PEENING EFFECT ON FLOW RESISTANCE OF AIR

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ABSTRACT

Shot peening produces many dents on the surface of work material. Geometry of dent is a segment of sphere similar to dimple of golf ball, therefore peened surface may be affects the flow resistance of air.
Drag coefficient was measured in air flow on polished and various peened specimens. Used shot diameter are 1.00 - 2.38 mm. The velocities of air flow are 5 - 25 m/s. Raynold's number are 2.98×10^4 - 1.49×10^5. The surface roughness of specimen are 0.1 - 32.5 μm produced by polishing and shot peening. Area coverage of shot peened specimens are 21 - 100 %. The pitches of fringe to fringe of dent obtained from profile records on peened surface are examined.
The relation between resistance (D) of air flow and drag coefficient (Cd) is as follows:

$$D = Cd \cdot K \cdot \frac{1}{2} \rho V$$

where K: geometry of specimen
ρ, V: density and velocity of air

Drag coefficient of shot peened specimen decreased 2.4 - 11 % compared with polished one, and decreased 0.81 - 8.1 % by area coverage and also decreased 0.86 - 3.4 % by pitch of fringe.

KEYWORDS

Shot peening, drag coefficient, flow resistance, area coverage.

INTRODUCTION

Shot peening produces many dents on the surface of metal and induce various peening effects. Many dimples on the golf-ball have several flying effects. Geometry of dent produced by shot peening is dimple-like, therefore peened surface may have the effect as the decrease of the air flow resistance.

There are many papers on the effect of surface roughness of cylinder specimen in the air-flow hitherto [1-8]. In these reports surface roughness was made from convex particles, then the comparison on resistance in the air-flow between the case of dimple-like concave surface roughness and the case of such results is difficult.

In this study, many dents which were different shapes in the past papers were made by shot peening, and tested within the Reynold's number $Re = 2.98\times10^4 - 1.49\times10^5$. Then, the drag coefficients of various shot peened cylinders were compared with of non-shot peened or polished cylinders and convex abrasive surface cylinders.

EXPERIMENT

Instrument

Apparatus and geometry of specimen used in this experiment were shown in Fig.1. Air flow was generated with a blower and conducted the wind tunnel. Specimen was set at the end of the wind tunnel and inclined against air flow. Then, air pressure around the specimen was measured.

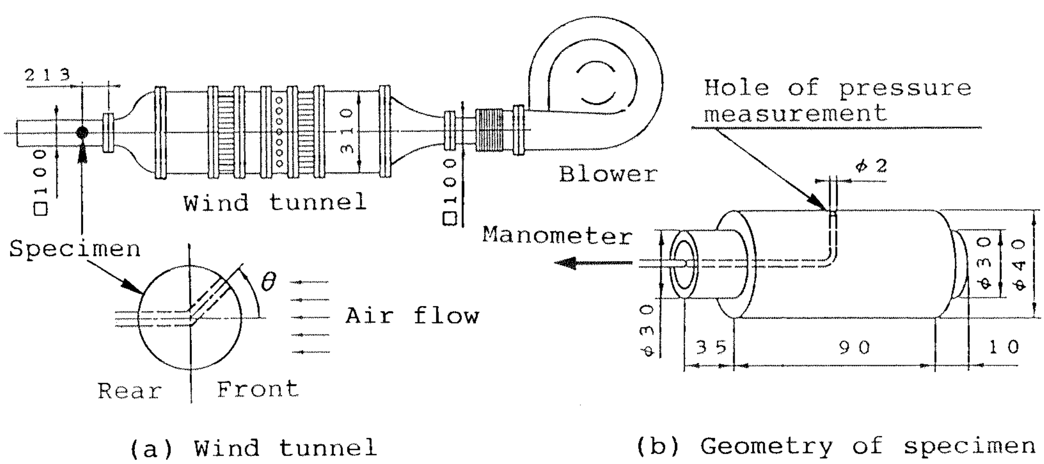

Fig.1 Wind tunnel and specimen

Experiment conditions

Five kinds of air velocity were used and Reynold's numbers were determined. Inclination of air pressure measurement-hole angle θ was varied every 5 deg from 0 to 100 deg and every 10 deg from 100 to 180 deg, as shown in Table 1 and 2.

