EFFECT OF PEENED SURFACE CHARACTERISTICS ON FLOW RESISTANCE

Hiromitsu Kiyoto★,Katsuji Tosha★

★Meiji University, 1-1-1 Higashimita,Tama-ku,Kawasaki 214-8571, Japan

ABSTRACT

This paper experimentally considers the influence of the dimple on the flow resistance of peened surfaces. In this study, in order to clarify the influence of peened surface characteristics on flow resistance, test cylinders were shot peened under the following conditions. Centrifugal and direct pressure peening machines were used. The centrifugal machine was used for shot velocities varying from 30 m/s to 50 m/s and shot diameters of 2.00-2.38mm. A direct pressure machine was used with projection pressure of 2.5atm and shot diameters of 1.00-1.19mm. The work material is aluminum alloy, whose diameters were 30, 35, 40mm. Air velocity in the wind tunnel over the peened surfaces was varied from 10-20 m/s.

Results of this experiment include:(1) When the test cylinder has a large surface roughness, and air velocity exceeds a fixed value, the point that flow changes from laminar to turbulent flow shifts to turbulent, and the drag coefficient decreases. (2) The drag coefficient decreases with increasing surface roughness on the peened test cylinder. (3) When the test cylinder diameter is relatively large, the influence of the surface of a wall of the wind tunnel increases and then the air velocity increases locally. (4) The drag coefficient decreases with profile surface roughness produced by shot peening, this is why the peened surface affects air velocity V or the Reynolds number characteristic length L.

KEYWORDS

Shot peening, drag coefficient, flow resistance, Reynolds numbers, critical Reynolds number, laminar flow, turbulent flow

INTRODUCTION

Shot peening is a one of the cold working processes inducing work hardening, compressive residual stress, etc on metal, and simultaneously producing numerous spherical dimples. It is well known that the many dimples on golf-balls produce several flying effects. Because peened surfaces are covered with similar dimples, it is logical to assume the peened dimples also have an effect on air flow resistance.

There are many papers on the effect of surface roughness of cylinders in an air-flow[1-3]. However, there are few articles describing on the influence of surface roughness produced by shot peening

In this study, in order to clarify the influence of peened surface characteristics on flow resistance, test cylinders were shot peened under various conditions. The pressure distributions on the test cylinder surface were measured by using a small wind tunnel. The influences of air velocity, peening conditions and the test cylinder diameters on drag coefficient were studied.

Experimental procedure

The wind tunnel used in this experiment is shown in Fig.1. Air flow is generated by the blower and rectified through the commutation cone and the contraction cone. The test cylinder was set in the end of the wind tunnel and exposed to the air flow. The test cylinder used is shown in Fig.2. Air pressure around the test cylinder was measured with a manometer. As shown in Table1, three values of air velocity were selected and the Reynolds numbers were determined from the velocity.

