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Shot Peening and Coverage

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1 Introduction

As for the processing conditions of shot peening, there are the amount of shot, shot size, arc height, coverage, etc. However, when remarking to the coverage, no systematical study concerned with the relationship with the fatigue strength, can be seen. It would not be also certain that the over peening where fatigue strength will reduce if processing time is too long, exists[1]. It can be said that it is not clear about whether the optimum conditions between the coverage and fatigue strength can be decided. However, it is difficult to specify the value of coverage because the measuring method of coverage is not designated. Therefore, it is difficult to discuss the relationship between the coverage and fatigue strength.

In this paper, the following studies to specify the value of coverage were made:

[1] experimentally obtain the relationship between the diameter of dent formed by shot peening, shot size, the shot movement energy (shot speed and shot weight) and the hardness of peened work, and express the experimental results to the formula by multiple regression analysis.

[2] it was shown that the coverage can be simulated by the Monte Carlo method. (3) in order to study over peening phenomenon, the fatigue tests with the coverage of 36 %, 98 % and 1000 %, were carried out. It was realized that there were no fatigue strength reduction with 1000 % coverage.

2 Experimental Procedures

2.1 Formulation of Dent Diameter

2.1.1 Shot Peening Machine

The shot peening machine employed here is a type of impeller. The diameter of impeller is ö350mm, and the shot peening machine is for experimental studies. Fig.1 shows point A where the direction of an impeller-tangent be coincident with the base. In order to obtain the maximum arc height at the point A, the control gauge was adjusted. Therefore, it can be expected that the most shots are perpendicularly applied in the point A. To make the sample for measurement of dent diameter and the sample for fatigue tests, the all shot peening processes were carried out under the point A.

2.1.2 The Specimen for Dent Diameter Measurement

The specimen for dent diameter measurement was taken as a width of 19mm, a length of 71mm, and 5mm of thickness. The material used was SUP 10(JIS G 4801), and the hardness of specimen was 666 HV, 505 HV, and 438 HV, prepared by quenching and tempering. In order to remove decarburized layer of both sides, 0.2 mm was removed by wrapping processing, to have mirror finished surface.

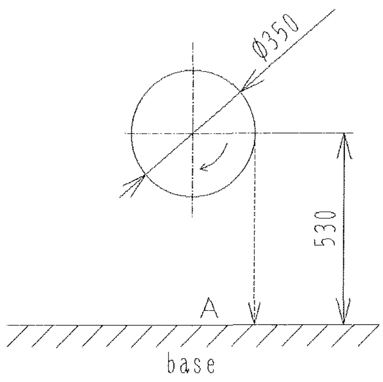

Figure 1: Shot peening position

2.1.3 Steel Shot

The shot used was the round cut wire of hardness 680 HV. The shot size is ∅1.2 mm, ∅1.0 mm, ∅0.77 mm, and ∅0.4 mm, and was carefully sieved. Consequently, the average weight of 50 shots, M was 9.92 mg, 5.80 mg, 2.58 mg and 0.37 mg, respectively.

2.1.4 Shot Peening Conditions

The shot peening conditions are shown in Table 1. The shot speed, V can be calculated by, $V = 1.3\ 2\pi\ (ID/2)\ IRPM/60$, where the circumferential speed of impeller (mm/sec) calculated from the diameter of impeller, ID = 350 mm, and the number of impeller revolutions per minute, IRPM, be multiplied by 1.3 times[2)].

2.1.5 Measurements of Dent Diameter

The measurements of dent diameter were carried out by the 23 times magnifying glass. Since the dent was not a true circle, it was assumed as an ellipse. The dent diameter was decides by the geometric average of the long and short axis.

2.2 Measurements of Surface Roughness

The measurements of surface roughness were carried out about the specimens of coverage 100%.

