RELATION BETWEEN MICROSTRUCTURE OF SHOT-PEENING STEEL AND ITS MECHANICAL CHARACTERISTICS

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Abstract: Nowadays, the competition in the auto industry is getting more intensive than ever and it is essential to offer car-users products of a lower price and a higher quality. On this account, one of our most critical tasks is to maximize the required performance of component parts of automobiles, considering their manufacturability and designing them as compact as possible.

Keeping this issue in mind, authors of this paper have decided to examine steels for mechanical parts of vehicles minutely, studying how their microstructure is altered by shot-peening process and how their mechanical characteristics, as an automobile part, are changed consequently.

As a result of study, a remarkable alteration has been recognized in the microstructure of steel and also the mechanism of micro-structural alteration has been defined. These results are amply reported in the paper.

Key words: fatigue life, microstructure and steels.

1. General Instructions

In the automobile manufacture of this 21st century, we need to improve fuel economy for protection of global environment without increasing manufacture cost. And thus it is strongly desired to use low-cost materials, reinforcing the materials used for the parts where to require more strength in order to satisfy both elements of higher performance and lower cost. In this study, we directed our attention to carburized steel, which is commonly used for gears of automotive parts, and made a detailed investigation about the shot-peening conditions of for carburized steel gears and also about the property of surface after shot-peening. In addition, we performed fatigue tests for gears that have got different surface characteristics due to fabrication in different processing conditions, comparing them with no shot-peeing carburized steel in respect to fatigue life. Finally, from the results of tests and analysis, we added an observation regarding utilization of shot-peening process to seek possibility of improvement in gear's fatigue life.

2. Method of Experiment

An actual gear of SNCM220 was used as a specimen. Table 1 shows its chemical composition. Fig. 1 shows carburizing, quenching and tempering conditions, which was done prior to shot-peening, and Table 2 shows shot-peening conditions, which was done after carburizing, quenching and tempering. Gear A was only carburized, quenched and tempered but Gears B, C and D went through shot-peening process after carburizing, quenching and tempering, under different conditions; condition I, II and III respectively. And the following properties at tooth root of each gear were evaluated after shot-peening: residual stress (surface, 30μm and 60μm from the surface), surface hardness, surface roughness and depth of carburizing abnormal layer at surface state. A fatigue test was performed for all the gears A, B, C and D to determine their fatigue life.

Table1 Chemical anylysis of SNCM220 steel (mass%)

Steel	C	Si	Mn	P	S	Cu	Ni	Cr	Mo
SNCM220	0.22	0.18	0.83	0.01	0.01	0.01	0.57	0.59	0.19

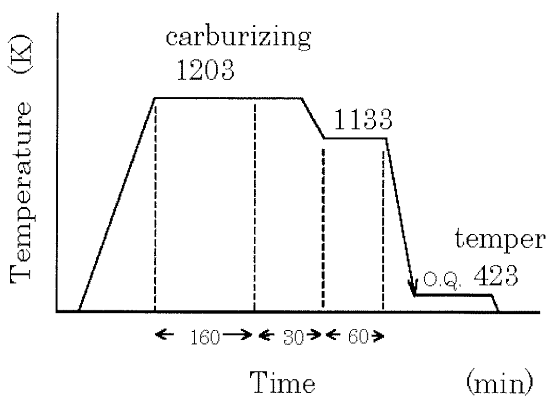

Fig.1 Heat pattern of specimen

Table2 Working conditions used for shot peening experiment

Condition of shot peening	I	II	III		
Size (diameter)	0.8mm	0.03mm	0.4mm	+	0.03mm
Material	Fe-1%C	Fe-1%C	Fe-1%C		Fe-1%C
Pressure	0.5MPa	0.5MPa	0.5MPa		0.5MPa
Time	50s	50s	50s		50s

3. Results of Experiment

3-1. Residual Stress

Fig. 2 shows the relation between respective shot-peening conditions and residual stress. Only carburized – quenched – tempered Gear A was given the lowest residual stress; while Gear C showed the highest value of residual stress of all the gears evaluated. And Gear D showed the second highest, then Gear B, the third.

3-2. Surface Hardness

Fig. 3 shows the relation between respective shot-peening conditions and Vickers number. Gear D showed the highest value of surface hardness: 880 Hv, which was followed by others gears in order of B, C and A.

