Effect of Parameters of Ultrasonic Shot Peening on the Physicomechanical Properties of the Surface Layer of Flat Samples

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Abstract. The work is devoted to the study of the influence of the parameters of ultrasonic shot peening on the physicomechanical properties of the surface layer of flat samples of 08ps steel, AMg2 and M2 alloys. The results of determination of residual stresses, microhardness are given. As a result, it was established that the processing time makes the largest contribution in the selected modes.

1. Introduction

The use of surface plastic deformation (SPD) methods at the final stages of manufacture allows to improve the operational properties of parts and thereby increase the service life of machines. SPD methods allow you to process parts of various configurations and at the same time ensure high quality of the surface layer and high productivity of processing processes [1-2].

Physico-mechanical properties of the surface of parts determine their reliability during operation [3-4]. The main characteristics of the physico-mechanical properties of the surface of the parts are:

- depth of the hardened layer (hardening depth);
- level and sign of residual stresses;
- hardness.

One of the reasons for premature failure of parts is tensile residual stresses (RS). Therefore, the urgent task is to create a compressive RS in the surface layer, contributing to an increase in fatigue strength.

As a result of SPD, the surface roughness decreases, the hardness (microhardness) of the metal increases, and compressive residual stresses appear in the surface layer of the part.

The most effective and common SPD processes include [5]:

- bead-blasting treatment (pneumatic blasting);
- hydroblasting treatment;
- ultrasonic shot peening.

The effect of the parameters of ultrasonic bead-blasting processing on the physicomechanical properties of the surface layer of flat samples (Fig. 1) from 08ps steel, aluminum alloy AMg2, copper M2 are investigated.
2. Method of the experiment. Samples and equipment
Sample materials - steel 08ps, alloys AMg2, M2. Sizes of the samples, mm - 70 x 19 x 2 (Fig. 1). The initial roughness of the samples is Ra 1.25. Processing was carried out on the UZU-6TM installation. Ultrasonic shot peening (USP) modes during the experiment:
- waveguide oscillation frequency - 17.50 and 19.35 kHz;
- working bodies - a mixture of metal balls (table 1);
- the processing time of the samples is shown in table 2. USP modes are given in table 2.

![Figure 1. Sketch plate with control points.](image)

| Mixture of balls | Diameter of balls (mm) | The mass of balls in the mixture (g) |
|------------------|------------------------|-------------------------------------|
| 1                | 0.68                   | 20                                  |
|                  | 0.68                   | 5                                   |
| 2                | 1.00                   | 15                                  |
|                  | 1.58                   | 25                                  |

Table 1. The composition of the mixture of balls for USP.

| Sample | Processing time (s) | Frequency (kHz) | Mix |
|--------|---------------------|-----------------|-----|
| 1      | 20/5                | 19              | 1   |
| 2      | 25/10               | 19              | 1   |
| 3      | 30/15               | 19              | 1/2 |
| 4      | 35/20               | 19              | 1/2 |
| 5      | 20/5                | 17.5            | 2   |
| 6      | 25/10               | 17.5            | 2   |
| 7      | 30/15               | 17.5            | 2   |
| 8      | 35/20               | 17.5            | 2   |
| 9      | 20/5                | 17.5            | 1   |
| 10     | 25/10               | 17.5            | 1   |
| 11     | 30/15               | 17.5            | 1   |
| 12     | 35/20               | 17.5            | 1   |

Table 2. USP modes for 08ps steel and AMg2, M2 alloys.

Micro roughness was measured with a 5.6 mm MARSURF PS1 instrument. Residual stresses were determined by X-ray diffractometry using an XStress 3000 Robot complex [6].
The microhardness of the surface of the samples according to Vickers was measured with a Shimadzu HMV-G instrument (and HV\textsubscript{0.01}); it was measured at 5 control points before and after the ultrasound examination. The value of HV\textsubscript{0.3} was determined on the surface of the samples.

When plotting the distribution of microhardness and RS over depth, the samples were etched at point 1 with a step of 10 μm. The diameter of the etching spot is 10 mm. Equipment Used: Movipol-5. The microhardness HV\textsubscript{0.01} was determined by the average value from the results of 5 measurements in the etching spot at each etching stage. The choice of load is due to the requirement that the diagonal of the print does not exceed the depth of the etched layer.

3. Analysis of the experimental results
The average microhardness of the surface of specimens from 08ps steel to USP is 6 HV, and for specimens from AMg2 and M2 alloys - 3.7 HV and 5 HV, respectively.

3.1. Microhardness

![Graph showing microhardness distribution](image1)

Figure 2. The influence of USP on microhardness for 08ps steel.

![Graph showing microhardness distribution](image2)

Figure 3. The influence of USP on microhardness: a) AMg2; b) M2.
For the specimen made of 08ps steel with the highest microhardness (sample 8), a diagram of the microhardness distribution over depth was constructed (Fig. 4). A sharp decrease in microhardness is observed at a depth of 10 μm from 13.04 to 8.98. Further, the HV value increases to a depth of 80 μm, after which a gradual decrease to 7.71.

At a depth of 200 μm, the microhardness exceeds the initial microhardness, which indicates that the depth of the hardened layer exceeds the depth of the layer studied by the authors.

3.2. Residual stress
The effect of the USP on the residual stresses measured along the axis of the samples is shown in Figures 5-7.

![Figure 4. Depth distribution of microhardness.](image)

![Figure 5. The influence of the USP modes on the level of RS for 08ps steel.](image)
Figure 6. The influence of the USP modes on the RS level: a) AMg2; b) M2.

Figure 7. Depth distribution diagram of RS.

For the sample with the highest microhardness (steel 08ps - sample 8), a plot of the distribution of OH over depth is plotted (Fig. 7). The etching modes are the same as in the determination of hardness. In the surface layer of the 08ps steel specimen, the residual stresses increase and vary in the range of -350 ÷ -120 MPa.

4. Conclusions
Table 3 shows the comparative results of the experiment on the influence of USP on the formation of physical and mechanical properties and surface geometry of the samples.

Table 3. The effect of USP on the surface properties of samples.

| Sample Condition | Steel 08ps | AMg2 alloy | M2 alloy |
|------------------|------------|------------|----------|
|                  | HV | RS level, MPa | HV | RS level, MPa | HV | RS level, MPa |
| Before USP       | 5,9 | -120 | 3,7 | -50 | 5 | -60 |
| After USP        | 8÷15 | -320÷-410 | 4÷8 | -106÷-148 | 9÷13 | -71÷-90 |
The results show that:

- The composition of the mixture of balls for USP also affects the formation of surface properties of the samples, but to a lesser extent than the processing time.
- The microhardness of the surface of the samples after USP increases: for steel 08ps - by 1.3–2.5 times; for the AMg2 alloy - 1.08 ÷ 2.16 times, for the M2 alloy - 1.8 ÷ 2.6 times.
- A field of compressive RS is formed in the surface layer of the samples after the SPD, the value of which decreases.

General conclusion:

- The use of ultrasonic testing has a beneficial effect on the physical and mechanical properties of the surface of the samples, which leads to an increase in fatigue and contact strength, corrosion resistance.
- The USP method can be recommended for widespread adoption in the processing of parts that are subject to increased reliability requirements for the operation of engineering products.

References

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