IMPROVEMENT OF HARDENED SURFACE BY SHOT PEENING

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ABSTRACT

In the application of shot peening to automotive parts, this process has been the commonly used surface treatment for springs. Today, a tend among automobile manufacturers is to use this process for other parts, e. g. transmission gears, with the aim of increasing durability. The authors have recently conducted several experiments on the effect of this process on soft-nitrided parts which are now undergoing remarkable development, and on widely used plated parts after they have been case-hardened by carburizing. These experiments have proven that the fatigue strength of soft-nitrided or casehardened surface is increased, and that reduction of the strength of hardened surf-face after plating is avoided, contributing greatly to reduction of the weight of such parts without loss of strength.

KEYWORDS; Soft-Nitriding, Tufftriding, Cr-plating, Residual stress, Fatigue strength.

1 OUTLINE OF TEST RESULTS

1-1 Effect of Shot peening on Soft-Nitrided Parts

Soft-nitriding which is also called as Gas Soft-Nitriding, Liquid Nitriding known as Tufftride process has the features shown in Table 1 and is in wide use for various automotive parts. This treatment, however, may not be applicable to common carbon steel where high performance is desired because of shallow case depth and lower surface hardness.

This paper deals with our observations on the effect of shot peening on soft-nitrided steel to see how its mechanical properties are improved. The test consisted of two groups of carbon steel (S45C equivalent to SAE 1045), of which one was shot peened after Tufftriding, and the other was only hardened with the same treatment, for 90 minutes at 580℃ in the salt bath composed of 1.5 ~2.0% of cyanide, 35 plus minus 2% of cyanate and the rest of Na_2CO_3. The surface roughness, fatigue strength, hardness distribution, residual stress distribution and test conditions are indicated in Fig. 3.

Table 1 Typical Soft-Nitriding parts

Purpose	Parts	Notes
Fatigue	Crankshaft	fillet
	Engine valve spring	400° C ~ 420° C
Wear	Crankshaft	Journal Balancer-weight side
Scoring	Camshaft	
	Rockerarm shaft	
	Engine valve	
	Valve lifter	
	Gear	Low and medium load
	Bearing cage	
	Shafts	
	Differential gear carrier	

Shot peening with glass beads gave somewhat higher surface roughness, whereas the fatigue strength was increased by about 20%. This increase in the fatigue strength could be mainly to improved distribution of the hardness and residual stress. Use of steel balls in place of glass beads under the same conditions as for carburized hardened parts gave a better result with regard to the surface hardness and distribution of the residual stress. It was assumed that the amount of increase in the fatigue strength would be inferior to, or at most equal to, that obtained with glass beads because of the considerably higher surface roughness produced.

On the other hand, in the case of using fine steel shot with the same Almen intensity as glass beads peening, the surface roughness was similar to that obtained with glass beads. One point worth mentioning here is that the surface roughness was similar to that obtained by Tufftriding and lapping, with sufficient depth of compound layer. From this latter experiment, it was determined that the use of fine steel ball shots can promote fatigue STRENGTH as much as the use of glass beads, indicating that the method is effective and economical. (Fig. 1)(Fig. 3)