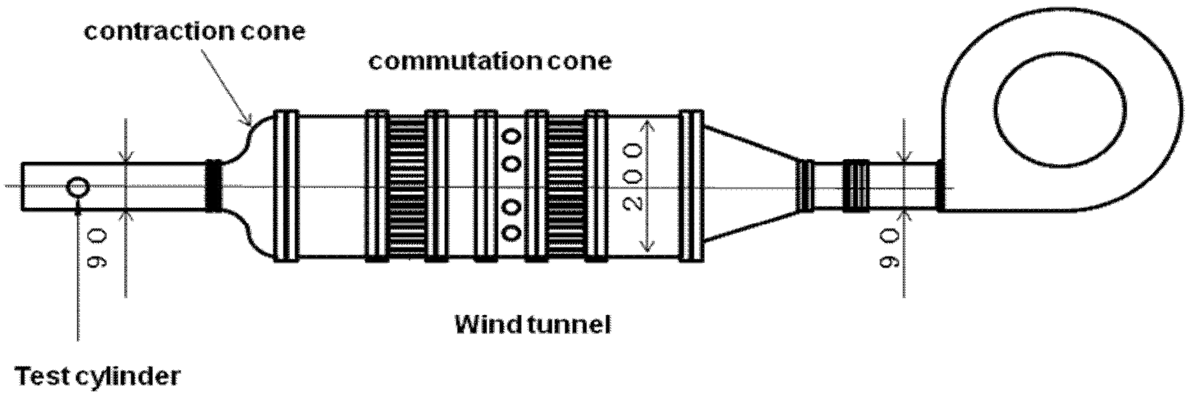


Fig. 1 Wind tunnel

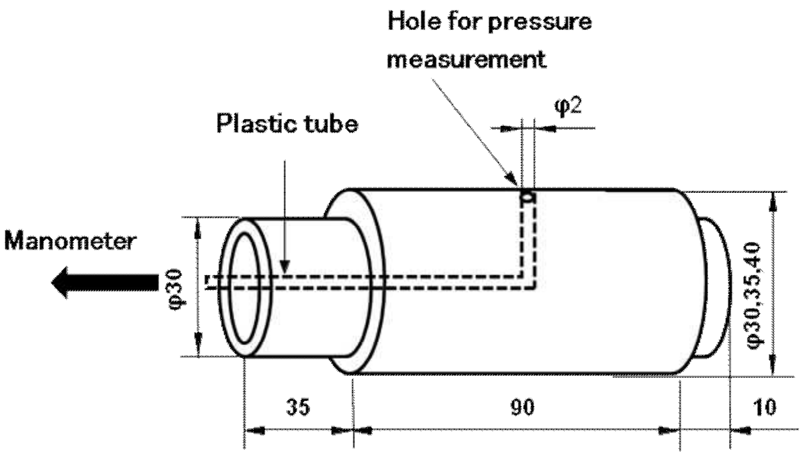


Fig. 2 Geometry of test cylinder

Table 1 Air velocity and Re

Air velocity V (m/s)	Re ($\times 10^4$)
10	5.96
15	8.94
20	11.9

Calculation method of drag coefficient Cd

The pressure drop $P-P_0$ was measured using a manometer and Cp was calculated from following formula.

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

where P_0 : Pressure of atmosphere [Pa]
P : Pressure on cylinder surface [Pa]
ρ : Air density [kg/m^3]
V : Air velocity [m/s]
Cp : Pressure coefficient

Using the value of Cp･cosθ, the drag coefficient Cd was calculated from following approximation formula.

$$Cd = \int_0^{\pi} Cp \bullet \cos\theta \, d\theta \approx \pi \bullet \sum_{n=1}^{\mathbf{n}} Cp \bullet \cos\theta_n$$

where θ ：Angle against direction of air flow [deg.]
Cp･cosθ ：Level ingredient of Cp

Resistance R of the air flow was calculated by the following formula.

$$R = Cd \bullet dL \bullet \frac{1}{2} \rho V^2$$

where d ：Cylinder diameter [m]
L ：Cylinder length [m]

Experimental conditions

Table2 shows the peening conditions, diameter and surface roughness of the test cylinder. In this experiment, in order to clarify the influence of the peening conditions, surface roughness, cylinder diameter and air velocity on the drag coefficient were discussed. The diameter of the shot used is defined table2 as Ds.

Table 2 Surface conditions and diameter of test cylinder

Test cylinder	Surface condition	Diameter (mm)	Surface roughness Ra(μm)
1	Ground	30	0.69
2		35	0.39
3		40	0.21
4	Shot peened projection pressure 2.5atm (Ds = 1.00-1.19 mm)	30	6.7
5		35	9.7
6		40	8.2
7	Shot peened shot velocity 30m/s (Ds = 2.00-2.38 mm)	30	12.5
8		35	12.2
9		40	13
10	Shot peened shot velocity 40m/s (Ds = 2.00-2.38 mm)	30	15.4
11		35	16.9
12		40	17.9
13	Shot peened shot velocity 50m/s (Ds = 2.00-2.38 mm)	30	25.5
14		35	19.7
15		40	22

EXPERIMENTAL RESULTS
Effect of air velocity

Figures 3 and 4 show the relation between angle θ on the pressure coefficient Cp of test cylinder #1(ground, diameter 30mm, Ra=0.69) and test cylinder #13(shot peened, diameter 30mm, Ra=25.5) under an air velocity 10 - 20 m/s. As shown in Fig.3 Cp values didn't change when the air velocity is from 10 to 20 m/s. But as shown in Fig.4, when the air velocity exceeds 15m/s, Cp values changed. In Fig.4 test cylinders surface was changed from ground to shot peened. In Fig.4 the change of Cp distribution implies that the critical Reynolds number value was reached in the air flow across the test cylinder circumference [1]. Since the only difference between Fig.3 and 4 is the surface caused by peening, it is thought that peened surface influences the Reynolds number.