Table 1 Air velocity and Re

Air velocity V (m/s)	Re ($\times 10^4$)
5	2.98
10	5.96
15	8.94
20	11.90
25	14.90

Table 2 Inclination of hole

Angle θ (deg.)	Mesurement point
0-100	5deg. step
100-180	10deg. step

In this experiment, the surface roughness of test cylinders are as follows, ground specimen Rmax: 1.6μm, polished specimen with abrasive paper Rmax: 0.1 μm, and shot peened specimen Rmax: 4.7-32.5μm.

Furthermore, five specimens which has convex roughness surrounded with the abrasive-paper (#240-1000), were used to compare with shot peened specimens, as shown in Table 3.

Table 3 Surface roughness of specimen

Specimen	Surface condition		Surface roughness Rmax (μm)
5	Polished		0.1
1	Ground		1.6
3	Shot Peened (ds=1.00-1.19 mm)		4.7
2			6.4
6			11.5
4			21.1
11	Shot Peened (ds=2.00-2.38 mm)		10.0
12			13.6
13			21.0
14			32.5
21	Covered with Abrasive Paper	(#1000)	7.0
22		(#800)	8.2
23		(#600)	11.2
24		(#400)	16.8
25		(#240)	31.2

On the coverage, five kinds of area coverage (0, 21, 56 ,80, 100 %) were used as shown in Table 4.

Table 4 Area coverage of specimen

Specimen	Surface condition	Area coverage λ (%)
1	Ground	0
2A	Shot Peened (ds=1.00-1.19 mm)	21
2B		56
2C		80
2		100

On the pitch of dent, five kinds of pitch of dent(0.263, 0.286, 0.313, 0.340, 0.361 mm) were used as shown in Table 5.

Table 5 Pitch of dent of specimen

Specimen	Surface condition		Pitch of dent pd (mm)
6L	Shot peened	ds= 0.50-0.59 mm	0.263
6M		ds =0.71-0.84 mm	0.286
6		ds =1.00-1.19 mm	0.313
6N		ds =1.41-1.68 mm	0.340
11		ds =2.00-2.38 mm	0.361

<u>Calculation method of drag coefficient Cd [9]</u>

$P-P_0$ were measured and Cp was calculated from following formula

$$Cp = \frac{2\ (P-P_0)}{\rho V^2}$$

Then, from mean value of $Cp \cdot \cos\theta$, Cd was calculated from following formula

$$Cd = \pi \cdot \overline{Cp \cdot \cos\theta}$$

where
- P_0 : Pressure of atmosphere [Pa]
- P : Pressure on cylinder surface [Pa]
- ρ : Air density [kg/m]
- v : Air velocity [m/s]
- θ : Angle against direction of air flow [deg.]
- Cp : Pressure coefficient
- Cd : Drag coefficient

and then, resistance R of air flow is as follows:

$$D = Cd \cdot K \cdot \frac{1}{2} \rho V$$

where K : geometry of specimen

RESULTS OF EXPERIMENT

Affect of air velocity

Fig.2 shows relation between a angle θ and a pressure coefficient Cp on the same shot peened specimen under the air velocity 10 and 20 m/s. Thereafter, as shown in Fig.3, Cp·cos θ values were the same among the air velocity from 5 to 25 m/s. This result was confirmed on various specimens.

