ENVIRONMENT SURROUNDING THE SHOT PEENING TECHNOLOGY IN JAPAN

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1. Why Was Shot Peening Technology Not Used Extensively?

The practical use of shot peening (hereafter referred to as S. P.) technology to strengthen metals has been used since around 1920. Many research reports were already published around 1940 according to reference. .In Japan, however, it is understood for the present that S. P. is effective, but S. P. application is not accerelated positively except S. P. to springs as a present situation. There are, of course, some companies which have had bright achievements over the last 20 years.

Reasons that S. P. technology is not used as extensively in Japan as in foreign countries are :

(1) Since S. P. effects are not expressed quantitatively and universally, its application is limited to counter plans coping with claims before design alteration.

(2) S. P. effects are not designed to be included at a designing stage. (Designers can not use S. P. as a design tool.)

(3) The effect of shot peened parts (i. e. an evaluation method) has not yet been sufficiently achieved.

(4) Factors affecting the reliability of shot peened parts are not fully grasped so that the quality guarrantee has been doubtful.

Recently, these disadvantages are being improved upon remarkably, resulting in an increased tendency to reconsider S.P.

2. Improvement of Shot Peening Facilities

The outline of S.P. theory is to process physically near the metal surface of target materials by throughput to particles on the surface of target materials for the quality improvement of the metal surface. As a result, hardness of the surface of target materials is increased and compressive residual stress is applied near the surface. These effects are the main factors of material strengthening.

Accordingly, S.P. equipment must effectively satisfy the above mentioned factors without fluctuation and with sufficient durability as a machine.

Fig. 1 shows the outline of the most extensively used impeller type shot peening equipment. A target piece placed on a turn table is rotated by a motor designed to prevent the dispersion in a circumferential direction. The impeller rotates about 70 m/min throughputting shot particles by centrifugal force. Providing that the distance from the center of the turn table to the radius direction is the X axis and that to the vertical direction is the Y axis, the strength of shot particles at the cross section shown in Fig. 1 was examined. Fig. 2 shows the result, in which arc height levels are largely fluctuated by each value of

