Combined Surface Treatment by Shot Peening and Power Brushing

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ABSTRACT

It has been found that a large improvement of fatigue strength of machine elements has been obtained by combined processing of both shot peening and power brushing than either processing alone, whereas power brushing alone has almost the same effect as shot peening, concerning the improvement of fatigue strength. On one hand, the authors have tried repeated plane bending fatigue test using specimens of Schenck type, so that the effects of combined processing may have been clarified, and maximum improvement of fatigue strength of 79% was obtained. The residual stress distribution in the direction of depth was, also, examined. On the other hand, provided that the shot peened surface layer were removed chemically by about the depth where the peak stress existed, the fatigue strength, furthermore, increased and showed 98.3% of improvement. However, such an improvement was not recognized in case of power brushing alone.

KEYWORDS

Shot peening; power brushing; fatigue strength; residual stress.

INTRODUCTION

The processing that cleans a surface of metal part by motor-driven brush is called power brushing, and is applied for descaling of hot rolled materials, deburring, etc. The materials of brush are extending from such a metal as carbon steel, stainless steel and brass wires to non-metal as artificial fibre. However, the mechanical effects of brushed parts, especially the improvement of fatigue strength which is almost equal to that of shot peening, are seemed not so much to be investigated. In this paper, the authors state various properties, especially an improvement of a fatigue strength by power brushing and a convenient effect of a combination of power brushing and shot peening.

SHOT PEENING

Test Pieces

The repeated plane bending fatigue test using specimens of Schenck type(Fig.2), of which the thickness is 3.0mm were done. The material is tool carbon steel No.5 (SK5) on the market and the chemical composition is shown in Table 1. The specimen is not heat treated according to a standard instruction, but the heat treatment consisted of 860°C/oil quenched and 400°C/70min/water cooled in succession. As a result, the surface roughness is intentionally made coarse, so that the effect of shot peening or power brushing may be seen more clearly. In the other test the same test pieces were used.

Table 1. Chemical composition of SK5

Element	C	Si	Mn	P	S
Wt%	0.79	0.25	0.41	0.017	0.008

Test results

Fatigue strength of shot peened specimens is shown in Table 2, where peening conditions are written. In Fig.3 are shown the S-N diagrams of un-peened and shot peened specimens. Except the case in which arc height is lower, an increase of fatigue strength of about 60% is obtained by shot peening.

Table 2. Fatigue strength and its improvement

Surface Treatment		Arc Height	Fatigue Stbength kgf/mm^2 (MPa)	Improvement %
As heat treated		—	28.5(279)	—
Shot peening Shot: SB5 (mean diameter 0.5mm) Peripheral speed of impeller 50m/s	Projected weight of shot, in g			
	2700	0.290mmA	45.5(446)	59.7
	700	0.200mmA	43.5(426)	52.6
Power brushing L=30mm, V=10m/s l=0.5mm, t=15min	d=0.5mm	0.053mmN	45.5(446)	59.7
	d=0.7mm	0.058mmN	40.0(392)	40.4

POWER BRUSHING

Apparatus of Power Brushing

Many stainless steel wires were bundled in radial direction in a disc form, and this element was named "disc brush". A disc brush is driven by a motor and finishes a surface of a specimen The apparatus designed and made for this experiment is shown in Fig.1. It shows power brushing processing pf a specimen. A specimen is held on a moving device which reciprocates both in vertical and horizontal directions simultaneously by two motors and is brushed uniformly all over the surface by rotating disc brush. The diameter of the disc brush is 160mm and the peripheral speed is 5m/sec~10m/sec.