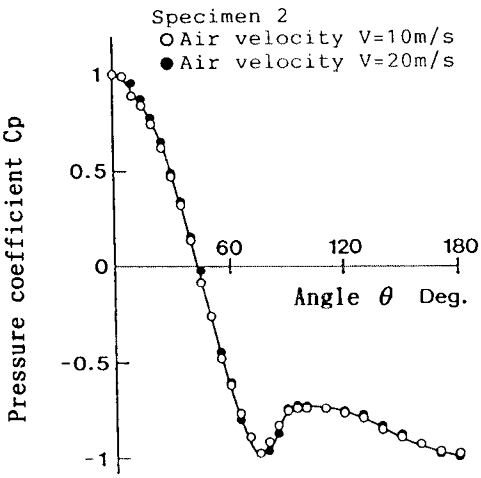

Fig. 2 Relation between θ and Cp

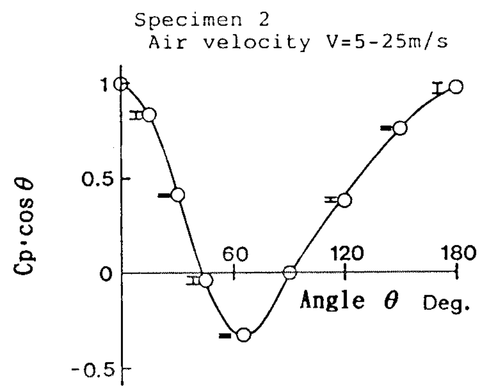

Fig. 3 Relation between θ and Cp·cos θ

Air velocities were changed 5-25 m/s for all specimens, and Cd values were calculated. This result is similar and constant as shown in Fig.4. After all, whenever the air velocities were changed within 5-25 m/s, the same specimen shows the same Cd value [10].

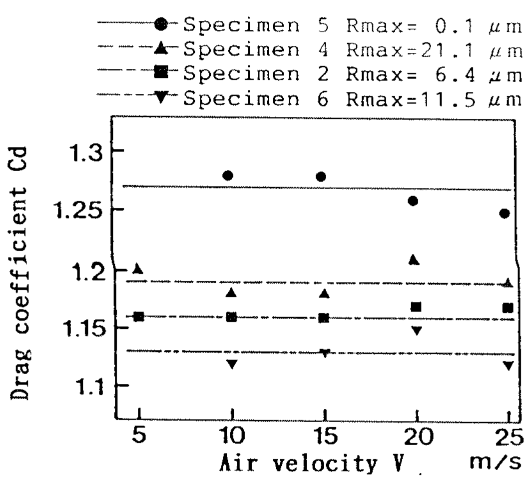

Fig. 4 Relation between V and Cd

Comparison between polished and ground surface

Fig.5 and 6 shows relation θ - Cp and θ - Cp cos respectively on the ground and the polished specimen. The air velocity was 15 m/s. The pressure difference appeared on rear flow of the specimens. Cd value of the polished specimen 5 is larger than that of the ground specimen 1.

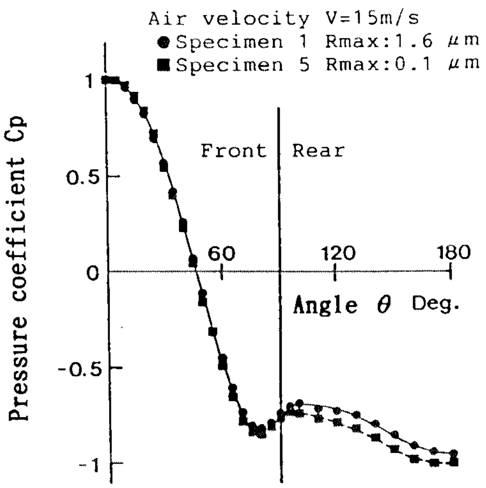

Fig. 5 Relation between θ and Cp

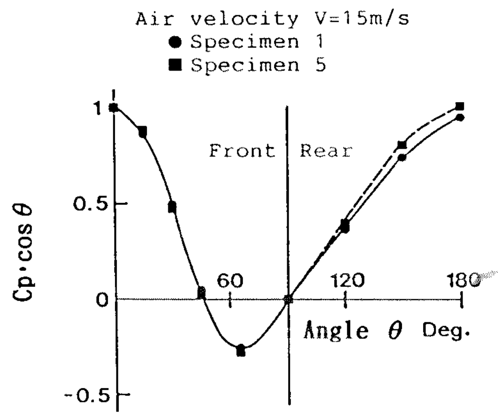

Fig. 6 Relation between θ and Cp·cos θ

Comparison between ground and shot peened surface

Fig.7 and 8 shows relation θ - Cp and θ - Cp · cos θ respectively. The air velocity was 15 m/s. The shot peened specimen 6 showed the minimum Cd value among shot peened surfaces. The pressure difference appeared on the front flow of the specimens.