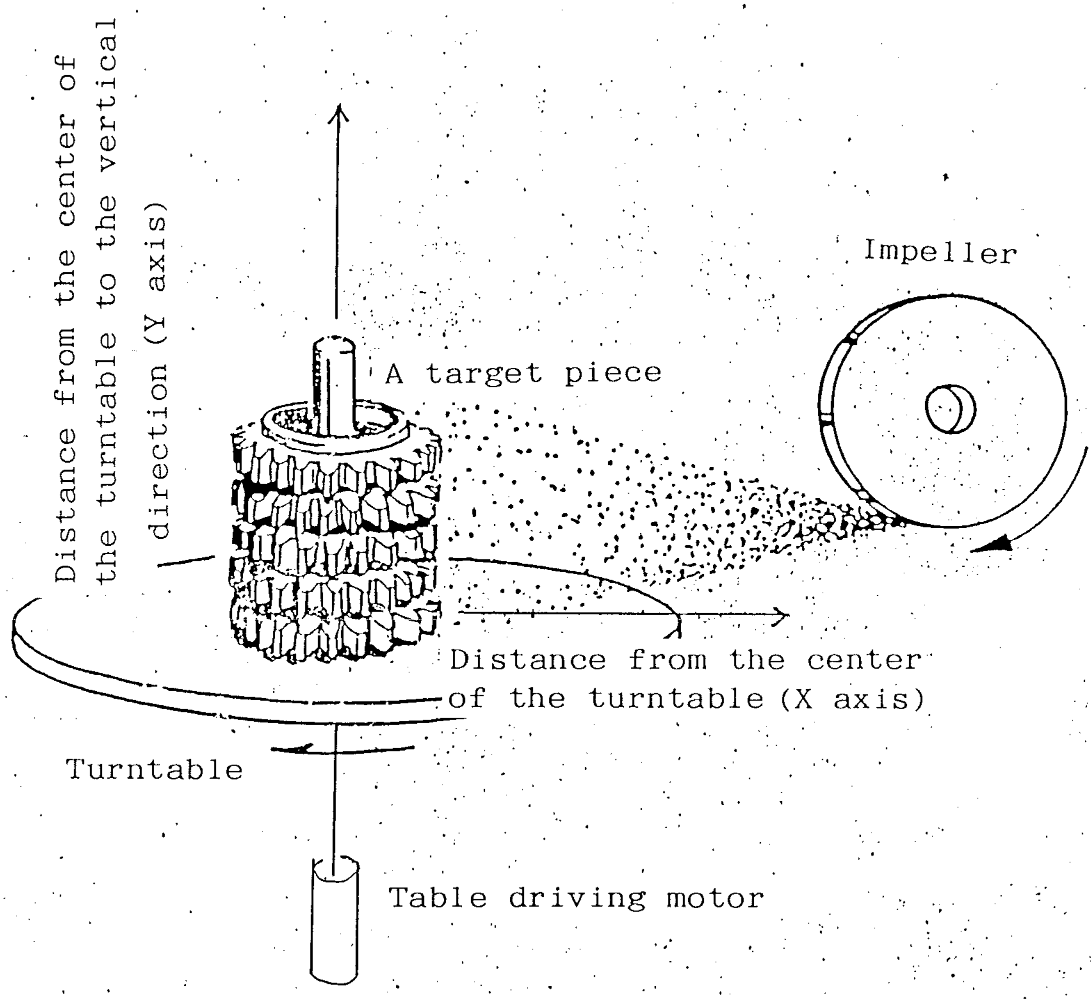

Fig. 1 : Outline of impeller type S.P. equipment

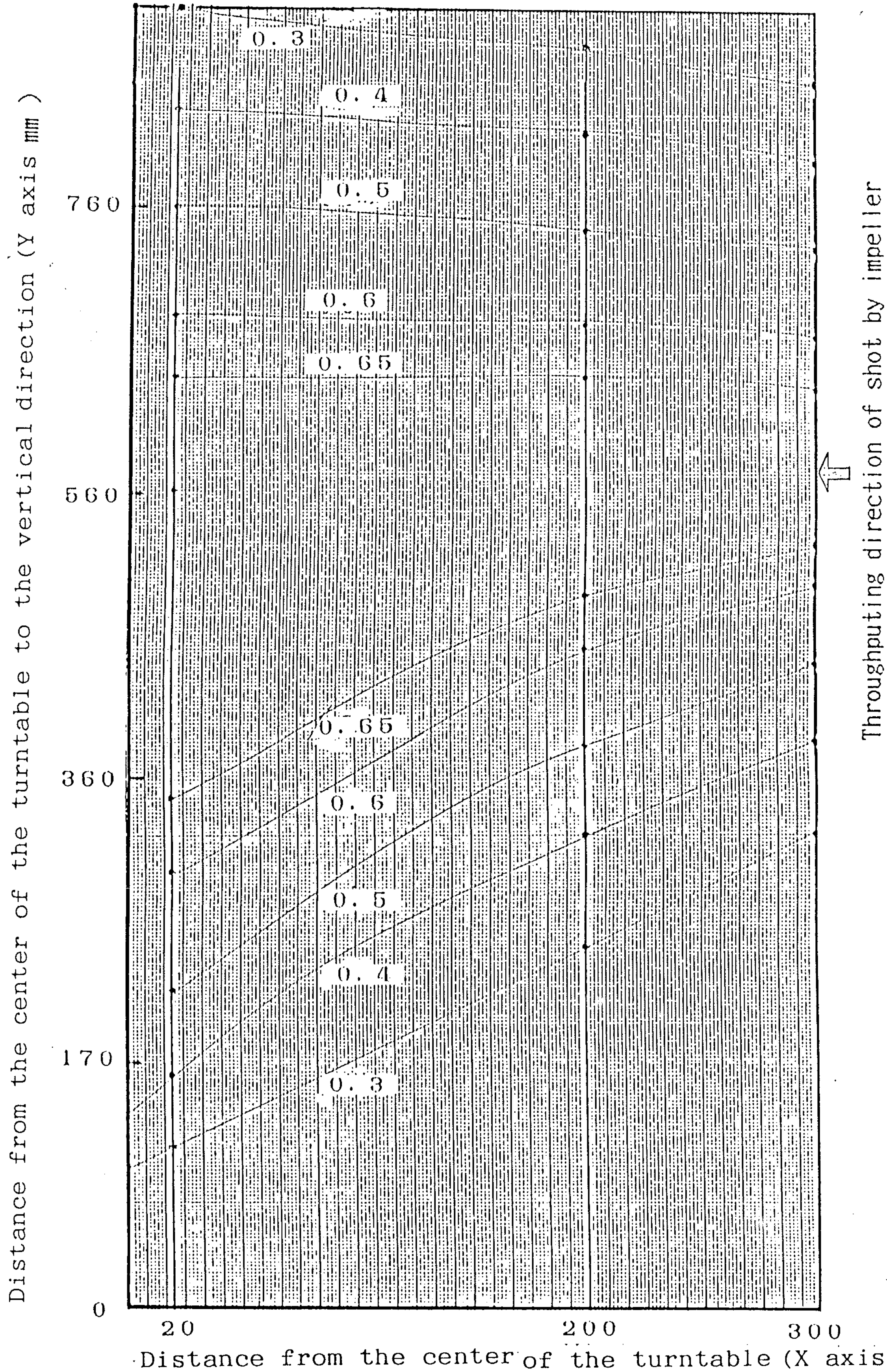

Fig.2 Arc hight contour-line at various position surrounded between X axis and Y axis.
Condition : Used steel with 0.8 mm diameter shot and "A" strip Almen gauge. Velocity of shot is 68m/sec,throughputing weight and time is 100Kg/min and 4 min respectively.

various positions surrounded by the X and Y axes.
(The fluctuations may be one of the causes for the lack of reliability of S.P. effects.)

Such equipment may be suitable for wide quality requirements which include low arc height levels and no limit for the highest level. However, provided that an arc height level is required to have an upper limit or must be high, a piece of work must be placed at an extremely limited position causing inconvenience.

Fig. 3 is the outline of S.P. equipment designed to improve on such inconvenience called direct pressure-nozzle type. In this equipment, shot particles are packed in a tank and jetted instantaneously from a nozzle by applying pressure to the tank with air.

Merits of this equipment are (1) the throughput speed of shots can be controlled freely by pressure. Intensive S.P. is possible because the speed nearly twice that of the impeller type is easily obtained and (2) control of the motion of the nozzle permits S.P. at the desired position on a target piece. The motion of the target piece and the nozzle can, of course, be interlocked.[1]

In a word, S.P. is progressing from the method of piecework payment in which shots were simply throughput onto target materials to a controlled method. A problem of this method is that each nozzle and target piece must have the