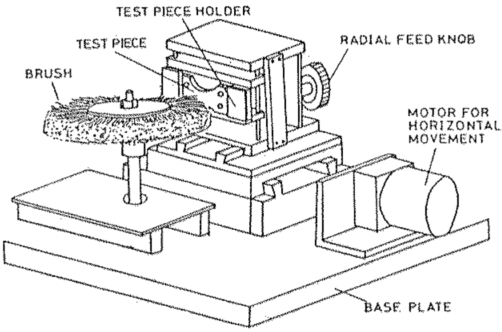

Fig.1 Schematic representation of power brushing apparatus

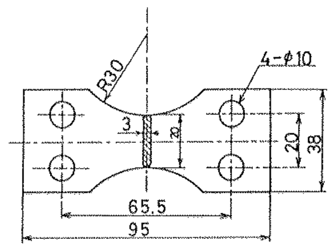

Fig.2 Dimensions of fatigue test specimen of Schenck type

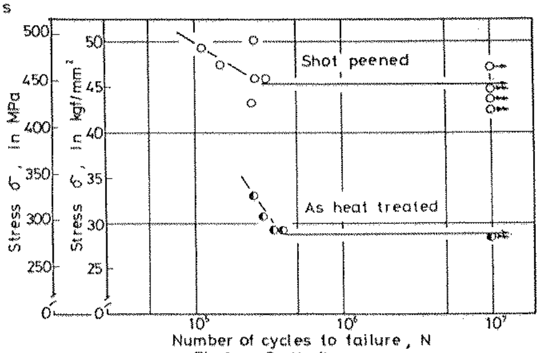

Fig 3 S-N diagram
Shot peened
Shot : SB 5, (mean diameter 0.5 mm)
Projected weight of shot : 2700 g
Peripheral speed of impeller : 50 m/sec

Table 3. Surface roughness of X- and Y-direction

Surface Treatment		Rmax μm X	Rmax μm Y	Rz μm X	Rz μm Y	Ra μm X	Ra μm Y
Shot peening	Shot peened all over	22.9	20.1	21.3	17.3	3.79	3.63
	not peened part, 15 mm width	21.8	21.8	18.2	18.9	3.34	3.59
Power brushing	Brushed all over	8.30	9.06	7.30	7.50	1.86	1.91
	Power brushing after shot peening	7.86	7.80	6.24	6.65	1.69	1.68
	Power brushing of not peened part	13.3	14.0	11.0	11.0	1.82	1.78

Surface Roughness

In Table 3 is shown the surface roughness of a specimen after shot peening or power brushing, where x- and y-directions correspond respectively to longitudinal and transverse ones of the specimen. It is noticed that although a change of a surface roughness of a specimen was hardly seen between before and after shot peening, it was fairly improved in case of power brushing and the roughness of a brushing direction was finer than that of a perpendicular one to the former.

Improvement of Fatigue Strength by Power Brushing

In Fig.4 are, also, shown results of fatigue test that were obtained with brushed specimens under the optimum wire brushing condition which was presumed based on experience up to the present, among the ones shown in Table 4. The touch and approach distance in the Table 4 means the length that the disc brush is forced to meve so as to press against the specimen, after the periphery of the disc brush touches. From Fig.4, it can be seen that a processing of power brushing alone, also, has the same extent of improvement as shot peening.

Table 4. Conditions of power brushing

Material of wire, M	Stainless steel	
Diameter of wire, d mm	0.5	0.7
Length of wire, L mm	30	
Peripheral speed, V m/s	10	
Touch and approach distance, l mm	0.5	
Duration time of brushing, t min	5	

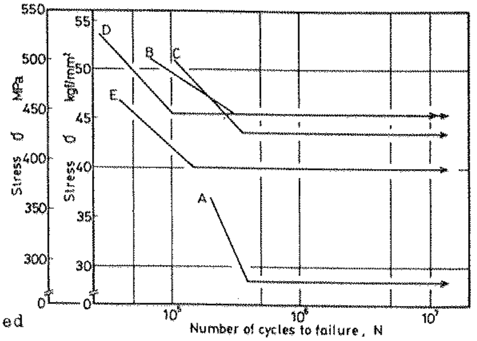

Fig.4 S-N diagrams of specimens variously treated

A: As heat treated
B: Shot peened
Shot: SB5
Peripheral speed of impeller: 50m/sec
Projected weight of shot: 2700g
C: Shot peened
Shot: SB5
Peripheral speed of impeller: 50m/sec
Projected weight of shot: 700g
D: Power brushed
d=0.5mm, L=30mm, V=10m/sec,
l=0.5mm, t=15min
E; Power brushed
d=0.7mm, L=30mm, V=10m/sec,
l=0.5mm, t=15min
Note: The plots are omitted to avoid confusion due to scattering.