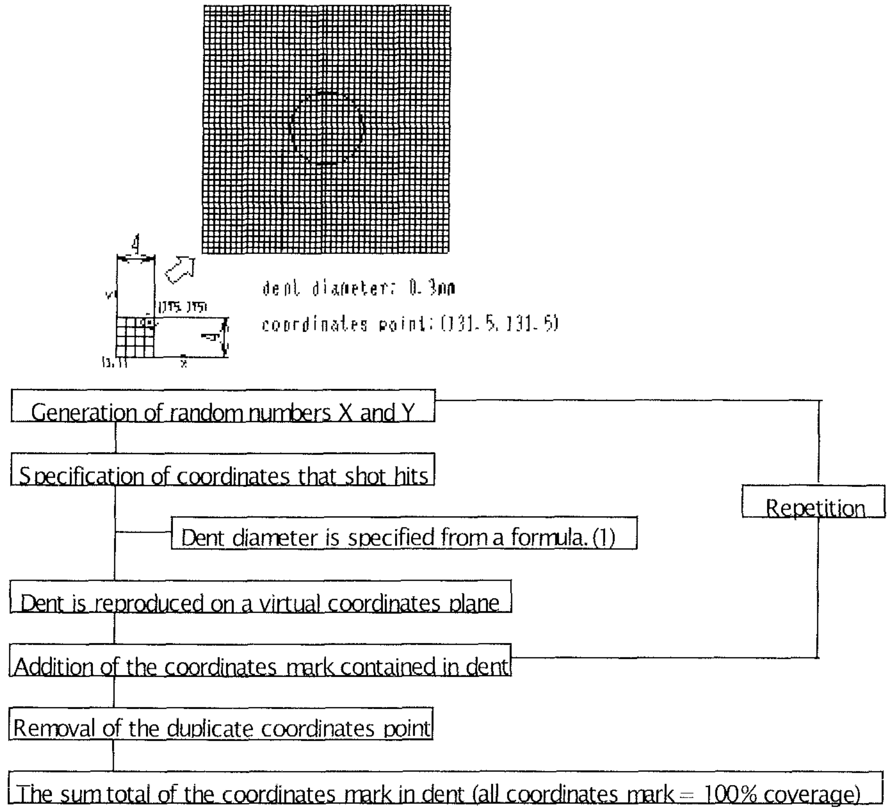

Figure 2: Simulation method of coverage

2.3 Simulation Method of Coverage

The simulation of coverage showed Fig. 2 was carried out about the following procedures by using personal computer. It was presupposed that the 4 × 4 mm real plane corresponds to the virtual coordinates plane that consists of 175 × 175 points. A coordinates point has from (1, 1) to (175, 175), and the point has 175 × 175 = 30625 point in the area of 4 × 4 = 16 mm^2. In order to specify a random coordinates point as if rain falls on this coordinates plane, it was simultaneously generated two different random number from 0 to 1 in the direction of X and Y, and the generated random number is assigned to the division into equal parts from 1 to 175. Next, the circle of the size equivalent to dent diameter applied by the actual shot, is placed focusing on the coordinates specified with two previous random numbers. The number of all the coordinates points included in a circle here is integrated, and if it compares with all coordinates, the coverage of one dent will be calculated. According to the definition of coverage, the coverage when applied many dents must avoid the duplicated integration of the overlap part of dent.

2.4 Relationship Between Coverage and Fatigue Strength

The fatigue test is a cantilever rotary bending fatigue test. The hardness of specimen is 530 HV. The shot peening conditions are, shot diameter 1.0mm, and impeller revolutions number 3500 rpm. The specimen self-rotates by 60 rpm under the point A of the Fig. 1. The coverage was adjusted by changing shot application time as 3, 36 and 360 sec.

