Influence of Shot Peening on the Fatigue Strength of Various Heat Treated Steels

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ABSTRACT

The fatigue strength of constructional steel has been determined in dependence on hardening heat treatments - bulk and surface ones, which were conducted before shot peening. There has been shown that an increase of fatigue strength of the samples depends - at the same shot peening parameters - on kind of the preceding treatments.

KEYWORDS

Shot peening, fatigue strength, normalizing, toughening, induction hardening.

INTRODUCTION

30 HGSA steel /0.30% C, 0,1% Mn, 0,1% Cr, 1,1% Si/ is applied in aircraft industry at production of machine parts alike hollow shafts /turbocompressor shafts, chassis elements and others/. The permanent progress at construction of aircrafts and their engines demands constructional stuffs with higher and higher strength requirements. It causes a continual looking for new technologies and improving methods of constructional stuffs.

A purpose of the study is to determine an influence of the bulk and induction heat treatments, preceding the shot peening process, on the change of the shot peening effect. This effect at various heat treated states and after shot peening. There is shown that the increase of fatigue strength of the 30HGSA steel depends not only on the shot peening process, but on heat treatments, which preceded this process /Nakonieczny, 1983/.

REALISATION OF THE EXAMINATION

Samples for testing

The samples for testing have been made of steel bar /steel grade 30HGSA/ by cutting method and next submitted to two kinds of the bulk heat treatment, normalizing and toughening. So prepared two technological variants of samples have put to further treatments - shot peening and induction hardening.
At least the following technological variants were accepted to testing:
- normalizing
- toughening
- normalizing and shot peening
- toughening and shot peening
- normalizing and induction hardening
- toughening and induction hardening
- normalizing, induction hardening and shot peening
- toughening, induction hardening and shot peening

Parameters of heat treatments and shot peening

1. Normalizing; 870-880°C, cooling with a furnace
2. Toughening; oil hardening 870-880°C
   oil tempering 580-600°C
3. Induction hardening; $I_s = 1,4A$; $I_a = 2,0$ A; $U_a = 4,3$ kV
   shift's speed of a coil v = 3,3-4,4 mm/sec
   water quenching
   a/ layer thickness 0,8-1,0 mm
   b/ surface hardness of the normalized samples 620 HV1
   surface hardness of the toughened samples 590 HV1
4. Shot peening;
   a/ round steel shot
   b/ peening intensity 0,24A
   c/ surface coverage 100%

Examination of the fatigue strength

The examination of the fatigue strength were conducted with a fatigue machine of the firm Schenck at rotary bending conditions; testing base $Na = 1.10^7$ cycles, frequency = 100 Hz.
As a measure was a fatigue strength limit taken from Wöhler stress-number curve.

Examination of the surface layer state

Examination range included:
- macroscopic inspection of the fracture surface
- microctructure examination
- hardness measurements

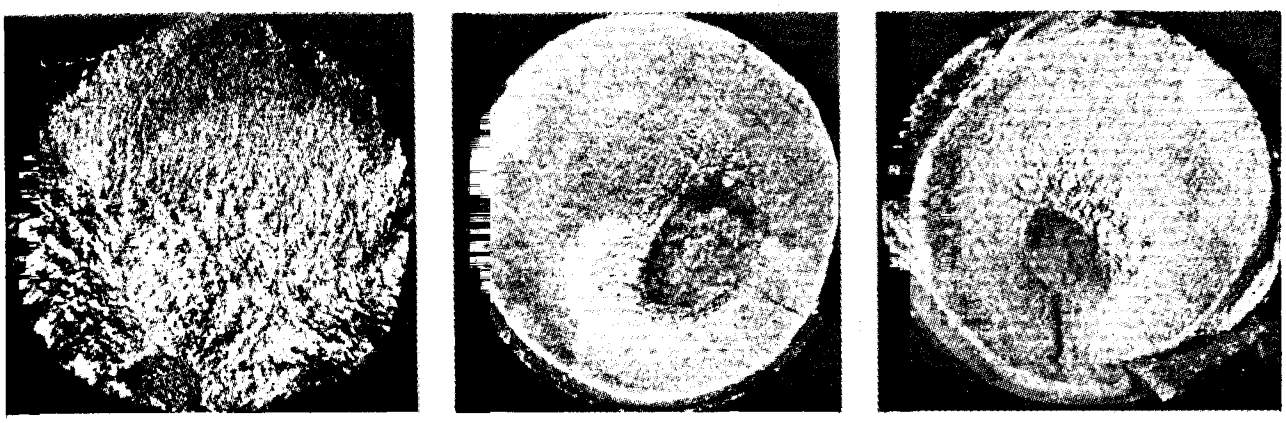
RESULTS

Results of the fatigue examinations are given in table 1.