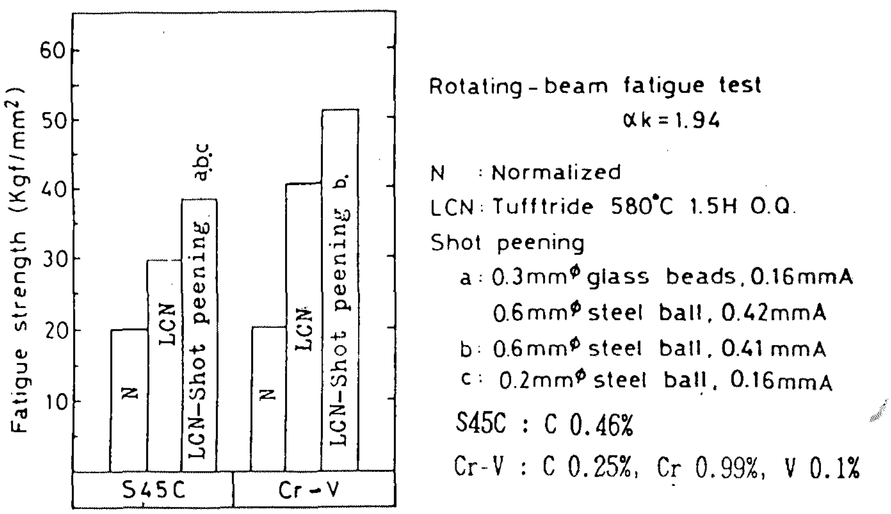


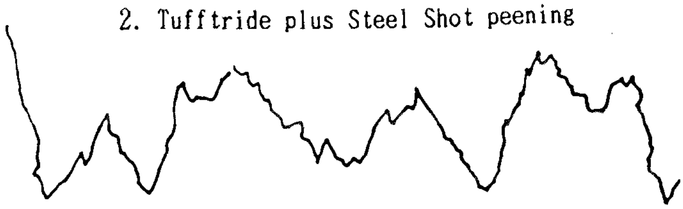
Fig. 3 The effect of shot peening on the fatigue strength of Tufftride S45C and Cr-V steel

Fig. 1 The effect of shot peening on surface roughness of tufftrided S45C

1. As Tufftride

Max. 4.5μm
After lapping (0.09μm)

2. Tufftride plus Steel Shot peening

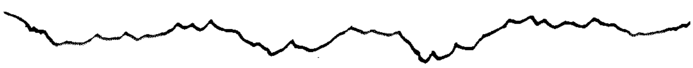


Max. 18.5μm
After lapping (2.41μm)

3. Tufftride plus Glass Shot peening

Max. 9.5μm
After lapping (1.72μm)

4. Tufftride plus modified Steel shot peening



Max. 8.09μm
After lapping (0.44μm)

Fig. 2 The effect of shot peening on surface roughness of tufftrided Cr-V steel

As Tufftride Max. 7.17μm

Tufftride plus steel shot peening Max. 6.81μm

Meanwhile, new materials with have superior nitriding characteristics at lower cost have been developed in order to bring the mechanical properties close to those obtained by carburizing parts, with less distortion. The development of such materials has opened up new possibilities for the hardening of some automotive parts.
This paper also concerns our experiment with one such material, "Cr-V", of which the surface roughness, fatigue strength, surface hardness and distribution of residual stress were measured after Tufftriding and shot peening. In this case, the surface roughness was rather improved even though the sample was shot peened with the same steel ball shot as are used for carburized parts, because of higher surface hardness and deeper nitrogen penetration. (Fig. 2). No significant difference was, however, observed as to the hardness, whereas the distribution of residual stress was improved, and the fatigue strength was increased by as much as 20%. (Fig. 3)

1-2 Relationship Between Compound Layer and Shot peening in Tufftriding

1-2-1 Corrosion Resistance

Excessive intensity of the shot peening treatment can aggravate surface roughness and cause minor cracks in the compound layer, adversely affecting the corrosion resistance of the surface. In the application of shot peening, much care must therefore be taken not to destroy the compound layer. There is no reduction in the corrosion resistance as long as the shot peening is done properly. In our search for better application of shot peening to soft-nitrided steels, four groups of test samples were subjected to a 5% Salt Water Shower Test as specified in JIS Z 2371. The results of this test are given below (and in Table 2) in the order of the corrosion resistance values observed;
Sample treated by Tufftriding (with compound layer remaining) = Sample shot peened after Tufftriding > Sample only treated with Tufftriding (with diffusion layer; without compound layer) > sample not treated. From this test, it was clear that the tufftrided surface can be further improved by adding shot peening if it is done without damaging the compound layer.