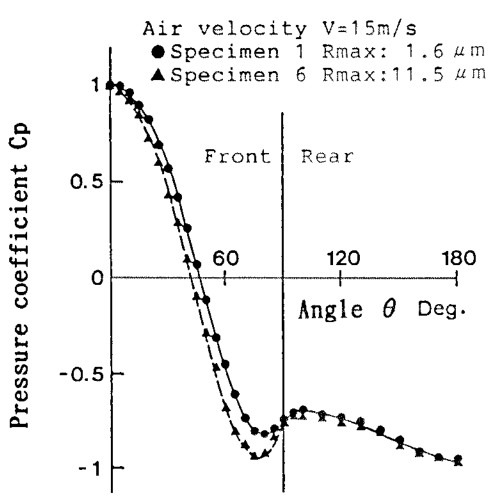

Fig. 7 Relation between θ and Cp

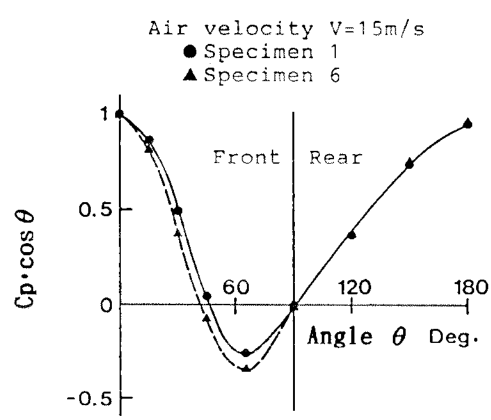

Fig. 8 Relation between θ and Cp·cos θ

Cd and surface roughness.

Fig.9 shows the relations between surface roughness Rmax and Cd. Cd of the polished surface was the maximum, and Cd of all shot peened specimens were small value.

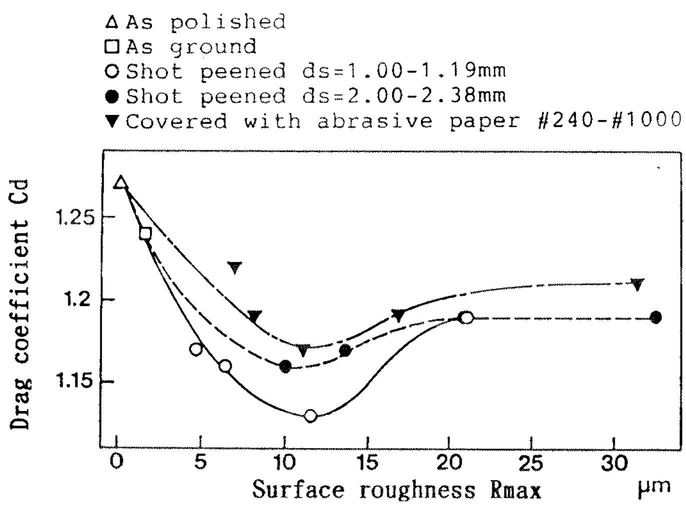

Fig. 9 Relation between Rmax and Cd

The specimen of surface roughness 10.0 μm showed the minimum Cd value 1.16 among shot peened specimens with shot diameter 2.00-2.38 mm. The specimen of the surface roughness 11.5 μm showed the minimum Cd value 1.13 among shot peened specimens with shot diameter 1.00-1.19 mm. This Cd value was the minimum in the experiment.

Cd of the convex abrasive surfaces surrounded with abrasive-paper under the same roughness of Rmax were larger than that of a shot peened surfaces.

Cd and area coverage

Fig.10 shows relation between the area coverage λ and Cp. These area coverage are 21 and 80 %, and air velocity is 15 m/s. The pressure difference appeared on front flow of specimens.

Fig.11 shows relation between λ and Cd. In this figure, Cd decrease as λ increase. Area coverage λ 80 % shows the minimum Cd 1.14, and a full coverage shows more larger. After all, Cd of the specimen which has a few non-peened area is smaller than the full coveraged one.

