The effect of shot peening on fatigue strength of zinc coated steels

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Introduction

Development of modern mechanical systems requires application of newer and newer constructional, technological and material solutions. Extant technologies and manufacturing methods, which may be the source of higher reliability and durability of machines and their parts, are very often compeltely forgotten. Unconventional employment of known and effective technologies leads to obtaining surprisingly positive results in many cases. So-called combined technologies are very good example. These technologies combine two or more constituent methods, known and successfully applied singly to improve functional qualities of materials and machine parts. Normalizing, induction hardening and shot peening, or toughening, carbonizing and shot peening are typical combined technologies. The next example of using these methods is connection of surface plastic forming with electroplating deposizion of coatings. Each of above mentioned methods is known, though there is no information on combination of these treatments.
It should be stressed that combined technologies are not result of a simple connection between particular constituent methods.
In elaboration of a given combined technology for accepted utilizable criterion, problems arise with selection of technological parameters and sometimes, when using plastic formings with sequence of particular constituent technologies.

Materials tested

For testing two steels were chosen. 40H /0.41%C, 1%Cr, 0.57%Mn/ used for screws and 65G /0.65%C, 1.2%Mn/ used for elastic elements. 40H steel was toughened to 28-32 HRC, and then samples were made from it with forms and dimensions given in Fig. 1.

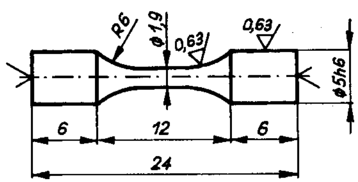

Fig. 1 Sample for fatigue strength tests under conditions of stretching--compressing loads.

Geometry and dimensions of the samples made from 65G steel toughened up to 38-42 HRC are presented in Fig. 2.

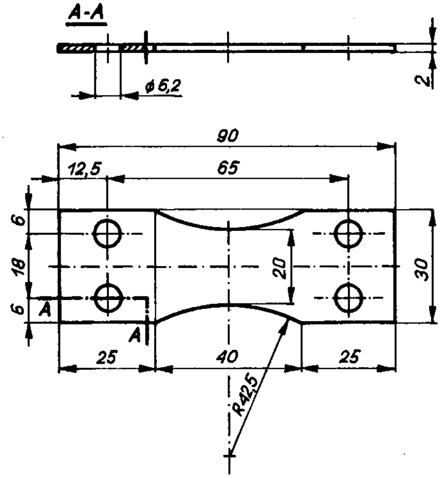

Fig. 2 Sample for fatigue strength tests under conditions of stretching-compressing loads.

Methodology of testing

Among many galvanic coatings zinc coatings widespread in the industry to protect machine parts against corrosion were selected for tests. Influence of two baths i.e. alkaline weak-acid, on fatigue strength of steel used for screws and 65G steel applied for elastic elements was tested. Moreover different sequence of employing surface plastic forming and zinc coating deposition was carried out. Surface plastic forming was performed by two methods, i.e. by shot peening and loose abrasive cleaning.
Basing on above ssumptions the following research variants were settled:

1. A - toughening
2. B - toughening + alkaline bath
3. C - toughening + loose abrasive cleaning + alkaline bath + + loose abrasive cleaning
4. D - toughening + shot peening + alkaline bath
5. E - toughening + alkaline bath + shot peening
6. F - toughening + shot peening + alkaline bath + shot peening
7. G - toughening + weak-acid bath
8. H - toughening + loose abrasive cleaning + weak-acid bath + + loose abrasive cleaning
9. I - toughening + shot peening + weak-acid bath
10. J - toughening + weak-acid bath + shot peening
11. K - toughening + shot peening + weak-acid bath + shot peening

Variant A is the basical, used for comparison with the rest. Variants of 40H and 65G steels are marked /40H - I, 65G -II/ to differentiate, although correspondence of variants conditions is preserved, i.e. variants HI is equivalent to variant I I due to treatments carried out. Parameters of loose abrasive cleaning, shot peening and zinc electroplating were chosen on the base of

earlier research and industrial works /2, 3, 4, 5/. Parameters of zinc coating depositions for alkaline and weak-acid baths for tested steel grades are given in Table 1.
To dehydrogenate zinc coated samples, they were annealed at 200°C by 1 h after electroplating /4, 5/.

Table 1
Parameters of galvanic process of zinc deposition

	Current density /A/dm2/	Deposition duration /min/	Voltage /V/	pH	Temperature /°C/
Round samples					
Alkaline bath	1.5	96	5	12	20
Weak-acid bath	1.5	48	8	5.5	20
Flat samples					
Alkaline bath	1.5	45	5	12	20
Weak-acid bath	2	35	8	5.5	20