Sample		Time (Hrs) 0.5	2	4	6	8	10
S45C	Non-treated	○	⧄	⧄	⧄	■	■
	Tufftride C.L=15~16 μm	◎	◎	○	○	○	□
	" C.L= 0 μm	◎	□	□	□	□	⧄
	" + Shot peening	◎	◎	○	○	□	□
Cr-V	Non-treated	○	⧄	⧄	⧄	⧄	■
	Tufftride C.L=15~16 μm	◎	◎	◎	◎	◎	◎
	" C.L= 0 μm	◎	□	□	⧄	⧄	⧄
	" + Shot peening	◎	◎	○	○	○	○

◎:0% ○:1~10% □:11~25%
⧄:26~50% ■:>51%

Table 2 Results of 5% Salt spray test (by JIS Z 2371)

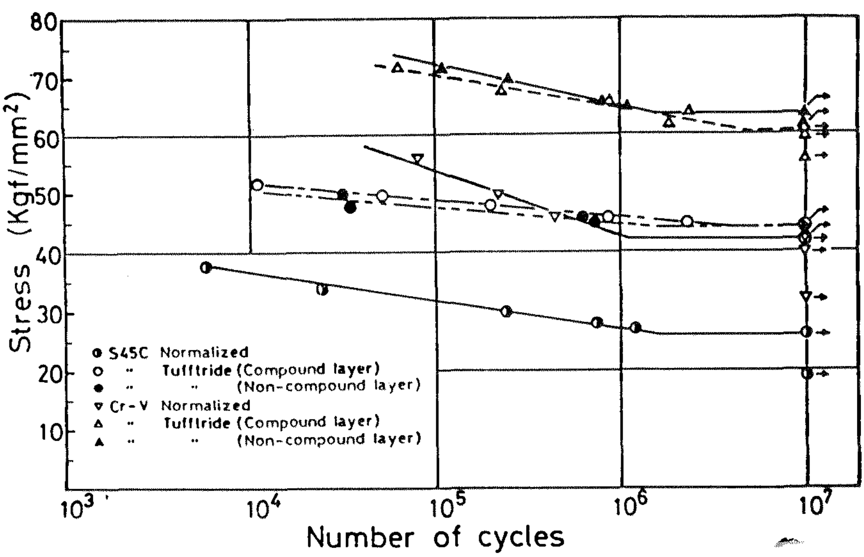


Fig. 4 Influence of compound zone and not compound zone on fatigue strength.

1-2-2 Effect of Compound Layer on Fatigue Strength

The results of a test concerning the fatigue strength of the compound layer are given in Fig. 4. In this particular test, the compound layer formed after Tufftriding were all removed by an electrolytic lapping. In S45C (SAE 1045), no significant differences in fatigue strength were observed regardless of the presence of compound layer.

For "Cr-V" steel, the fatigue strength was increased by 40% when the compound layer was removed or not removed, as compared to S45C (SAE 1045).

Fig. 5 shows the result of the bending test, indicating the relationship between the permanent stress and the load until cracks occurred when the sample was bent under load. In "Cr-V" steel, when the compound layer was removed by lapping, greater permanent stress was observed. As compared to "Cr-V" steel, S45C steel showed a greater amount of permanent stress. However, it is very advantageous that stress can be relieved easily even when the fatigue strength is increased by as much as 20%.