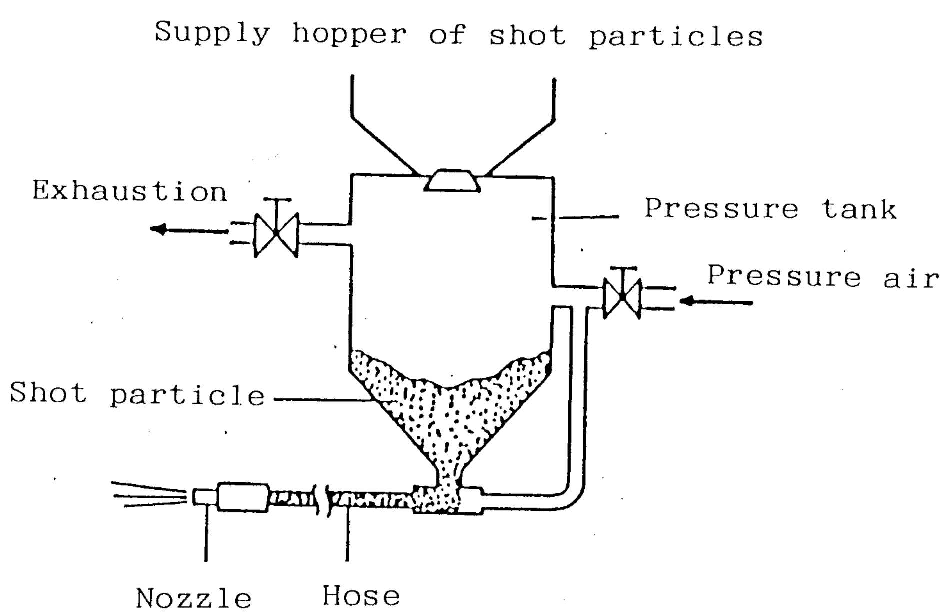

Fig. 3 : Outline of direct pressure-nozzle type
S. P. equipment

function of rotation or alternating motion. Accordingly, its structure tends to be more complicated than that of the impeller type and includes more working parts, with some parts remaining to be improved for durability and maintenance of the machine.

3. Effect of new shot peening

S. P. effects are various; this article includes the improvement of fatigue strengh for carburizing quenched parts such as gears and shafts.

(1) Fatigue strengh of carburizing quenched parts

1) Change in surface hardness

There are many factors which influence fatigue strengh of the tooth root of gears and bending fatigue strengh of shafts. Hardness, which influences fatigue strengh, is compared before and after S. P. in this article.

Table 1 shows changes in surface hardness before and after S. P. for gears and shafts carburizing quenched by various methods. It shows that S. P. increased the surface hardness. It can be easily imagined that S. P. produces good effects on failure of the gear surface as well as the tooth root of gears.

As is well-known, the relationship between hardness and fatigue strengh is generally quantitized and applied to a design. It is understood from this table that the

Table.1 Change in surface hardeness before and after S.P. by various S.P. and carburizing methode.

carburizing mode	Carburizing steel by JIS	Hardness before peening	Hardness after peening (I)	(II) ※
Conventional carburizing (small retained austenite)	SNCM420 SCM420	(Hv)680 ~760	Hardness increase (Hv) 60 ~ 120	
Special carburizing (large retained austenite)	SNCM420 SCM420	350 ~660	Hardness increase (Hv) 220 ~ 300	

Note: (I)S.P. by the impeller type (V=70m/sec)
(II)S.P. by the direct pressure-nozzle type (V=over 100m/sec)
※The effect of inter granular oxidation is large in a hardeness increase.

combination of heat treatment and S. P. methods changes remarkablely the surface hardness, suggesting that case hardening steel suitable for S. P. can be expected to appear.

2) Effect of the application of residual stress

Compressive residual stress improves fatigue strengh for many quenched parts; this is also a well-known fact.

In general, fatigue strengh (σw) of quenched material is shown by fatigue strengh (σw_o) determined by the hardness of material and residual stress (σr) in the following equation.

$$\sigma w = \sigma w_o - m\sigma r$$

(m : Coefficient of mean stress)

In this equation, if σr is a compressive value, σw is shown by ($\sigma w_o + m\sigma r$), resulting in increase. If σr is a tensile value, σw is shown by ($\sigma w_o - m\sigma r$), resulting in decrease. S. P. treatment is effective as a means of increasing compressive residual stress.

The layer of intergranular oxidation produced at a carburized part deteriorates hardenability near the surface and tends to form troostite structure. As a result, the residual stress value becomes (+) several Kg/mm^2. Under such conditions, the application of S. P. improves the residual stress value to -60 to -80 Kg/mm^2. Therefore, S. P. is useful as a counterplan against the inconvenient formation of intergranular oxidation.

A further increase in compressive residual stress was examined recently through the improvement of S. P. facilities by Kojima et al. [2] [3]

Fig. 4 is the distribution curve of residual stress, when S. P. was applied under various conditions to the test strip of 30mm¢ x 300mm on which SCM 420 was carbulized 1 mm. where

A : Only heat treatment, which is quenching and tempering, was applied. The residual stress value at the surface is + 30Kg/mm^2 and that at 20 μm from the surface is the maximum -35 Kg/mm^2.