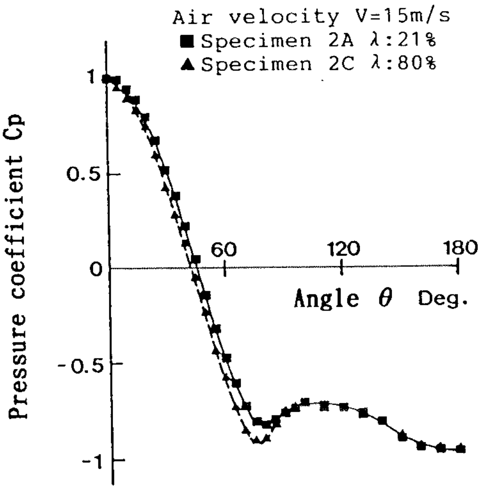

Fig. 10 Relation between θ and Cp

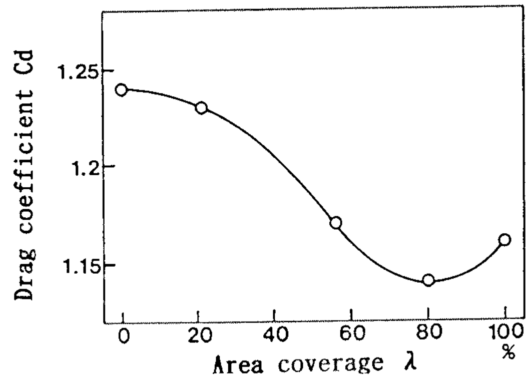

Fig. 11 Relation between λ and Cd

Cd and pitch of dent

Fig.12 shows relation between pd and Cp. Pitches of dent pd were 0.286 and 0.313 mm. Air velocity was 15 m/s. Cd of both specimens were smaller, but the pressure difference appeared on front flow.

Fig.13 shows relation between pd and Cd. In this figure, Cd was the minimum 1.13 where the pitch of dent is 0.313 mm. Cd of others were 1.16-1.17.

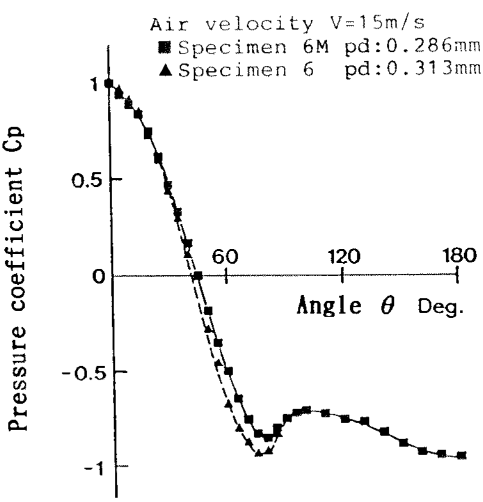

Fig. 12 Relation between θ and Cp

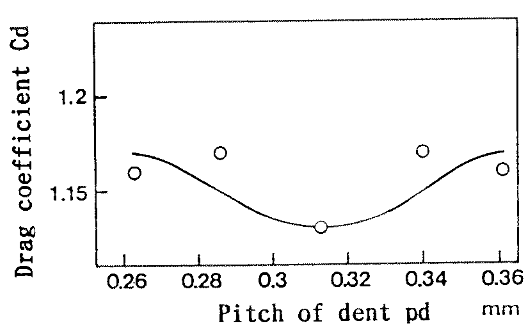

Fig. 13 Relation between pd and Cd

CONCLUSION

[1]In the experiment of surface roughness, reduction rates of Cd were the minimum 2.36 % and the maximum 11.0 % as shown in Table 6, and the optimum surface roughness was 11.5 μm.

Table 6 Cd and surface rourhness

Surface Roughness (μm)	0.1-32.5
Drag Coefficient: Cd	1.13-1.27
Reduction Rate of Cd (%)	2.36-11.0

[2]In the experiment of area coverage, reduction rates of Cd were the minimum 0.806 % and the maximum 8.06 % as shown in Table 7, and the optimum area coverage was 80 %.

Table 7 Cd and area coverage

Area Coverage (%)	0-100
Drag Coefficient: Cd	1.14-1.24
Reduction Rate of Cd (%)	0.806-8.06

[3]In the experiment of the pitch of dent, reduction rates of Cd were the minimum 0.855 % and the maximum 3.42 % as shown in Table 8, and the optimum pitch of dent was 0.313 mm.

Table 8 Cd and pitch of dent

Pitch of Dent (mm)	0.263-0.361
Drag Coefficient: Cd	1.13-1.17
Reduction Rate of Cd (%)	0.855-3.42

[4]Cd of convex abrasive surfaces surrounded with abrasive papers as same as shot peened surface roughness were larger than that of shot peened surfaces.

[5]The reason why the decrease of Cd on shot peened surface seemed like a small vortex flow in each concave dent.

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