Table 5. Fatigue Strength and its improvement (Combined Processing of shot peening and power brushing)

No. of experiment	Projected weight of shot, in g	Diameter of wire d mm	Length of wire L mm	Peripheral speed V m/s	Fatigue Strength kgf/mm² (MPa)	Improvement %
1	2700	0.5	30	10	50 (490)	75.4
2	2700	0.5	10	5	51 (500)	79.0
3	2700	0.3	30	5	49 (480)	71.9
4	2700	0.3	10	10	49 (480)	71.9
5	700	0.5	30	5	48.5(475)	70.2
6	700	0.5	10	10	49.5(485)	73.7
7	700	0.3	30	10	48.5(475)	70.2
8	700	0.3	10	5	46 (451)	61.4
As heat treated					28.5(279)	—

Note: 1. Shot peening: SB5, 50m/s Power brushing: l=0.5mm, t=15min
2. Arranged with orthogonal array L_8

Test Results

It would be expected larger improvement of fatigue strength by power brushing in addition after shot peening. Then, they have tried experiments to know the effects of combined processing. As are known in Table 5, the projected weight of shot is considered for an experimental factor of shot peening, and the other three factors, that are wire diameter d, length of wire L and peripheral speed V were adopted in regard to power brushing. The number of level of each factor was all two. Furthermore, the orthogonal array L_8 was used for design of experiments to investigate the effect of combinations of three factors. In the same Table are shown the fatigue strength of each test and the rate of improvement of fatigue strength based on the one of the specimen which was only heat treated and not shot peened. Although the significant difference was not found from these results, wire diameter was presumed the most important factor that influences on the fatigue strength, together with the projected weight of shot. Particularly, it is remarkable that the rate of improvement is 79.0% in case of experiment 2.

Residual Stress Distribution

Since the fact that the same extent of improvement of fatigue strength by power brushing alone as shot peening, as stated above, was inferred from a residual stress caused by the processing, its distribution was measured by X-ray diffraction and shown in Fig.5, as (a). Examples of a distribution of residual stress (b) caused by shot peening alone, and (c) by combined processing are, also, shown in the same Figure. Comparing these two results, (a) and (b), with each other, it is noticed that, although both residual stresses are similarly compressive, the absolute value of maximum peak stress is lower than that of shot peening. The fact that the improvement of fatigue strength is nevertheless the same extent, is supposed to be due to the favorable effect of residual compressive stress and, besides, the reformation of surface roughness by power brushing. Furthermore, it is recognized that the shape of distribution (c) shown in the same Figure, which is in case of combined processing of both ones, is supposed as if the distribution of each case, (a) and (b), were superposed, and the absolute value of the stress in the neighbourhood of surface was raised and the position of peak stress was shifted to the free surface. This was supposed as

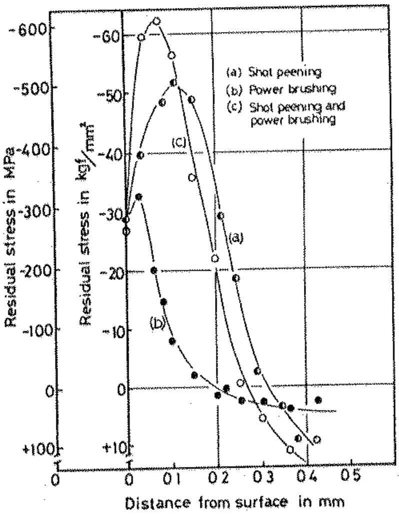

Fig. 5 Distribution of residual stress caused by various surface treatment

the cause, together with the improvement of surface roughness, for greater effect of im&rovement of fatigue strength.

CHEMICAL MILLING

In order to investigate how the fatigue strength of steel parts varies, when the thin surface layer of shot peened or power brushed part is chemically eroded little by little, fatigue tests were done with four sorts of specimens, the surface layer of which were respectively removed with an etching solution (ethyl alcohol 90%, nitric acid 10%) by depth of 0.05, 0.1, 0.2 and 0.3mm, after surface treated under the conditions which are shown in Table 6. The test results are shown in Figs.6 and 7 by means of S-N diagram. Furthermore, Fig.8 shows a relation between fatigue strength and depth of erosion. As is seen in Fig.8, although the fatigue strength of both the shot peened and power brushed specimens is the same and 45.5kgf/mm^2(446MPa), the behaviour of a change of fatigue strength after chemical milling is entirely different from each other. On one hand, in case of shot peening, as the depth of erosion increases, the fatigue strength also rises, until the maximum value of 56.5kgf/mm^2(554MPa) is obtained when the depth of erosion is about 0.1 mm, hereabout the peak stress exists. The percentage of improvement in this case is remarkable and 98.3% as compared with as heat treated specimen. Thereafter, it falls off monotonically to about 40kgf/mm^2(392MPa). On the other hand, in case of power brushing, such an increase of fatigue strength as in case of shot peening does not occur, and on the contrary, it falls off suddenly to about the same value of 40kgf/mm^2(392MPa) as the surface layer is removed. It may presumed that the difference of the behaviour is due to the residual stress in the surface layer.

