grain diameter d_{zK} on the surface roughness R_a of the Ti-Al-Zr-Nb alloy

4 Discussion of the Experimental Results

The surface of the experiment samples was gradually roughened in the shot peening process. As a consequence, roughness R_a is different in measured values of tested grain diameter d_{zK} (Figs. 7, 8). The roughness R_a of the Mg-Al-Zn-Mn alloy for grain diameter d_z is 14 μm. The roughness R_a of the Ti-Al-Zr-Nb alloy for grain diameter d_{zK} is 9.6 μm. These values are material properties of the experimental samples.

The quantity of abrasive material q_{nR} for tested dimension of the grain d_z and for the Mg-Al-Zn-Mn alloy was determined from interval 20 to 85 kgm^{-2}. The quantity of abrasive material q_{nR} for tested grain diameter d_{zK} and for Ti-Al-Zr-Nb alloy was determined from interval 42 to 170 kgm^{-2}. These values are material properties of the experimental samples, as well.

The necessary quantity q of tested grain diameters for Mg-Al-Zn-Mn alloy is from the interval 4 to 6 gcm^{-2} (Fig. 3) and the necessary quantity of tested grain diameters in the case of Ti-Al-Zr-Nb alloy is from the interval 10 to 15 gcm^{-2} (Fig. 4). The value of the necessary quantity q_{nR} can be exactly assigned for the material (alloy) and for the chosen dimension of the grain (Figs. 3, 4).

Conclusions

According to the analyses, study and realized experiments, the following conclusions can be made:

- The determination of the necessary quantity of abrasive material q_{nR} is important. Too much abrasive material can cause crack formation on the shot peened surface. Subsequently, there is higher value of stress concentration (for necessary quantity > q_{nR} - Fig. 2, with constant speed). It causes a decrease in the fatigue limit of the material [17] as well as a decrease in the lifetime of the machine.

- The measured accounts were the basis for the drawing of the roughening curves – the change depends on the roughness R_a as well as on the quantity of the shot peening material q_{nR} which falls on the measured surface.

- The roughness of the shot peened surface is affected by the grain size of the shot peening material. If the diameter grows, the roughness of the shot peened surface grows, too.

- The necessary quantity of the shot peening material q_{nR} (corundum) influences the grain diameter d_z. The value of the necessary quantity q_{nR} can be exactly assigned for a material (tested alloy) and for a chosen dimension of the grain.

- The roughness R_a grows with the increasing quantity of the abrasive material.

- The necessary quantity of the shot peening material q_{nR} for the whole covering of shot peened surface can be assigned from the roughening curves [16]. The necessary quantity for the Mg-Al-Zn-Mn alloy is from the interval 4 to 6 gcm^{-2} and for the Ti-Al-Zr-Nb alloy it is from the interval 10 to 15 gcm^{-2} (Figs. 3, 4).

- The roughness R_a is constant for reached covering grade q. It is valid for q=5 $g.cm^{-2}$ of diameters of shot peening material – for corundum.

- Corundum is the most suitable substance for the shot peened Mg-Al-Zn-Mn alloy and Ti-Al-Zr-Nb alloy. Using corundum, we achieved cleanness of the shot peened surface and less necessary quantity of abrasive material q_{nR} with higher roughness.

Acknowledgement

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