B : In addition to A, S. P. treatment by the conventional impeller type was applied.

C : Same as B, but controlling time and shot size. The curve, which shifted to the inner direction residual stress, showed the maximum -70 to -80 Kg/mm^2.

Using a newly improved pressure type nozzle method, D ~ G curves can be arbitralily obtained by controlling shot particles by type, size and speed. In other words, S. P. is now at the stage not of simple throughput of shot particles against target materials, but of controlled peening to satisfy the distribution of required compressive residual stress. This is permitted by progress in both aspects of software and hardware.

Fig. 5 shows the results of a rotational bending test

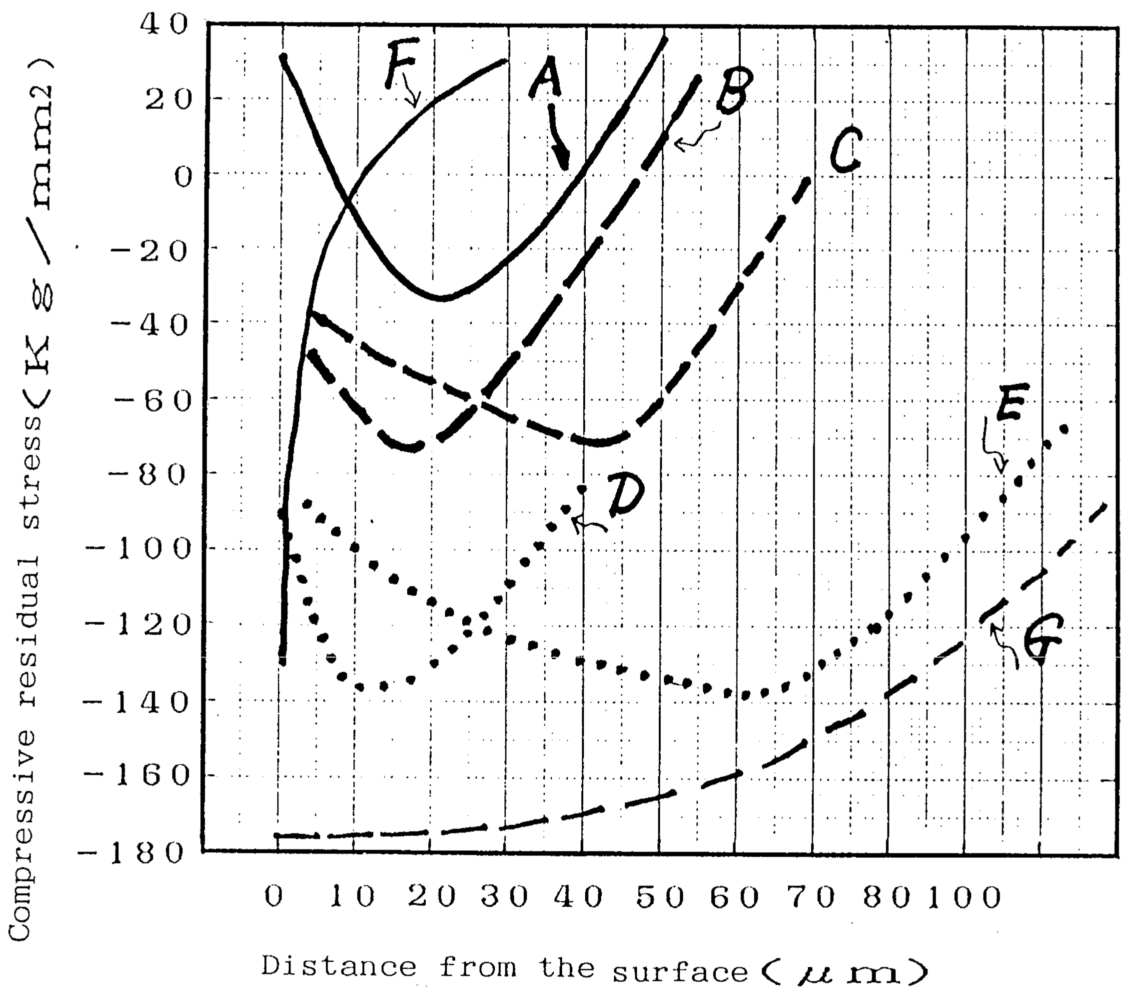

Fig. 4 : Distribution of residual stress at the cross section of various parts after applying the treatment of carburizing quenching and tempering only or followed by S. P.