3 Experimental Results and Discussions

3.1 Formulation of Dent Diameter, *C*

Generally, the dent diameter tends to increase in proportion with increasing shot speed and shot weight. The dent diameter also tends to increase in proportion with decreasing the hardness (HVW) of material applied. Therefore, the dent diameter, C, was formulated like equation (1), where ρ is density.

$$C = a_1 (M V^2)^{1/3} HVW^{-1/3} + a_2 (M/HVW)^{1/2} + a_3 (3M/4\pi/\rho)^{1/3} + a_4 \quad (1)$$

with $a_1 = 0.074$, $a_2 = 726.728$, $a_3 = 0.049$, $a_4 = 0.011$, C: dent diameter (mm), M: weight(kg), V: speed (mm/s), HVW : vickers hardness, π: the circular constant, ρ: density (g/mm^3)

The 1st clause is based on the assumption that the volume of dent and deformation resistance (hardness), are proportional to the shot movement energy. The influence of shot weight in the 2nd clause and the influence of shot size in the 3rd clause are taken into consideration. By using the equation (1), partical regression coefficients, a_1, a_2, a_3, and a_4 can be obtained from multi-

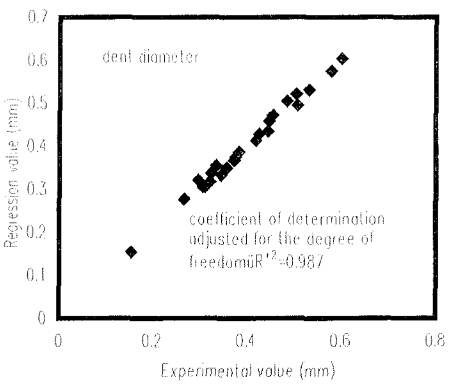

Figure 3: Relationship between experimental and regression value about dent diameter

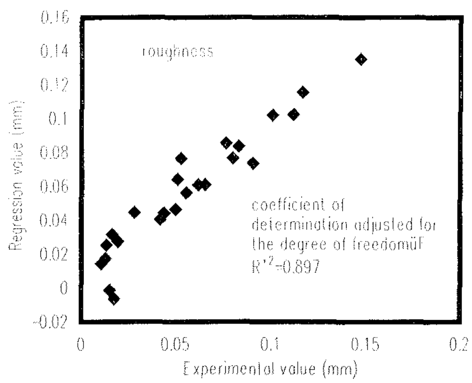

Figure 4: Relationship between experimental value and and regression value about roughness

ple regression analysis of experiment data. Fig. 3 shows the comparison between the experimental values and regression values. The Fig. 3 shows that equation (1) has sufficient accuracy, as the regression equation of dent diameter.

3.2 Formulation of Maximum Surface Roughness, *R*

It will be expected that the formulation for the surface roughness is also possible by the similar method of the dent diameter. The same processes can be carried out by using equation (2). Fig. 4 shows the comparison between the regression results and experimental results. It can be said that the regression equation accuracy of roughness is bad compared with dent diameter since coefficient of determination adjusted for the degree of freedom, R^{*2} is low. It can be assumed that the main reasons be due to relatively high scattering of the surface roughness.

$$R = a_1 \, (M\,V^2)^{1/3}\, HVW^{-1/3} + a_2\,(M/HVW)^{1/2} + a_3\,(3M/4\pi/\rho)^{1/3} + a_4 \qquad (2)$$

with $a_1 = 0.020$, $a_2 = 2602.19$, $a_3 = 0.726$, $a_4 = 0.104$

3.3 Simulation of Coverage

Fig. 5 shows the comparison between the measured coverage and the simulated coverage for application time. The shot peening conditions used are that the shot is 0.77 round cut wire, impeller revolutions number is 3500 rpm, and the amount of shot application is 122,000 pieces/sec. The shot application density under these conditions can be measured about 1.81 pieces /mm^2/sec. The hardness of specimen is 545 HV. The measured coverage can be obtained by measuring paper's weight of the enlarged photograph shot-peened surface, comparing the shot-peened surface and un-shot-peened surface. When simulated dent diameter by equation(1), the dent diameter can be determined as ∅0.297 mm. The time change of coverage by using the random number series 1 and 2 of MS-DOS BASIC was calculated. The simulations show good relationship with measurements. It can be realized that the actual coverage be simulated by using this method.

