EFFECT OF SHOT PEENING ON FATIGUE LIFE OF MACHINE ELEMENTS

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ABSTRACT

Effect of shot peening on fatigue life of selected machine elements has been determined by analysis of stress changes developed in a metal surface. The state of stress in the surface layer has been featured by the value of hardness and its distribution, state of internal stress and finally by shape of the surface. It has been pointed out that the shot peening process produces such changes in the surface layer stresses which considerably improve fatigue life of a peened part. In the second part of the present work some examples of a practical application of the shot peening technique have been given. Namely, shot peening of drilling rods, crank-shafts, gear-wheels and truck's chassis elements. It has been pointed out that the peening process extends the fatigue life to the great extent.

KEY WORDS

Fatigue life, state of stress in the surface layer, shot peening of drilling rods, shot peening of crankshafts, shot peening of gear-wheels, shot peening of truck's steering system elements, cold working.

INTRODUCTION

Machine elements which are now manufactured must meet ever growing performance requirements for an extended fatigue life and high wear resistance. These properties are strietly connected with each other and, as a matter of fact, result from property of the element's surface layer. The surface layer is of a great importance in a process of fatigue craks arising. This is usually the layer of the greatest stresses increased by micro-notches and surface flaws. This is where mechanical, physical and chemical properties of material change in comparison to the core. Superficial graine are exposed to a detrimental influence of treatments and of environment. In practical applications there are some methods which help reduce the detrimental factors. The work hardening is one of them, and shot

peening seems to be the simplest one.

Changes in State of Stresses in the Surface Layer Affected by Shot Peening

State of the surface layer can be determined by the following data:
- value and distribution of hardened spots
- microstructure
- shape of the surface
- state of the internal stresses

Values of the numbered parameters depend on sort of material, state of treatment and initial state of the surface layer. Let us consider effects of the parameters on some functional properties of the material, first of all on the fatigue life.

Work-hardening of the Surface Layer

By work-hardening of the surface layer is meant an increase of hardness in a certain thin material layer Relationship of microhardness of a gear teeth surface to peening intensity is given in Fig. 1.

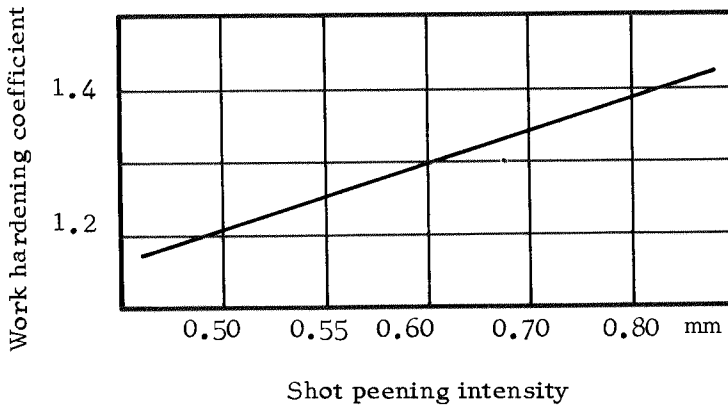

Fig. 1. Relation of work hardening coefficient to shot peening intensity.

Hardness of the surface layer is strongly affected by peening intensity. When a part is exposed to alternating service loads thickness of the hardened layer is of a great significance. The thicknees decides whether an initial fatigue crack will begin in the layer just below that of hardened or on the surface of the part. A great thickness of the hardened layer is favourable but to a limited value. A further increase in the thickness leads scarcely to an increase in fatigue life.

State of Internal Stresses

Solids exposed to mechanical, thermal and chemical influences undergo changes that lead to imposing stresses. When the influences decline, so do some stresses but not all. That remained are called internal stresses. A given internal stress pattern have a various effect on the fatigue life. The effect depends also on a way

of exerting changing loads on a part. In Fig. 2, is shown a distribution of internal stresses for test pieces treated with nitriding, carburizing and cold working.