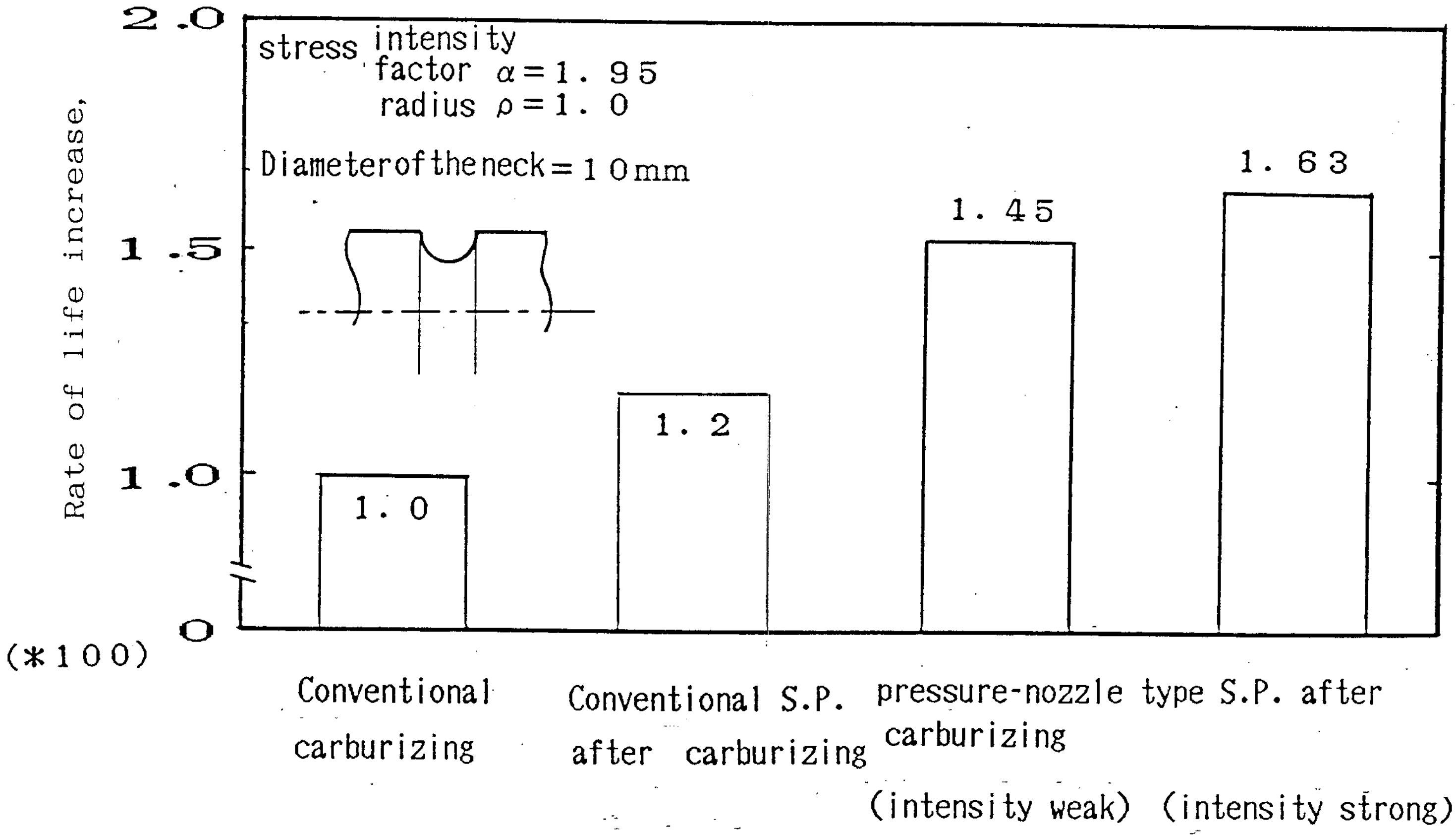

Fig. 5 : Result of rotational bending fatigue test by the Ono-method for shot peened materials

for the following heat treated and shot peened materials. It can be seen from the table that fatigue strength is remarkably improved upon by the new type nozzle method compared to the conventional impeller method.

4. Evaluation method of S.P. items

General evaluation methods are arc height and coverage determination by the Almen gauge. Assuming that time required to saturate an arc height value is nearly 100% for coverage determination, the application of S.P. for two or three times as long is called coverage 200 % or 300 % respectively. Therefore, coverage 300 % or arc height 0.45 mm AC2 is written in a S.P. blueprint. (A : A test strip of the Almen gauge, C2 : rules of bending determination by S.P. of the Almen gauge, mm : millimeter. Be careful of foreign blueprints which may use inches.)