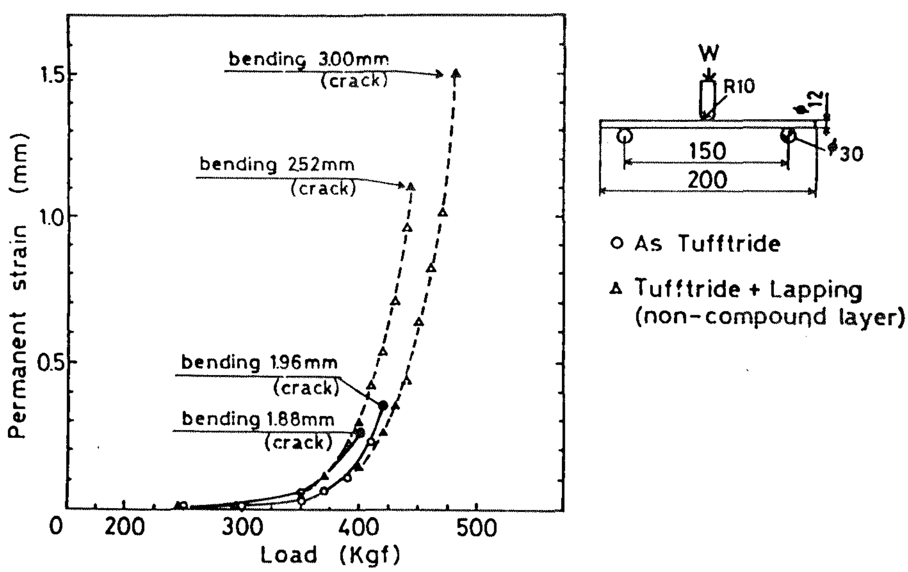
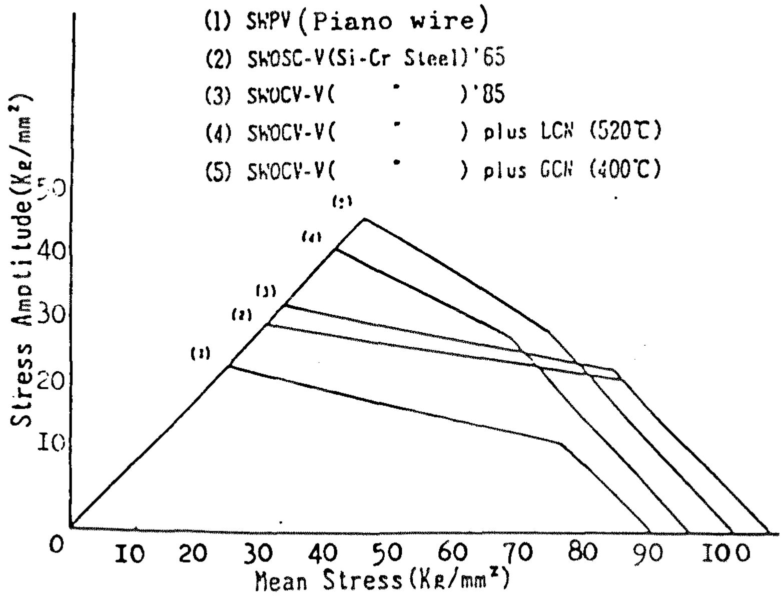


Fig. 5 Bending test of Tufftrided Cr-V steel.

Next let us discuss low temperature nitri-carburizing, which is one of the method of improving the durability of engine valve springs. Engine valve springs, which operate under high load at high temperature, are often made of silicon-chromium steel. The non-metallic inclusion in silicon-chromium steel produced by the modern methods contains little Al_2O_3; the non-metallic inclusion itself is highly ductile and rather insesitive to the notch effect. Consequently, it is an effective material in modern high-performance engines. When it is additionally low-temperature soft-nitrided at about 400℃ for 2 to 3 hours, there is no drop in core hardness. With the addition of shot peening, an effective compressive stress distribution is obtained, and consequently this is attracting much attention as a surface treatment for improving the durability of valve springs. Fig. 6 shows the durability of Japanese-made engine valve springs. It can be expected that surface treatments using nitrogen will continue to attract attention for application to automobile parts.