SUMMARY

In order to investigate the effect of shot peening and power brushing, repeated plane bending fatigue tests were done, using specimens of Schenck type, of which the material were tool carbon steel No.5 (SK5) and heat treated. The summary is as follows:

(1) The roughness produced by power brushing was fairly improved, and that obtained by power brushing after shot peening was still more improved, while that obtained by shot peening alone was almost the same as the heat treated ones, probably because of initially produced coarse surface roughness.
(2) The effects of both shot peening and power brushing on improvement of fatigue strength were equivalent and it was 59.7% as compared with specimens as heat treated.
(3) By power brushing the shot peened specimens, the greater improvement of fatigue strength has been obtained and it approached to 79.0% as compared with un-peened ones.
(4) In case of combined processing of both shot peening and power brushing, the shape of residual stress distribution is supposed as if the distribution curve of each ones were super-

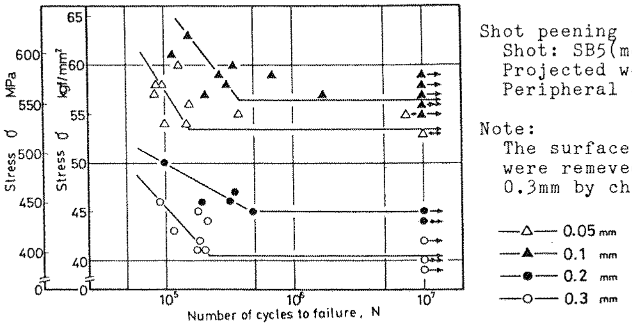

Fig. 6 S-N diagram

Shot peening
Shot: SB5(mean diameter 0.5mm)
Projected weight of shot: 2700g
Peripheral speed of impeller: 50m/sec

Note:
The surface layer of the specimens were remeved by 0.05, 0.1, 0.2 and 0.3mm by chemical milling

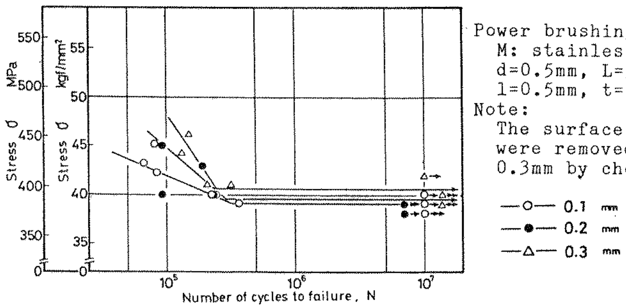

Fig. 7 S-N diagram

Power brushing
M: stainless steel
d=0.5mm, L=30mm, V=10m/sec,
l=0.5mm, t=15min

Note:
The surface layer of the specimens were removed by 0.05, 0.1, 0/2 and 0.3mm by chemical milling

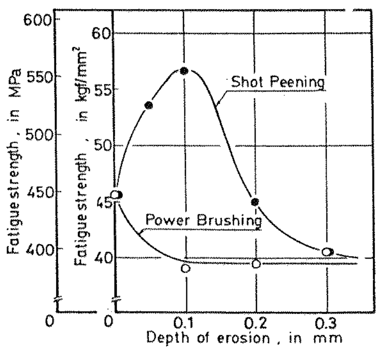

Fig. 8 Fatigue strength *vs* depth of erosion

Shot peening
Shot: SB5
Projected weight of shot: 2700g
Peripheral speed of impeller: 50m/sec

Power brushing
M: stainless steel
d=0.5mm, L=30mm, V=10m/sec
l=0.5mm, t=15min

Table 6. Conditions of surface treatment

Shot peening	Shot (mean diameter) Peripheral speed of impeller Projected weight of shot	SB5 (0.5mm) 50m/s 2700 g
Power brushing	Material of wire, M Diameter of wire, d mm Length of wire, L mm Peripheral speed, V m/s Touch and approach distance, l mm Duration time of brushing, t min	Stainless steel 0.5 30 10 0.5 15

posed, and the absolute value directly underneath the surface layer is raised and the position of peak stress is shifted to the vicinity of free surface.

(5) Provided that the shot peened surface layer were removed chemically by about the depth where the peak stress existed, the fatigue strength, furthermore, increased and showed 98.3% of improvement. However, such an improvement was not recognized in case of power brushing alone.

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