MEASUREMENT AND RESEARCH OF THE SHOT PEENING VELOCITY AND THE SURFACE HARDNESS

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ABSTRACT

This paper deals with shot peening. A steel ball impacts a metal object and a dent is left over. The dent formation includes the diameter and the depth, which can be measured precisely. The impact not only causes the changes of micro-construction and residual stress of the metal, but also hardens the surface of the object. In this report the tracks of the steel ball are recorded by means of a multi-exposure method. The impact velocity can be drawn out by studying the negatives or prints. And then the relation between the speed and the depth of dent is known. By using some known results, we get the important relation of impact velocity and hardness of the metal impacted. The relation will be confirmed to be helpful in industry manusfacture.

KEYWORDS

Shot peening; indentation of surface; impact velocity; micro-construction; track of steel balls.

INTRODUCTION

The shot peening is a good and simple method of indensification treatment of workpiece surface, which strengthens the surface hardness and prolongs the fatigue service life of machine parts at low cost. It is widely used in machinery industry, particularly in the manufacture of automobile, tractor, motor etc.The further investigation on the parameters of the shot peening and relation between them is necessary to improve efficiency of the shot peening and obtain the more satisfactory result. In hardening process, the impact velocity is a major factor which directly affects the quality of the metal surface under action. Very nice surface can be got if the velocity is under proper control. The Measurement of impact speed has been a difficult problem so far. High speed, very short distance and the influence of high pressure air current make the measurement very difficult. It is necessary to find a convenient and efficient way to get the speed. In this paper we present a multi-exposure method by using only one film and strobe light to measure the velocity.

EXPERIMENTAL METHOD

A dent is produced in the surface by shot peening, under which yield zone is formed. This is the result of plastic deformation. Plastic deformation leads to the change of micro-construction. Hardness of the metal changes too.

The experiment system consists of air compressor, shot peening device, camera, and strobe light, as shown in Fig.1. The shot peening is a steel ball of 6 (mm) in diameter; the impact distance is 30 (cm) and the impacted metals refer to Steel, brass and Aluminium. In order to get clear photographs for the trace of the steel ball, we select the corresponding light sources with different frequencies for different air pressure.

EXPERIMENTAL RESULT

Tracks of balls are recorded in various conditions as shown in Fig. 2 (a, b, c, d). As the face of balls in high speed is very clear in the prints, it is easy to get the velocity. It sugguests us that high-speed photography presents one of the best ways in research on shot peening.

Other results such as the relation of the indentation of surface W0' and the air pressure P, the relation between W0' and velocity V, and the relation of V and P, are shown in Fig. 3, Fig. 4 (a), Fig. 5 repectively.

METALLOGRAPHICAL ANALYSIS

Under powerful microscope, it is apparent that before shot peening all crystal grains almost have the same size, the boundary of which is straight and the ribbon annealing twin in which can also be clearly recognized. After shot peening the deformed micro-twin is produced in stressed layer, the density of which is decreasing with the depth. Planar defects are also the result of shot peening, between which dislocation lines and irregular dislocation circles mix up in high density. Such phenomena in micro-construction cause great change in hardness of metal.

THEORETICAL ANALYSIS

The impact of a ball to a surface is the so called contact problem in the elastisity [1]. By using the model of semi-space, the depth Wc of piont C as shown in Fig. 6, is discribed by the following equation if distributed load q with total force F acts in circle O :

$$W_c = \frac{1-\mu^2}{\pi \cdot E} \iint_A q \, d\phi \, ds \tag{1}$$

Wc can be drawn in Fig. 6

$$W_c = W_0 - z \tag{2}$$

for $r \ll R, \quad z \ll R$

then

$$\frac{z}{r} = \frac{r}{2R - z} \tag{3}$$

therefore

$$z = \frac{1}{2R} \cdot r^2 \tag{4}$$

substituting (4) into (2) then

$$W_c = W_0 - \frac{1}{2R} \cdot r^2 \tag{5}$$

substituting (5) into (1) then

$$W_0 - \frac{1}{2R} \cdot r^2 = \frac{1-\mu^2}{\pi \cdot E} \iint_A q \cdot d\phi \cdot ds \tag{6}$$

Acording to the Theorem of Uniqueness then

$$q_0 = \frac{3F}{2\pi \cdot a^2} \tag{7}$$

$$\frac{1}{2R} = k \cdot \frac{\pi^2 \, q_0^2}{4a} \tag{8}$$

Hence

$$a = \sqrt[3]{\frac{3}{4} \pi k F R} \tag{9}$$

$$q_0 = \sqrt[3]{\frac{6F}{\pi^5 k^2 R^2}} \tag{10}$$

$$W_0 = \sqrt[3]{\frac{9\pi^2 k^2 F^2}{16R}} \tag{11}$$

where $$K = \frac{1-\mu^2}{\pi E}$$

THEORETICAL RESULTS

Impact force F varies with the speed V of the ball. According to the mathematical results (9), (11), indentation W0 can be calculated out, as shown in Tab. 1. The relation curve between W0 and V is shown in Fig. 4 (b). Comparing (a) with (b), we can find that there are certain differences between them.