Shot peening of samples was differentiated due to specificity of the coating deposited. When surface plastic forming was carried out before electroplating, the samples were shot peened with cast steel shot of 0.4-0.8 mm graduation. Intensity of shot peening was 0.35 A, covering 100% /6/. Strenghtening of zinc coating was performed by shot peening with glass marbles of 0-50 µm granulation. Intensity of shot peening was 0.6 A, and covering of surface - 100%. Loose abrasive cleaning was realized with the UW10 device.
Before deposition of a coating the samples made from 40H steel were subjected to treatment by ceramic abradants for 1.5 h. After deposition of zinc layer, porcelain nodules were applied for 0.5 h. Identic loose abrasive cleaning was carried out before and after deposition of a coating on flat samples, from 65G steel. Cold work of the surface was obtained by using of kinetic energy of porcelain nodules with 10 mm diameter, time of treatment - 1.5 h. It should be stressed that process parameters were selected basing on typical industrial applications. Given treatment are used to obtain cold works on machine parts.
The method of loading of samples was chosen in accordance with conditions of loads, which are the most common for screws and elastic elements. The following types of loads were chosen:
1/ Stretching-compressing - for round samples, the most common in screws,
2/ Bending - for flat samples, appearing in elastic elements.
The first type of loads was used for tests of 40H steel. Experiments on that steel were carried out on testing machine type Schenck - PHGN - Klein-Pulser with 50 Hz frequency. Flat samples loaded with bending moment were tested on machine Schenck type FLATO, frequency of loading changes was 25 Hz. For both grades of steels tests were realized with the same stress ration R = -1 and testing base $N_G = 10^7$ cycles. Results of all testing variants are presented in the form of Wöhler curves.

Results

Results of tests on fatigue strength for 40H steel are given in Fig. 3, and for 65G steel in Fig. 4. Performed measurings of zinc layer thickness showed that apart from employing identic technological parameters for given electroplating process, different thicknesses of a layer were obtained. It was 13-17 μm for alkaline bath, and 10-12 μm for weak-acid bath.
The testings results show that deposition of galvanic zinc coatings, as well as application of surface plastic forming in connection with zinc coatings, have influence on value of fatigue strength limit and course of simple regression within range of limited fatigue strength /Fig. 3/.

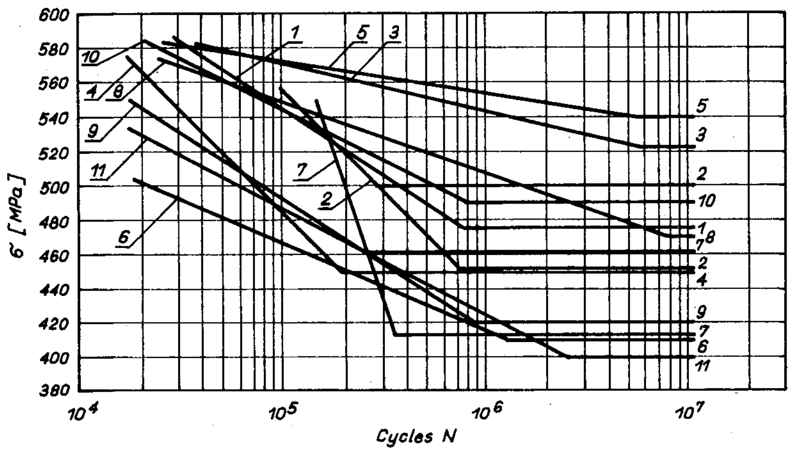

Fig. 3 Comparison of Wöhler curves for all testing variants for 40H steel: 1 - variant AI, 2 - variant BI, 3 - variant CI, 4 - variant DI, 5 - variant EI, 6 - variant FI, 7 - variant GI, 8 - variant HI, 9 - variant II, 10 - variant JI, 11 - variant KI.

Deposition of zinc coatings caused changes of strength within range of limited fatigue strength in relation to the basical variant. Course of simple regressions for 40H steel indicates that changes of loadings values for variants only with coatings deposited in alkaline bath /variant BI/ and weak-acid /variant GI/ in a less degree influence on strength of material than in the case of steel without coatings /variants: AI, KI/ /Fig. 3/. For variants, when surface plastic forming was applied shortening of durability within range of limited fatigue strength was observed in comparison with AI, CI, GI variants /Fig. 3/. Despite application of strictly determined conditions of electroplating, different thicknesses of zinc coatings for both baths on round samples were obtained. It reflected in fatigue strength.
For thinner coatings values of fatigue strength limits were than for coatings thicker, what was confirmed for alkaline and weak--acid baths. For variants with only zinc coatings deposited, slight