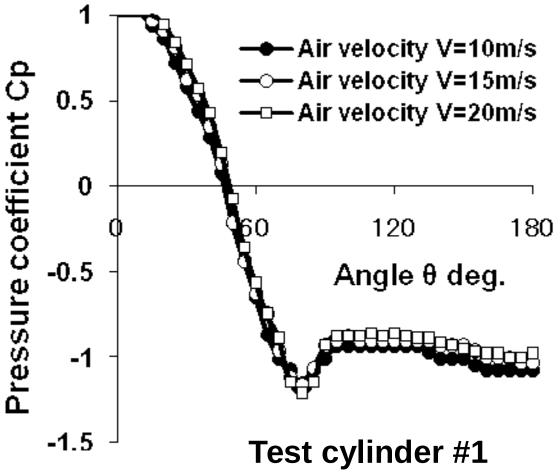


Fig.3 Relation between θ and Cp (ground)

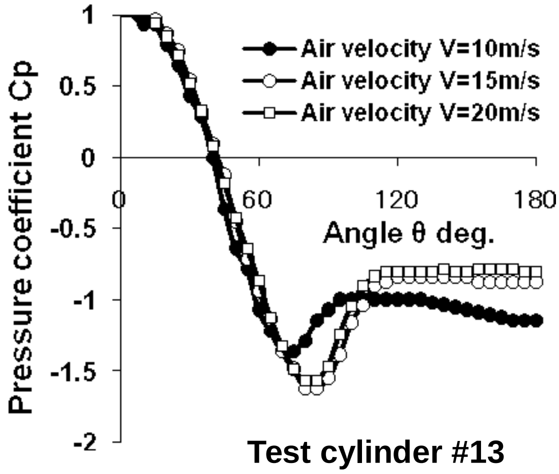


Fig.4 Relation between θ and Cp (shot peened)

Figure 5 shows the relation between V and Cd at a diameter of 30 mm. In the case of test cylinder #13, when the air velocity exceeds 15 m/s, Cd decreases conspicuously. The reason is due to the change of Cp values of test cylinder #13 as shown in Fig.4. In the case of test cylinder #1, when the air velocity exceeds 20 m/s, Cd increases slightly. It seems to be a accident error.

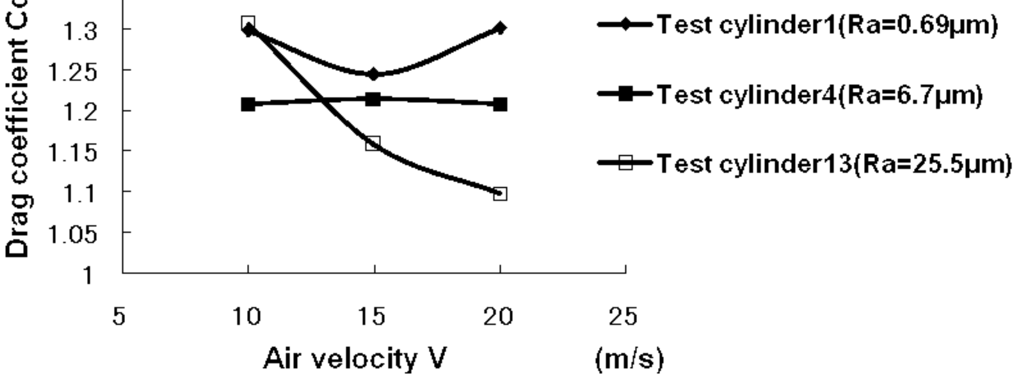
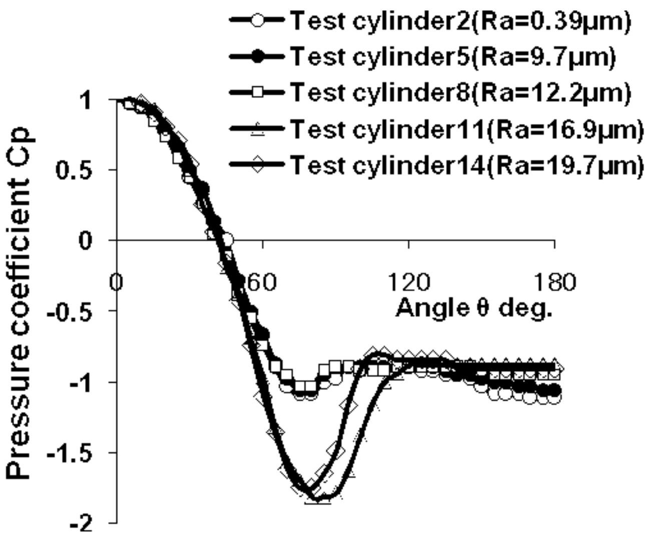


Fig.5 Relation between V and Cd

Comparison between ground and shot peened surface

Figure 6 shows the relation between θ and Cp on the ground and shot peened surfaces. From the result of Fig.6, as shown in Fig.7, the relation between surface roughness Ra and Cd is obtained under an air velocity of 15 m/s for cylinder diameter of 35 mm. The drag coefficient decreases with increasing surface roughness of the peened test cylinder. Because the drag coefficient decreases as the surface roughness produced by shot peening increases the peened surface can affect the air velocity V Reynolds number characteristic length L.