In shot peening we have the following relations [2]:

$$W_o = K_h \cdot 2R \cdot V \quad (12)$$

$$H_V = 287.6 - 28 \cdot K_h \quad (13)$$

where Kh is constant for hardness of material. Kh can be got from (12), where experimental data W0' are used, as described in Tab. 2. Further more by relation (13), Hv the hardness is caculated out. Then the curves of the relation between the velocity V and the hardness Hv are got as shown in Fig.7.

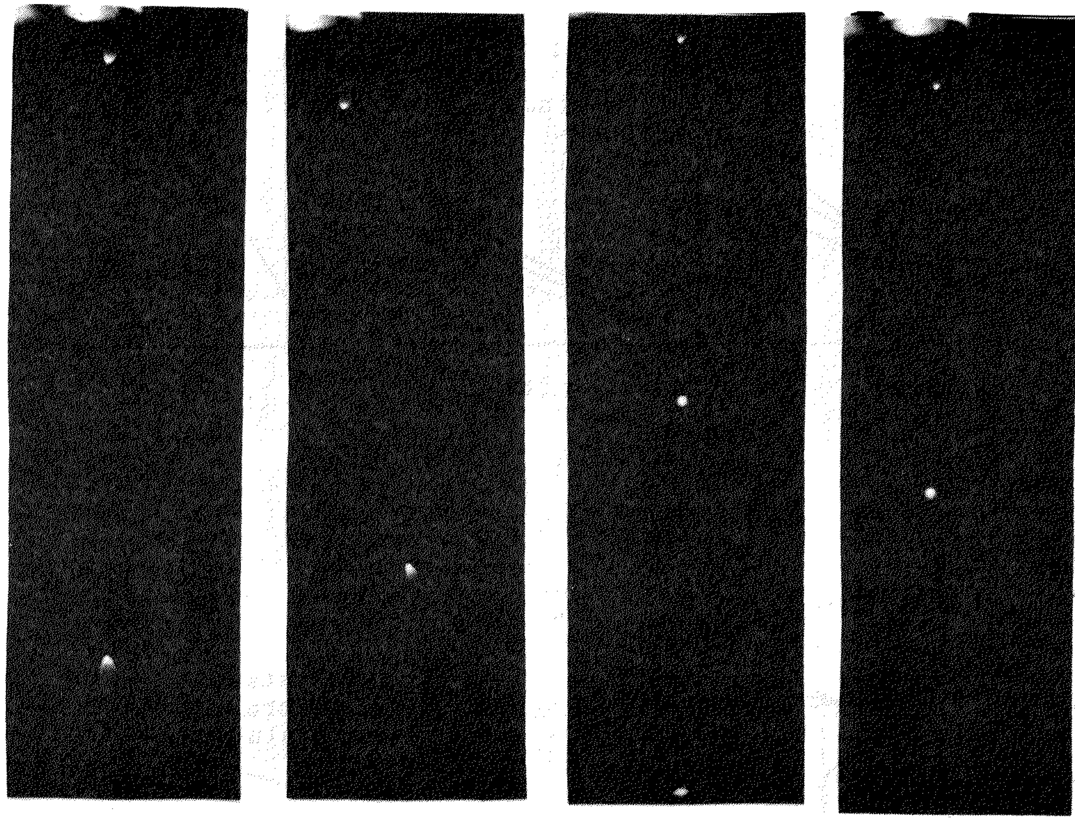
CONCLUSION

By using our system ,the experiments with different metals have been carried out repeatedly and successfully. From these experimental results it's very clear that there is a very direct relation between shot speed and the change of hardness. Especially, when the velocity is above 8 (m/s), hardness and indentation of metal surface is increasing sharp. Consquently, the velocity above 8 (m/s) must be considered firstly nomatter what the metal is. The quantity of airflow should be properly contolled to avoide affecting the speed of the ball.