Fig. 6 Endurance Limit of Valve spring materials



2. CHANGES IN THE CHARACTERITICS OF CARBURIZED AND CHROME-PLATED AUTO PARTS CAUSED BY SHOT-PEENING

Today, many auto. parts, after being subjected to hardening processes such as quenching/ tempering or carburizing, are chrome-plated or otherwise surface-treated to improve their durability, wear-resistance and corrosion-resistance. To determine the possible effects of the shot-peening process on characteristics such as fatigue strength when it is applied to parts which are carburized and then hard chrome-plated, a series of tests was conducted. The following are the test results; (Fig. 7).

- When carburized hardened and chrom-plating are performed (case 3), a 20% loss in their fatigue strength will result as compared with parts which are carburized hardened but not shot-peening (case 1). When shot-peening and then chrome-plating of carburized hardened parts (case 4), or when shot-peening is done in the final manufacturing process (i.e., after chrome-plating)(case 5), the fatigue strength can be maintained at a level almost equivalent to what is obtained in case 1.
- When the parts are heated at 200℃ for 3 hours after chrome-plating (case 7), the hardness decreases to some extent, so fatigue strength and pitting resistance will decrease. However, when shot peeing is done before or after chrome-plating (case 4 or 5), it is possible to obtain parts having hardness, fatigue strength and pitting resistance well comparable with those resulting in case 1. These favorable results are considered to be attributable to the compressive residual stress due to shot-peening, which prevents crack propagation.
- When tufftriding is applied to carburized hardened (case 6), both corrosion resistance and wear resistance improve without any losses in fatigue strength, in comparison to case 1. Furthermore, even higher fatigue strength can be expected if a proper shot-peening is selected.

3. CONCLUSION

Use of shot-peening process is becoming increasingly popular not only in simple applications such as deburring or descaling but also in more positive ways such as