Fig. 6 shows the relationship between S.P. time and arc height value. In curve A, time T is required to obtain coverage 100 % (= 98 %). Curve B shows the relationship between S.P. time and arc height value when shot particle sizes are varied.

Shot particles are worn out or crushed during operation and characteristics like Curve B are shown. The reasons of designating coverage 300 % on a S.P. plan are that arc height values are varied by position levels as shown in

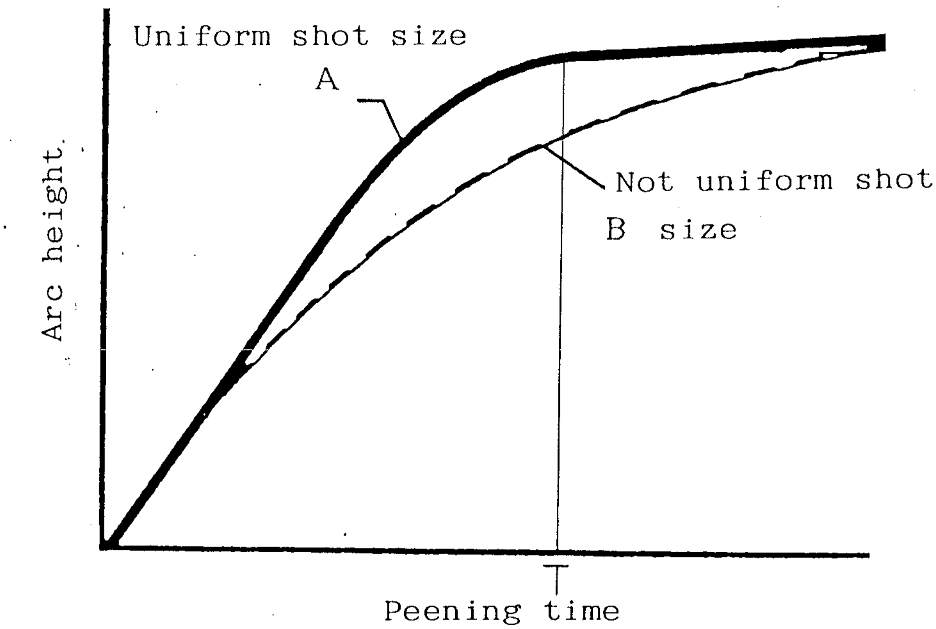

Fig. 6 : Effect of peening time on arc height values

Fig. 2 and arc height values are also fluctuated by change in shot size due to crush and wear. In short, it is presumed that because the contribution rate of these factors was not fully quantified, coverage is simply designated as 200 % or 300 % for safety.