REFERENCES

[1] Ximong Yao, Elastic and Plastic Mechanics, 1987

[2] Professor K.Iida, Dent and Affected Layer Produced by Shot Peening,1984



f=133.68HZ (a)   f=201.7HZ (b)   1cm   f=227.63HZ (c)   f=233.82HZ (d)

Fig.2

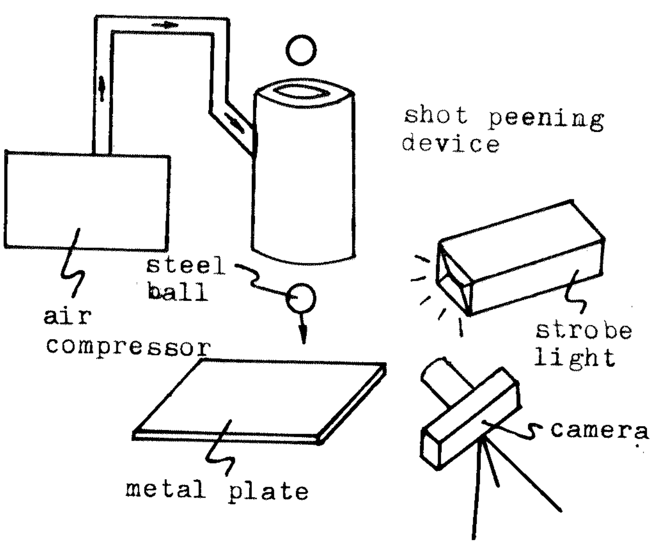


Fig.1

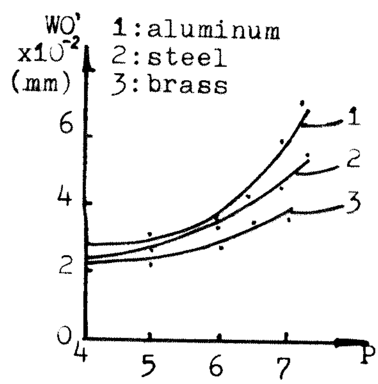


Fig.3

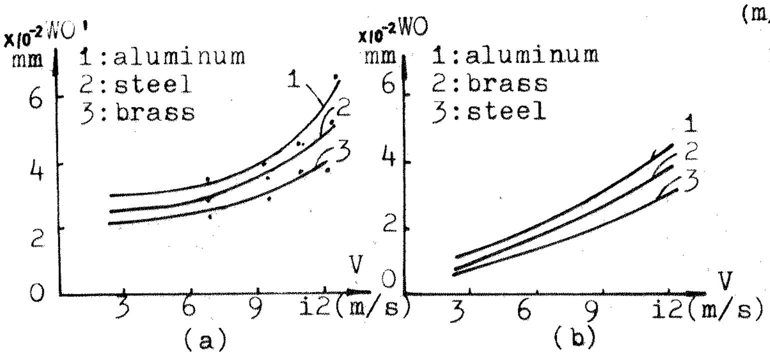


Fig.4

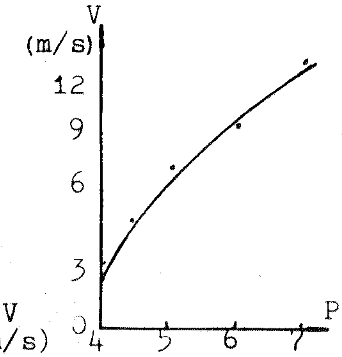


Fig.5

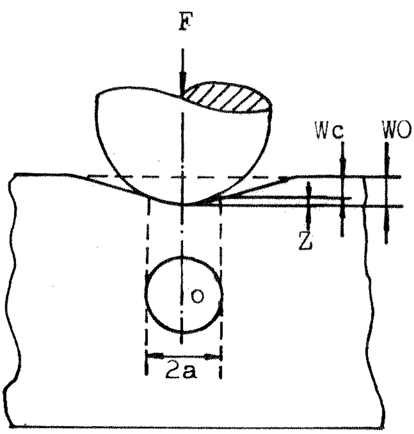


Fig.6

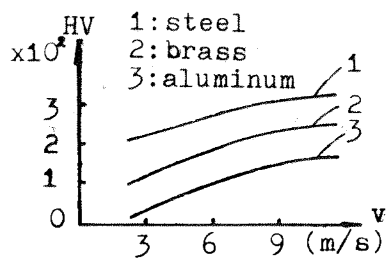


Fig.7

Tab.1

V (m/s)		2.26	7.69	9.15	11.6	12.2
brass	F (N)	249	1083	1334	1764	1877
steel		308	1343	1653	2186	2327
Al		203	885	1090	1442	1534
brass	WO ($\times 10^{-2}$ mm)	0.90	2.41	2.77	3.34	3.48
steel		0.73	1.94	2.23	2.69	2.80
Al		1.11	2.94	3.34	4.08	4.25

Tab.2

steel		brass		Al	
Hv	$Kh \times 10^{-4}$	Hv	$Kh \times 10^{-4}$	Hv	$Kh \times 10^{-4}$
199	5.38	102	6.67	9	8.16
287	4.31	211	5.22	123	6.39
297	4.07	225	5.04	139	6.17
312	3.88	242	4.87	161	5.89
315	3.84	246	4.76	165	5.83