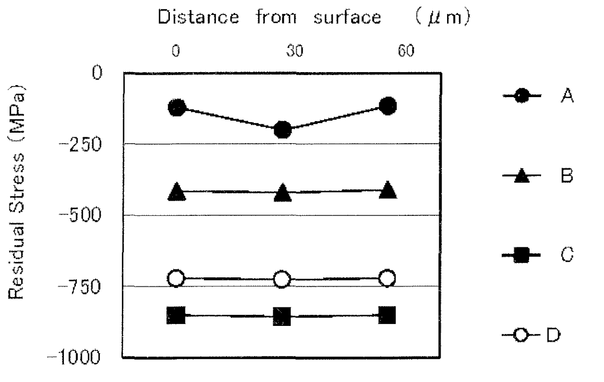

Fig. 2: Relation between Working Conditions of Shot Peening and Residual Stress

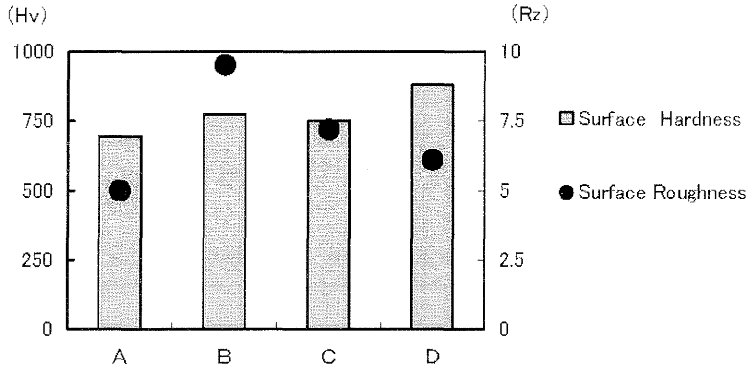

Fig. 3: Relation between Working Conditions of Shot Peening and Surface Hardness, Surface Roughness

3-3. Surface Roughness

Fig. 3 shows the relation between respective shot-peening conditions and surface roughness. Gear A showed the lowest value of surface roughness: 5 Rz, which was followed by other gears in order of D, C and B.

3-4. Depth of Carburizing Abnormal Layer At Surface State

A carburizing abnormal layer means a mixed area of internal oxidation and incomplete quenching microstructure in its surroundings, as illustrated in Fig. 4. The internal oxidation is a structure of oxygen that exists in the carburizing chamber combined with alloying element, such as Cr, Mn, etc., contained in the carburized steel, forming along crystal boundaries. Fig. 5 explains depth of incomplete quenching microstructure of respective gears. Gear A showed the largest value of depth of incomplete quenching microstructure, which was followed by other gears in order of B, D and C. The depth of Gear A, the largest value, was 21.0 μ m, meanwhile, it diminished by 7.7 μ m in Gear C, the smallest.

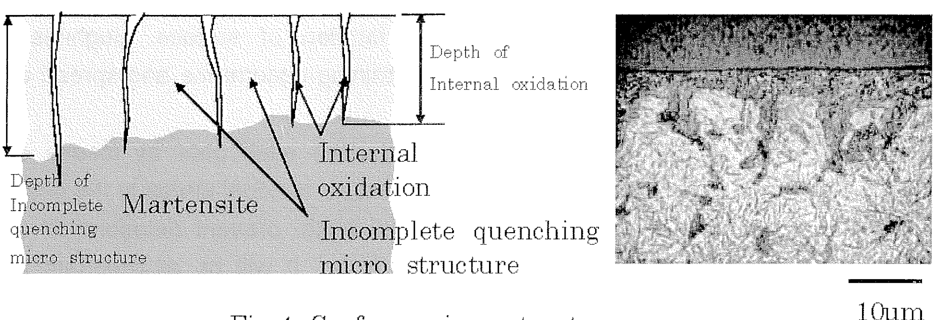

Fig.4 Surface micro structure

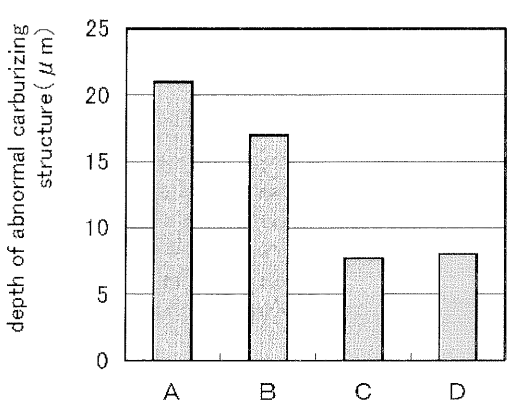

Fig. 3: Relation between Working Condition of Shot Peening and Depth of Abnormal Carburizing Structure