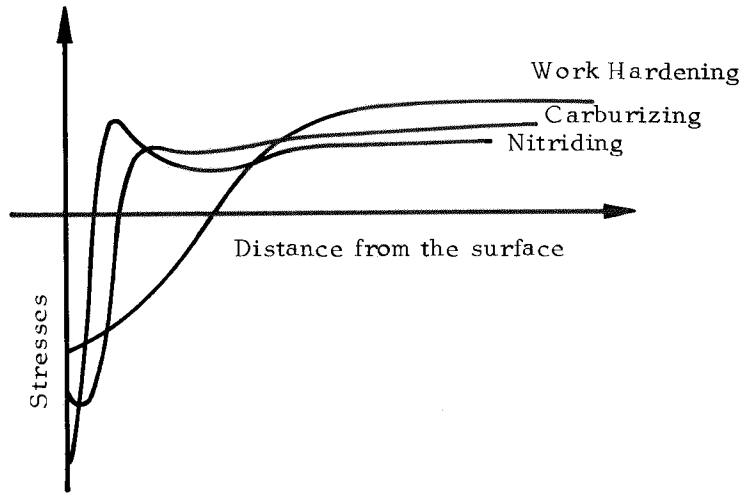

Fig. 2. Distribution of internal stresses in parts treated by: Nitriding, Carburizing, Work Hardening.

Even at the hirts sigh it is clear that the distribution of stresses in the nitrided and carburized test pieces differs from that of the cold-worked anes. On the basis of comprehensive researches /Nakonieczny, 1978/ it was stated that the distribution of stresses has a fundamental effect on safe fatigue life; compressive stresses in the surface are of a lesser significance. Shown in Fig. 2, the distribution of stresses for cold-worked test piece seams to be the most adventageous for the smallest gradient between compressive and tensile stresses. Such a distribution indicates that the mechanical properties of material change in a steady way within the cross-section. It leads to a decrease in stress-concentration within zone between the surface layer and the seft core and finally to an increase in the fatigue life. It must be admitted that in parts treated with diffusion hardening methods the seurce of formation of fatigue cracks lies just below the hardened layer. For this reason surface working methods are preferable.

The Structure of Material

The structure of peened material is shown in Fig. 3. A cold work in the surface layer of a rod is visible very well. The cold work results from plastic streins of some structural constituents particularly that of retained austenite which is formed during heat treatment. That is why the greatest increase in the fatigue life may be obtained by coupling the heat treatment with the cold working. On the basis of obtained results /Elizavetin, 1973/ it can be said that during shot peening some phase transitions take place. Namely, retained austenite changes into

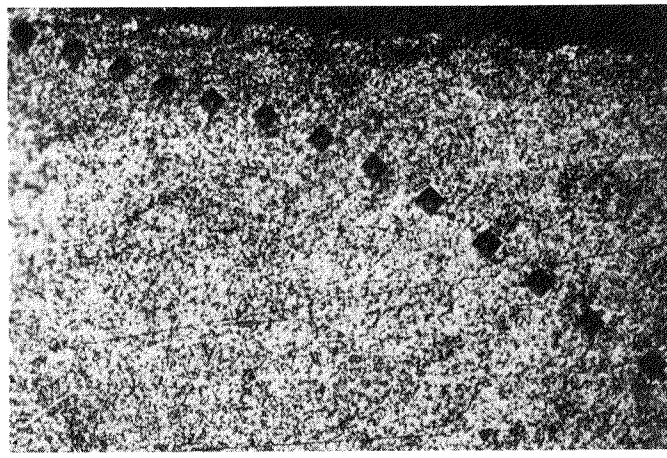

Fig. 3. Structure of a peened rod.

martenzite. This is accompanied by dispersion hardening due to secretion of carbides. Above mentioned structural transitions extand the material's fatigue life.

State of Surface

State of surface is determined by:
- surface roughness
- lay
- surface structure
- bearing surface

Roughness number of a peened surface largely depends on kind of used shot and on method of peening. Surface of machine elements subjected to peening with round steel shot, cast steel shot, glass beads change both their roughness and structure.

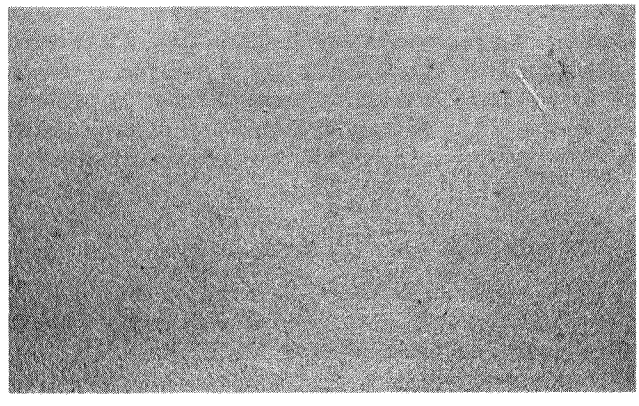

Fig. 4. Point structure of a the rod's surface peened with round steel shot of domestic origin.