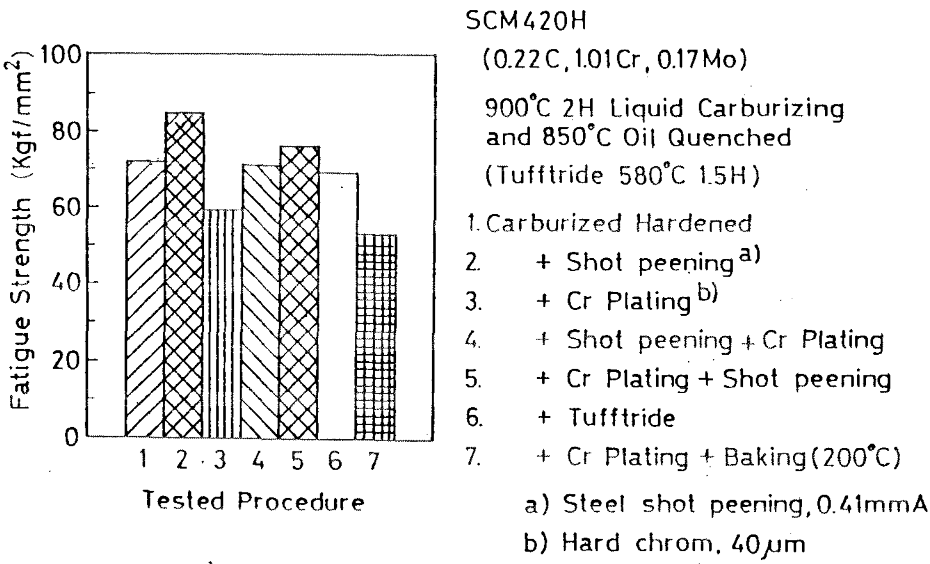
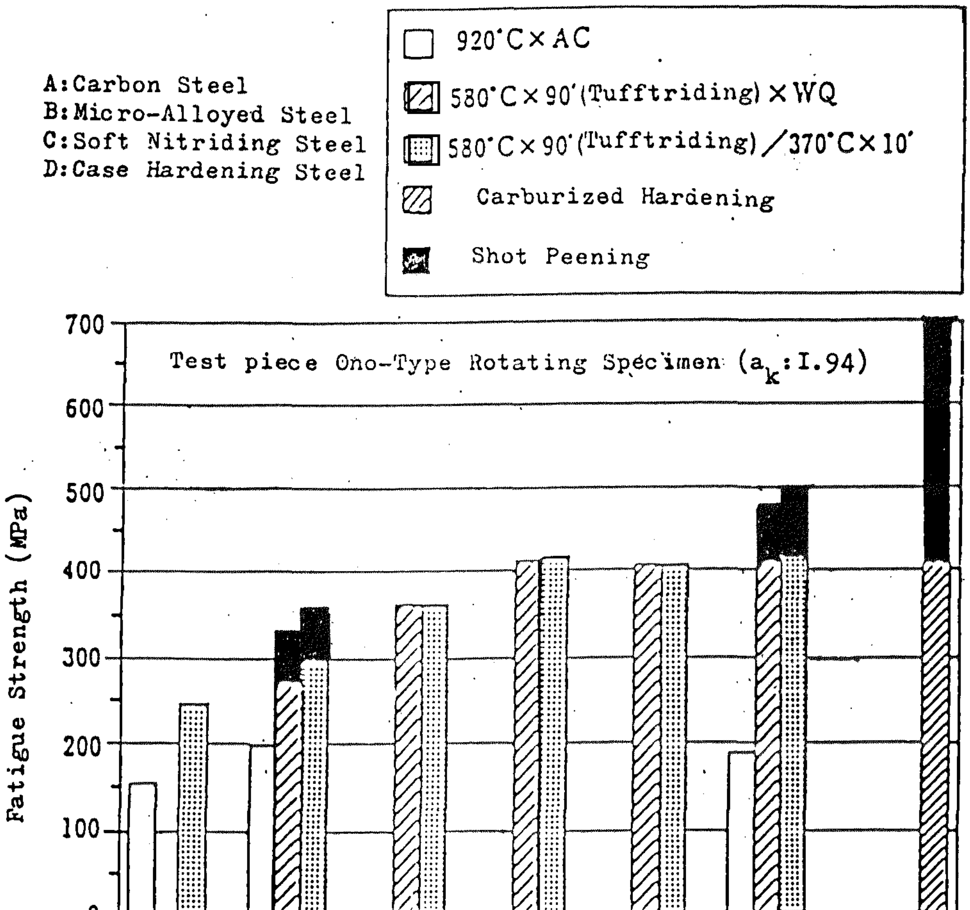


Fig. 7 The effect of shot peening on the fatigue strength of carburized and Cr plating (Rotating beam fatigue test $\alpha k=1$)

achieving higher strength of auto. parts by combining it with a low-temperature soft-nitriding. This trend is clearly evidenced by parts like engine valve springs.
In fact, there are many examples indicating that a carburized hardened gear will have increased fatigue strength when shot-peening, though shot peeinig is not discussed in detail here. Fig. 8 shows how the shot-peening process adds fatigue strength to carburized parts. As can be seen, the fatigue strength improves by 60% at maximum in the case of carburizing and by 15~20% in the case of soft-nitriding.
It must be noted that the soft-nitriding brings about improved seizure resistance and corrosion resistance in addition to improved fatigue strength. The process features the additional advantage of causing less distorsion than that inherent in heat treatment processes since it is specifically designed to be conducted at a low temperature.
Wider application opportunities for this particular process can be thus expected if the benefits of shot-peening are effectively combined with it.
Finally, the authors wish to thank the nemerous people who cooperated in providing the information that needed for this report.

Fig. 8 Comparison of Fatigue Strength



	A		B	C			D
C	0.21	0.48	0.37	0.23	0.28	0.26	0.15
Cr	—	—	—	1.00	0.50	0.68	0.95
Al	—	—	—	0.17	0.07	0.039	—
V	—	—	0.1	—	—	0.08	Mo 0.17

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