Table 2 Figure Life

	Figure Life
Gear A	6.5×10^4
Gear B	1.3×10^5
Gear C	4.5×10^5
Gear D	8.5×10^5

3-5. Fatigue Life

Table 2 explains the fatigue life of respective gears. The fatigue life of Gear A that had only carburizing-quenching-tempering was 6.5 X 10^4; meanwhile Gears B, C and D indicated longer fatigue life; 1.3 X 10^5, 4.5 X 10^5, 8.5 X 10^5 respectively.

4. Observations

For the purpose of observing the relation between fatigue life of gears and properties at surface state, Fig. 6 gives a summarization of integral values of residual stress (surface, 30 μ m and 60 μ m from the surface), surface hardness, surface roughness and the relation between depth of incomplete quenching microstructure and fatigue life. From this summary, we observed the importance of the following factors for the extension of fatigue life: to improve surface hardness, give compressive residual stress, diminish depth of incomplete quenching microstructure and prevent deterioration of surface roughness. And we determined that the last 2 factors (diminution of depth of incomplete quenching microstructure, preventing deterioration of surface roughness) contribute to improvement of fatigue life restraining occurrence and spread of fatigue cracks.

In order to prolong fatigue life of a carburized steel gear by means of shot-peening, it is essential to give the compressive residual stress to the gear, diminish incomplete quenching microstructure depth, prevent deterioration of surface roughness and improve surface hardness. It will be all-important to restrain occurrence and spread of fatigue cracks for the further prolongation of fatigue life

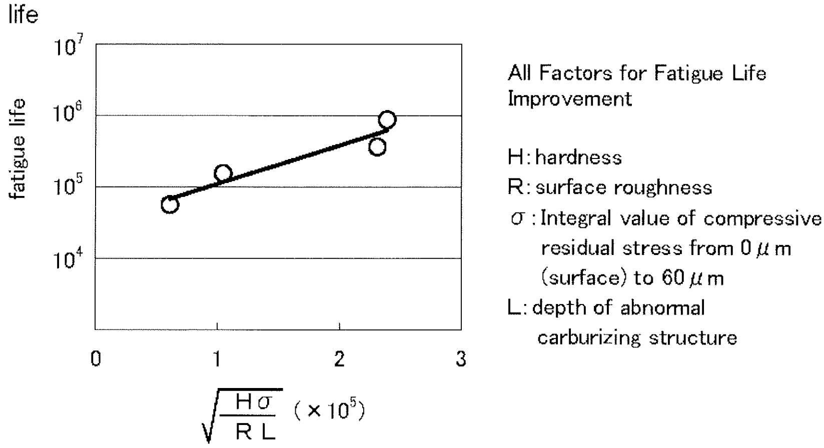

Fig. 6: Relation between All Factors for Fatigue Life Improvement and Fatigue Life

5. Conclusion

The following is the conclusion we achieved by performing surface evaluation and fatigue tests on carburized-quenched steel gears of SNCM220 with shot peening in 3 different working conditions:

(1) The difference of shot-peening conditions caused difference in surface properties. When shot-peening with the grain size ϕ0.15mm, the surface residual stress is larger than ϕ0.8mm and depth of incomplete quenching microstructure at the very superficial layer was diminished.

(2) It is highly important to improve surface hardness, give compressive residual stress, diminish depth of incomplete quenching microstructure and prevent deterioration of surface roughness for the prolongation of fatigue life of carburized-quenched steel gears.

(3) In order to improve the fatigue life of carburized-quenched steel gears, it is, again, important to diminish depth of incomplete quenching microstructure and prevent deterioration of surface roughness for the purpose of restraining occurrence and spread of fatigue cracks.

(4) In shot-peening conditions, the grain size is specially important and must be paid extra care on its control.