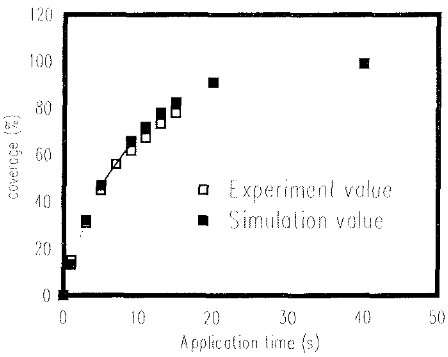

Figure 5: The Simulation result of coverage

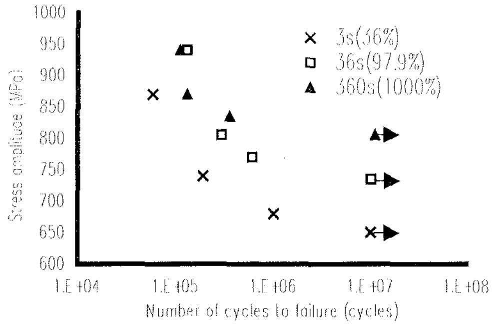

Figure 6: Relatoinship between coverage fatigue strength

3.4 Relationship Between the Coverage and Fatigue Strength

It can be seen from Fig. 5 that the fatigue strength tends to become higher in proportion with increasing application time (coverage rate). The coverage was measured 36 % when shot peened for 3 sec. As for the coverage for 36 sec and 360 sec, it can be presumed as follows. The dent diameter can be calculated as 0.406 mm from the equation (1) and the maximum surface roughness can be calculated as 0.053 mm from the equation (2). Then, under the condition of coverage 36 %, and 3 sec shot application time, the shot application density can be measured as 3.44 pieces/mm^2 by experiment. Therefore, the shot application density of 36 sec and 360 sec can be calculated as 41.2 pieces/mm^2 and 412 pieces/mm^2 respectively. The Coverage of 36 sec and 360 sec can be estimated as 97.9 % and 1000 %, following to the coverage simulation method of Section 2.3. Considering the above, the discussions can be extended to the relationship between the coverage and fatigue strength. Fig. 7 shows the distribution of residual stress. It can be explained from the Fig. 7 that the fatigue strength of coverage 36 % is small because the residual stress is low. On the other hand, since the coverage of 97.9 % and 1000% do not have a difference in the residual stress distributions around the surface which can show great influence on fatigue strength, and the surface roughness also does not show a large difference between the coverage of 97.9 % and 1000 % such as 0.045 mm for the coverage, 97.9 % and 0.048 mm for the coverage, 1000 %, further new parameter can be required to explain the difference of fatigue strength.

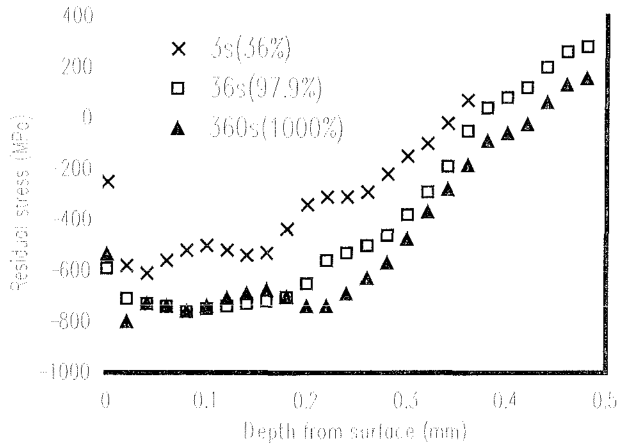

Figure 7: Distributon of residual stress

4 Conclusions

1. Applying various shot peening on the plate of hardness 666, 505, and 438 HV, it was found that formed dent diameter and roughness can be expressed by a equation.
2. The method to simulate the coverage by generating a random number, can be proposed.
3. It could be realized that that fatigue strength increases in proportion with increasing coverage.

5 References

[1] M. Hirose, Shot peening (1955), P 133, Seibundo Shinko Ltd..
[2] A. Oono, Study on Shot peening processing method of spring material (1985), P5