The latter is changed from anisotropic to point, which results in an increase in fatigue life. The increase results from increased micronotches radii and the structure anisotropy elimination.

Applications of Shot Peening Process

For some time past a number of works on improvement of fatigue life of machine elements have been carried out in the Institute of Precision Mechanies. The works have dealt with working out a manual and technical documentation for putting shot peening into current industrial applications. I intend to eutline new some of my ewn works /Nakonieczny, 1979/ carried out recently and concerning application of shot peening as a preferable method of work hardening. A shot peening process for carburized drilling rods was developed. This brought on 60% increase in their fatigue life. Recently a similar shot peening process for carburized gear-wheels was worked out. In the process only demestic equipment was taken into consideration. Some carburized specimens and gear-wheels of case-hardening steel §18% C, 1,15% Cr, 95% Mn, 8% Ti/ were subjected to fatigue unilateral bendind. The shot peened specimens and the gear-wheels preved 30% fatigue life increase. Shot peening was used to offset stress-concentration effects of structural notches in crankshafts of which main beening journals were regenerated with the aid of welding. Fatigue lifes of the crankshafts were lesser than those of new ones for the structural notches reasons /the notches arise during welding and lie close to the crankweb/. For the purpose of increasing the fatigue life the journals were redesigned in view of the fillet radius optimization and subjected to shot peening. This resulted in an imprevement of fatigue life up to the value credited with crankshafts delivered by a manufacturer. Some elements of truck steering system were peened to impreve their fatigue life. With the help of non-destructive methods, requirements for the surface layers of that element were determined. Shot size grading and process parameters were carefully estimated. On the basic of a fatigue test it was pointed out that the imprevement of fatigue life extended by 34%. The results are illustrated in Fig. 5.

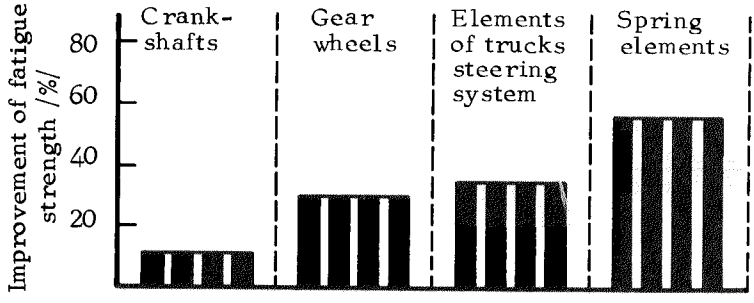

Fig. 5. Increase in fatigue life of some machine elements as a result of shot peening.

Scope of Application

Shot peening as a surface cold working is widely applied to such materials as: steel no matter what heat treatment, cast steel and cast iron treated or untreated, copper alloys, aluminium alloys, titanium alloys and some other metals. Shot peening my be well suited for some plastics. The major application of shet peening is related to:

- improvement of life and reliability of machine elements,
- straightening and forming of machine elements,
- pre-treatment for elements to be plated,
- improvement of fatigue characteristics of elements subject to alternating load /bolts, out of other elements/,
- pre-treatment for elements to be metallized or coated with plastics.

CONCLUSIONS

Shot peening give rise to an improvement in fatigue life by changing state of stresses in the surface layer of metal parts. The most significant change, with a view to affecting fatigue life, relates to casing stress-concentration effects of structural notches inherent in the heat treatment process. That is why heat treatment fellowod by work hardening give rise to an considerable increase in fatigue life of machine elements. The given review of some researches points out clearly that the shot peening process is highly advantageous and recommendable for many metal parts.

REFERENCES

Kudrjavcev, I.V. /1951/ Vnutrene napriazenija. Masgiz, Moskva.
Kudrjavcev, I.V. /1970/. Povysenie procnosti dolgovecnosti detalej masin poverchnostnym plasticeskim defermirovaniem. CNIITMAS, Moskva.
Nakonieczny, A. and Amanowicz W. /1978/. Określenie wpływu naprężeń własnych na wytrzymałość zmęczeniową dla wybranego przypadku stali hartowanych indukcyjnie. Sprawozdanie z pracy nr 110.00.0001, Archiwum IMP /nie publikowane/.
Elizovietin, M.A. /1973/. Povysenie nadieznosti masin. Masinostroenie,Moskva.
Nakonieczny, A. /1979/. Metody podwyższania wytrzymałości zmęczeniowej części maszyn. Materiały VIII Seminarium z zakresu metaloznawstwa i obróbki cieplnej. Wyd. IMP, Warszawa, Zeszyt 1, s. 33-39.