(Air velocity V = 15m/s, diameter 35mm)

Fig.6 Relation between θ and Cp

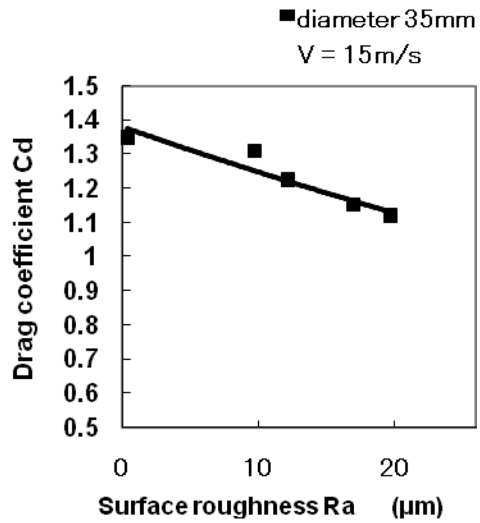


Fig.7 Relation between Ra and Cd

Effect of test cylinder diameter

Figure 8 shows the relation between θ and Cp under the air velocity 20 m/s and peened at shot velocity 30m/s. Figure 9 shows the relation between surface roughness Ra and Cd under an air velocity 20 m/s. The influence of the test cylinder diameter is not very large, but Cd value decrease, with increasing surface roughness beyond 12μm. The reason air flow increases locally is the result of the cylinder wall surface.

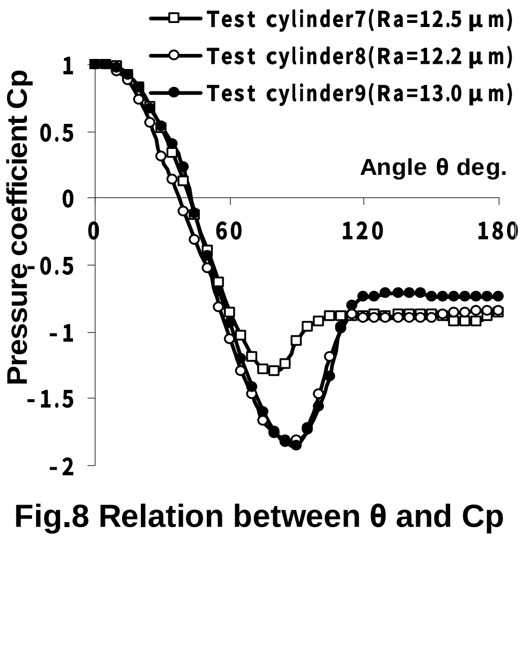


Fig.8 Relation between θ and Cp

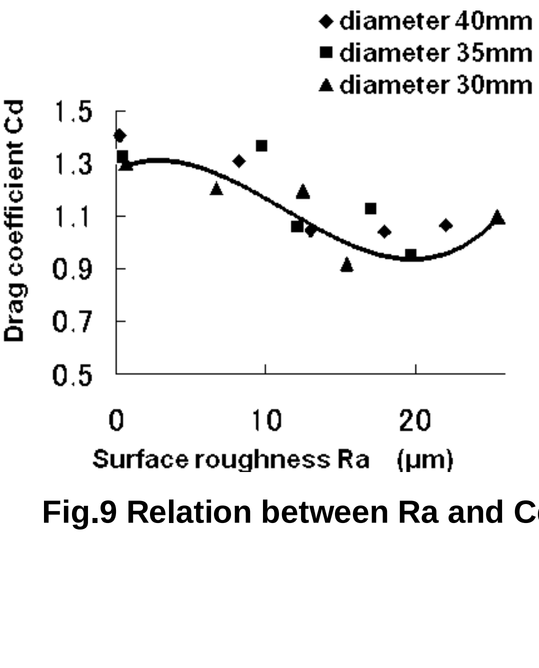


Fig.9 Relation between Ra and Cd

CONCLUSION

In order to clarify the influence of peened surfaces on flow resistance, the pressure distributions on cylindrical surfaces were measured by using a small wind tunnel. The following results, were observed:

(1) For test cylinders having large surface roughness, where air velocity exceeds a fixed value, flow changes from laminar to turbulent, and the drag coefficient decreases.

(2) The drag coefficient decreases with an increase of surface roughness on peened test cylinders, when the air velocity exceeds 15 m/s.

(3) When the test cylinder diameter is relatively large, the influence of the surface of a wall of the wind tunnel increases and then the air velocity increases locally.

(4) Because the drag coefficient decreases as the surface roughness produced by shot peening increases the peened surface can affect the air velocity V Reynolds number characteristic length L.

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