TABLE 1. List of results of the fatigue strength examinations

Kind of the surface treatment	Fatigue strength (MPa at 10^7cy.)	
	normalizing	toughening
without treatment	392	451
shot peening	422	540
induction hardening	618	490
induction hardening and shot peening	755	804

Normalized, toughened and next peened samples show similar coarse-grained fractures with distinct beach marks. Many fatigue initiaton sites are disposed on surface of the samples /fig.1a/.
Induction hardened and later peened samples /independently from a preparatory treatment/ have fine-grained fractures. Fatigue initiation sites of samples, which have been induction hardened only, appear on the sample surfaces /fig.1b/. The fatigue initiation sites of samples, which have been induction hardened and shot peened, are located just below the surface /fig.1c/.



a b c

Fig.1 Kinds of fatigue fractures: a - normalized and peened samples, b - toughened and induction hardened sample, c - toughened, induction hardened and peened sample.
Magnification 7,5x

For microstructure examination the metallographic microsections were, made, which were later etched with 2% nital.
Normalized samples have ferritic-pearlitic structure. Plastic strains, occured as a result of the shot peening, exist up to depth of 0,03 mm.
Normalized and induction hardened samples have in the surface layer a structure of fine-accicular martensite and fine-dispersed carbides. After

peening the samples show a cold work up to depth about 0,01 mm.
After toughening the samples have a sorbitic structure. The plastic strains occured as a result of the shot peening, exist up to depth 0,03 mm.
The toughened and induction hardened samples have in the surface layer a structure of fine-accicular martensite and carbides. The cores have a sorbitic structure.
The plastic strain zone of the peened samples has depth about 0,01 mm.
Results of measurements of hardness are given in table 2.

TABLE 2. Results of measurements of hardness

Treatment	Surface hardness /HV1/	Distance from the surface /mm/ Hardness HV0,05							
		0,03	0,13	0,25	0,60	1,0	1,4	1,8	Core
normalizing	236	283	291	291					293
toughening	342	341	338	341					340
normalizing and shot peening	394	321	300	300					300
toughening and shot peening	442	341	341	338					340
normalizing and induction hardening	620	617	710	710	726	710	429	289	255
toughening and induction hardening	591	633	633	633	726	638	396	349	349
normalizing, induction hardening and shot peening	723	710	896	710	710	710	710	402	251
toughening, induction hardening and shot peening	810	896	635	677	726	617	402	362	345

DISCUSSION ABOUT EXAMINATION RESULTS

The discussion of examination results carried out taking into consideration the total set of fatigue strength changes of 30HGSA steel - shown in fig.2.
30HGSA steel was heat treated and surface hardened by a cold work. Typical, applied in industry, parameters of induction hardening and shot peening were used.
The fatigue strength of 30HGSA steel in toughened state is higher than in normalized state. Shot peening of samples after the both treatments causes the increase of fatigue strength. The peening effect is 3 times more after toughening /20%/ than after normalizing /7%/. The reason can be the occuring of a martensite transformation during the peening process of the toughened samples as well as bringing much more stresses in the surface layer of the material, having martensite structure with precipitations of fine-dispered carbides, by increasing action of these carbides