When the relationship between arc height value and coverage was examined by varing S. P. time, the point where an arc height value is saturated is not always coverage 100 % (data are omitted). Instead, coverage reached nearly 100 % before the arc height value was saturated. It may be adequate that coverage was not shown by the above-mentioned concept, but by throughput per area of target material.

On the other hand, the three levels of an arc height value are standard depending on the Almen strip used. This is easy to handle and convenient for an operation check. However, it has not yet been established for mass production basis, although some means for determining an arc height value at a necessary position or change in compressive residual stress level real time during operation are being examined.[4] At this moment, a check at each operational step, the so-called process guarrantee and confirmation by determining residual stress with the use of X-ray by final sampling are considered to be the most reliable method.

The excess throughput energy of shots for target materials, the so-called over peening phenomenon, is one of the significant evaluation factors for the effect. Picture 1 is the SEM photograph of the front on which 500 g of 0.8 mm ϕ steel balls were peened per second at the speed of about 100 m/sec to S45C material prepared to HB178. Obviously, the surface is crushed to be damaged. This is one of the examples in which S.P. treating conditions are not matched with a material type, its heat treatment state and quality requirements.

5. S.P. technology in the future

Research activities aimed at strengthening of materials have been continued at all times and in many countries. S.P. technology is now reconsidered as one of the tools. Particularly, it is often applied to strenghten the tooth root of automobile gears and the gears and shafts of construction machineries used under severe conditions. It resulted in large contributions to the production of compact, lightweight and long life machines.

Looking at the history of S.P. progress, the first generation is the age in which hitting the metal surface with the tip of a hammer (means peening) was recognized as strengthening .

The age in which the theory was applied industrially (i.e. shots are simply throughput to target materials with a machine) is called the second generation, which, it seems,

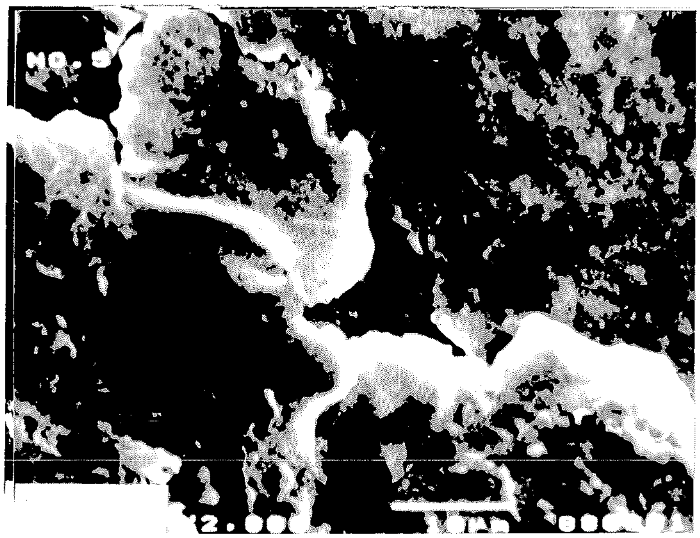

Photo.1 SEM image of the test piece of the S45C JIS material quenched and temperd to the HB178 after following shot peened by nozzle type.

took very long.

The third generation is the age of not only throughputting shots as in the second generation as mentioned above, but controlling to apply necessary hardness and compressive residual stress (including the direction of depth) at a position required.

The fourth generation is more refined than the third generation; in a hardware aspect, it is completely controlled S. P. equipment. And a highly reliable instrument with simple operation will be developed together. In a software aspect, it will be the age of using S. P. effects fully as a design tool. We expect the arrival of the age in which controlled peening is generally applied continuously after heat treatment to normal quenched and tempered materials (including tool steel) as well as carburizing quenched and tempered materials used as a strengthening member.

6. References

(1) Y. Furuta : Patent Application, No. 63-52341

(2) Y. Kojima et al. : Matsuda Technical Review, (1987) No. 5, P. 165

(3) Y. Kojima et al. : Automobile Technology, 42 (1988) No. 6, P. 755

(4) T. Naito : Patent Application Open No. 63-267164