drop of fatigue strength in relation to the basical variant was observed. In the case of using of alkaline bath for small thicknesses of coatings no changes of fatigue strength were found. Slight increase of fatigue strength for thin alkaline zinc coatings /5%/ is included within the range of limits of measuring error. Visible changes were observed in the range of unlimited fatigue strength in relation to the basical variant, and with variants of zinc coatings deposited, in which surface plastic forming was applied. It was noticed that employment of surface plastic forming causes fading of diversificarion of strength limit in relation to thickness of a coating.
Deposition of a coating and alkaline bath in connection with surface plastic forming have much more positive effect on strength in the case of alkaline variants than with coating from weak-acid bath. The best results were obtained for variants, in which loose abrasive cleaning and shot peening after coating deposition were applied, however for analogical variants, higher values of fatigue strength limits were achieved for alkaline bath.
The highest strength values were got for the variant, in which after deposition of zinc coating in alkaline bath shot peening was carried out. Increase of 15% of strength in camparison with the basical variant and more than 20% in relation to the variant with only alkaline coating deposited were obtained.
Employment of loose abrasive cleaning before and after deposition of a coating in bath of this type caused increase of strength in relation to the basical variant. For alkaline coatings the lowest strength was obtained for DI and FI variants, where shot peening preceded electroplating. When shot peening was performed before and after deposition of a coating, fatigue strength was even lower than for the variant with only alkaline coating. Influence of a coating produced from weak-acid bath connected with surface plastic forming did not give so positive results, as for coatings deposited from alkaline bath. But some parallelismus may be found in relation to fatigue strength for proper variants of alkaline bath. For variants, in which shot peening was employed only after deposition of zinc coating from weak-acid bath and loose abrasive cleaning, for this type of baths the highest strength properties were got. It should be stressed, that only for variant JI /weak-acid bath and shot peening/ higher limit of fatigue strength was obtained than for the basical variant.
Increase of fatigue strength /variant JI/ in comparison with the variant of coating thickness - 10 µm - is 10%, and for thickness 12 um - 20% /Fig. 3/.
Though employment of loose abrasive cleaning increased value of fatigue strength limit in comparison with the variant where only the coating from weak-acid bath, but still only comparable results with the basical variant were got. Similary, as it was for alkaline bath, for weak-acid bath the lowest strength properties were got for variant II and KI /shot peening before deposition of a coating/.
Wöhler curves for 65G steel are completely different comparing with 40H /Fig. 4/. Course of simple regressions obtained for variants BII and GII shows drop of fatigue life within the range of limited fatigue strength in comparison with the basical variant AII.
Employment of surface plastic forming caused increase of fatigue life for all testing variants. Among all technological variants in

which surface plastic forming was applied, the longest life was obtained in technology of surface hardening in accordance with variant I II and DII, i.e. when shot peening was carried out before electroplating deposition of coatings. Deposition of zinc coating from alkaline and weak-acid baths induced decrease of fatigue strength limit in relation to the basical variant by 5 and 10% /Fig. 4/. Application of combined treatments increased values of fatigue strength limits for all technological variants.

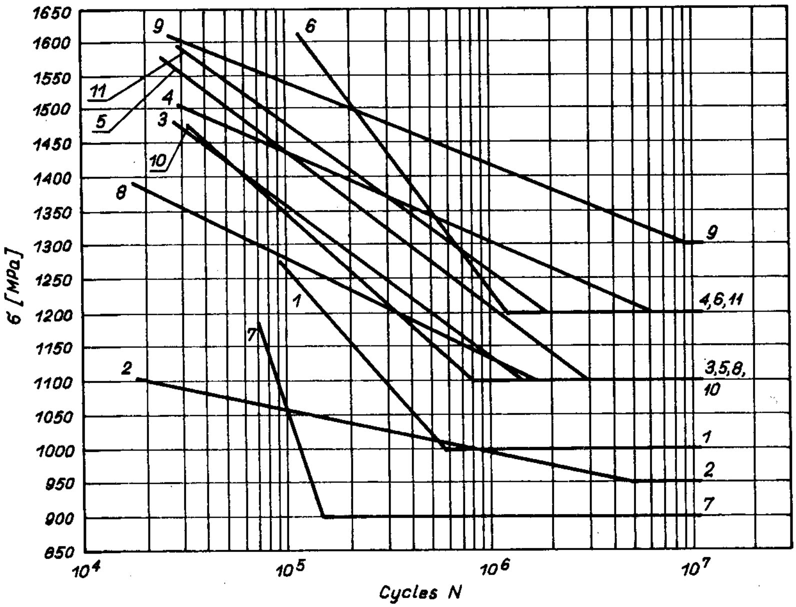

Fig. 4 Comparison of Wöhler curves for all testing variants for 65G steel: 1 - variant AII, 2 - variant BII, 3 - variant CII, 4 - variant DII, 5 - variant EII, 6 - variant FII, 7 - variant GII, 8 - variant HII, 9 - variant I II, 10 - variant JII, 11 - variant KII.

In variants, where loose abrasive cleaning and shot peening only after electroplating process were performed, the some increase of strength by 10% was obtained irrespective type of a bath.

Conclusions

1. It was demonstrated that fatigue strength depends on the type of material, type of a bath, the method and order of application of surface plastic forming and type of loads used, and that it must be determined on the base of tests each time.

2. Technological variants, which ensure under given conditions remarkable optimal /about 30%/ increase of fatigue strength:
a - for 40H steel loaded under stretching-compressing conditions - alkaline bath and shot peening after deposition of zinc coating Z_{rc} = 540 MPa.

b - for bending loads on 65G steel, toughening and shot peening before deposition in weak-acid bath Z_{gw} = 1300 MPa.

3. In all cases, advantageous influence of loose abrasive cleaning on fatigue strength was observed. For shot peening this influence depends on type of loads and sequence of its applications in a given technology.

4. In the case of shot peening advantageous influence of this technology on fatigue strength was observed, when it was applied after deposition of galvanic coating for stretching-compressing stresses, and before and after deposition for bending loads.

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