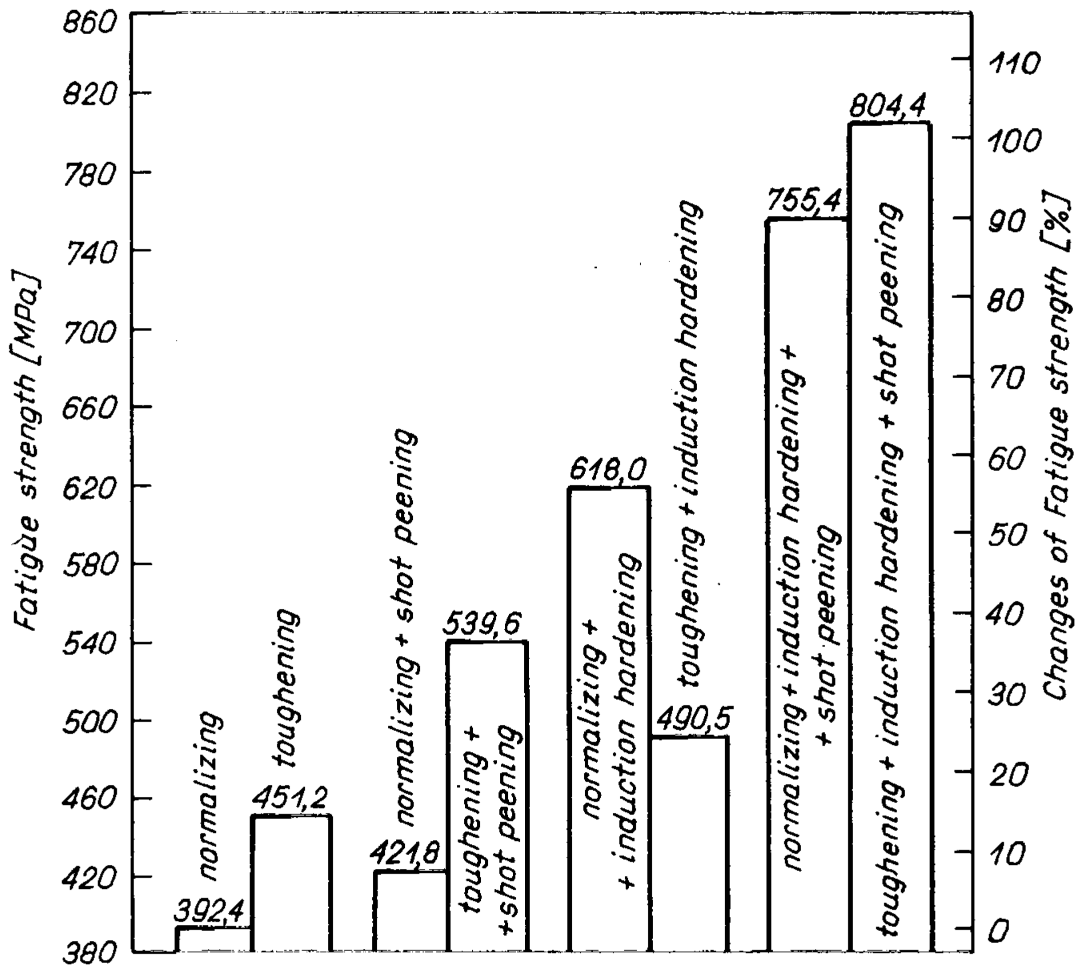


Fig.2. Fatigue strength of 30HGSA steel submitted to various treatments.

on grain boundaries.
The higher fatigue strength of the toughened and peened samples than normalized and peened ones, independently from better mechanical properties of samples after toughening, is caused by less differences in hardness between a surface layer and a core of the toughened samples. Table 2 /Nakonieczny, 1980/.
At the event of induction hardening, the lower fatigue strength of the toughened steel than the normalized one can be caused by occuring, at a typical industrial technology, the decarburization of the toughened material. Measurement of microhardness also showed the lower hardness of the layer at the toughening and induction hardening process than at normalizing and induction hardening one /Table 2/. Application of shot peening changes the qualitative and quantitative values of these particular technological variants including the induction hardening operation.
Connecting of the shot peening with the technological variant, including toughening and induction hardening, causes obtaining the higher fatigue strength than for the variant with normalizing instead of toughening.
The fact can be explained as follows:
The surface plastic working relieves defects of the surface layer, which

appeared to the much more degree after toughening and induction hardening than after normalizing and induction hardening. To these defects beling decarburization and microcracks.
Shot peening, applied after toughening and induction hardening, causes then the additional growth of the surface layer hardness /Table 2/, which in connection with higher strength of the core, effects so high increase of the fatigue strength /Nakonieczny, 1981/.
At connecting the technologies of induction hardening and shot peening, the effect of the peening is about 3 times higher, when the preparatory heat treatment is toughening /64%/ instead of normalizing /22%/.
The shot peening, used after induction hardening, changes the physics of the fatigue destruction. In fig.1 is shown that the fatigue initiation site for this technological variant appears just below the surface, where the structure notch is located.
The initial fatigue cracks of induction hardened samples, independently from heat treatment preceding this operation, begin on the surface of the samples /fig.1b/.
At the ending should be emphasized that as a result of applying the induction hardening and shot peening and especially by coupling the both technologies, the considerable increase of the fatigue strength of 30HGSA steel was achieved. In relation to the normalized state the increase amount to 92,5%, to the toughened state - 78,3%.

CONCLUSIONS

1. The effect of shot peening marked in increase of the fatigue strength of 30HGSA steel depends on preparatory heat treatments and surface heat treatment.

2. The effect of shot peening is about 3 times higher after toughening than after normalizing of 30HGSA steel.

3. The shot peening, applied after induction hardening, changes the nature of the fatigue cracks, moving the fatigue initiation site from the surface of the sample to its deep.

4. Among the examined technological variants of treatments of 30HGSA steel - the highest fatigue strength /Z_{go} = 804,4 MPa/ was achieved after toughening, induction hardening and shot peening.

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