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Study on protection performance of grinding wheel safety guard made of stainless steel

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Abstract

When a high speed rotating grinding wheel spontaneously fractures and fragments collide with the grinding machine's safety wheel guard, the guard should be thick enough to protect the machine operators and the instrumentation from the fragments. To avoid accidents, establishment of an ISO safety standard is imperative. Therefore, the authors built an experimental apparatus and performed various collision experiments. The apparatus consists of a launcher, a projectile made of white alumina abrasive and a target wall made of stainless steel. The resultant collision damage to the target wall can be divided into 3 patterns: fracture with penetration, fracture without penetration and non-fracture. The factor of safety for the wheel guard is indicated by the kinematic energy for a projectile fracture without penetrating. During collision experiments, a safety borderline thickness could be obtained to establish a safety standard. Furthermore, we discovered that the kinematic energy of the WA46O8V projectile is absorbed by deformation of the stainless steel guard, but not absorbed by the abrasive product itself.

Keywords: grinding machine, wheel safety guard, stainless steel, abrasive product, collision, penetration

1. Introduction

Stainless steel has excellent mechanical, chemical and artificial properties, thus, it is used for machine tool covers, control panels, wheel safety guards, and so on. It is especially useful in the semiconductor machine tool field as pure water is employed as cutting fluid. Consequently, rust free materials, such as stainless steel, are employed for machine components and/or covers. Nevertheless, a safety standard for a stainless steel wheel guard has yet to be established.

When a high speed rotating grinding wheel from a grinding machine spontaneously fractures and the fragments collide with the wheel safety guard, the kinematic energy of the fragments is absorbed by the guard. Therefore, the guard should be thick enough to protect the machine operators and the machine tool instrumentation from these projectiles.

The authors constructed an experimental apparatus consisting of a launcher, a projectile made of white alumina abrasive and a target wall made of a carbon steel sheet [1]. They then investigated the effect of the kinematic energy of projectiles on the target wall thickness [2]. This paper investigates the minimum thicknesses of the target wall made of stainless steel that could withstand the collision under each wheel peripheral speed or fragment mass.

To establish an International standard for wheel safety guard thickness, the standard must be established under the premise of worst case, that is, largest size and highest speed of fragments collide with the wheel safety guard. In this paper, the maximum kinetic energy of projectile WA46O8V, is compared with the collision energy for a fracture without penetration of the stainless steel wall and also investigated the collision mechanism.

2. Experimental equipment and conditions

Figure 1 shows the developed collision experimental apparatus. Table 1 shows the specifications of the equipment. Velocity of the projectile is measured by using 2 laser sensors installed in exist of the launcher.

As shown in Table 2, material of the target wall is stainless steel (SUS304, ISO9444). Thicknesses of the walls are 1.0 mm and 1.5 mm. Area of the wall is 450 mm × 450 mm and the wall is solidly mounted on a rigid support which is clamped onto the concrete floor.

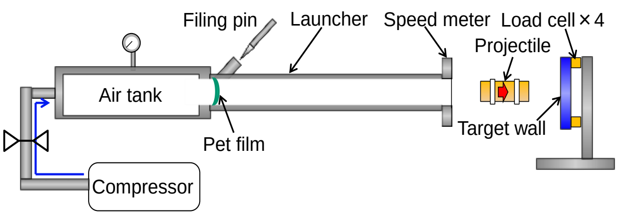

Figure 1. Apparatus for collision experiment.

Material of the projectile, WA46O8V, is white alumina

Table 1. Specification of experimental equipment.

Gauge pressure of air tank/MPa	0-0.5
Capacity of air tank/m^3	0.2
Launcher length/mm	6 000
Launcher bore/mm	ϕ100
Maximum kinematic energy/kJ	15
Maximum projectile speed/m·s^{-1}	120
Distance between ejection port and target/m	1.6

Table 2. Specification of target wall and projectile.

Target wall material	Stainless steel (SUS304, ISO9444)
Target wall size/mm	450 × 450
Target wall thickness/mm	1.0, 1.5
Projectile material	Abrasive product (WA46O8V)
Projectile mass/kg	3.4

Figure 2. Appearance of projectile (WA46O8V).

abrasive products whose grain size is between 300 to 350 μm, hardness is O, porosity is 46 % and bonding material is vitrified. Size of the projectile is 220 mm x ϕ90 mm with a mass of 3.4 kg. The outside of the projectile is covered by two Teflon rings to reduce the friction coefficient between the launcher bore surfaces. For safety, the experimental apparatus is set up in an underground room.

3. Results of collision experiments

Figure 3 shows the damaged target wall after the collision experiments under different collision velocities. From the figure, collision patterns can be classified into three patterns. Fig.3(a) shows the pattern which perfectly stopped the projectile. Fig.3(b) shows the pattern which could successfully stop the projectile but propagated a crack on the target wall. Fig.3(c) shows the pattern that is penetrated by the projectile. The projectiles were not fractured after the collision experiments, therefore collision energy was not absorbed by the fragment. That is, WA46O8V maintains rigidity, a perfectly plastic solid material under these experiments.

Table 3 shows the estimation of target wall damage under each collision energy for 13 separate collision experiments. Figure 4 shows the effect of the collision energy on the target wall safety thickness. Above and to the left of the line, the "×", shows where the wall was penetrated by the projectile. The lower right area "○" shows where the wall stopped the projectile. "□" on the dotted line indicates a fracture without penetration, and "■" shows underlined data to obtain the dotted line. The dotted line indicates the effect of collision energy on the guard thickness where crack damage may occur on the wall.

4. Theoretical analyses

To understand the mechanical properties of the abrasive products and the stainless steel wall, quasi-static tensile and impact tensile tests were performed prior to the collision experiments. The results indicate that the abrasive products were a rigid body and the stainless steel wall was a rigid, perfectly plastic solid. That is, the bending energy can be calculated by a bending hinge model of band plate [3], since the bending deformation occurred locally in the outer edge of collision surface. The bending moment, M_0, can be given as follows,

$$M_0 = \frac{\sigma b t^2}{4} \tag{1}$$

where t is wall thickness, b is cross-sectional width and σ is the stress of the wall. Bending energy E can be calculated using Eq.(1) and bending angle θ follows,

$$E = M_0\theta = \frac{\sigma b t^2 \theta}{4} = kt^2 \tag{2}$$

Eq.(2) shows that value of E is proportional to the square of the wall thickness, t.

5. Conclusions

The following conclusions were obtained under the collision experiment using stainless steel walls with white alumina abrasive products, WA46O8V.

[1] Collision patterns of the wall can be classified into 3 patterns: non-fracture, fracture without penetration and fracture with penetration.

[2] WA46O8V was shown to be a rigid, perfectly plastic solid material, thus collision energy was not absorbed by the fragment.

(a) Non-fracture V: 70 m·s^{-1}, t: 1.5 mm

(b) Fracture without penetration V: 81 m·s^{-1}, t: 1.5 mm

(c) Fracture with penetration V: 90 m·s^{-1}, t: 1.5 mm

Figure 3. Appearance of target wall damage after collision experiment.

Table 3. Effect of collision energy on target wall damage.

Cover thickness/mm	Projectile Velocity/m·s^{-1}	Collision energy/J	Damages
1.0	41.9	2 984	○
	45.7	3 550	
	51.7	4 543	
	53.4	4 847	□
	54.2	4 993	
	64.4	7 050	×
1.5	45.6	3 532	○
	56.4	5 408	
	69.7	8 258	
	70.0	8 330	
	78.4	10 449	□
	81.0	11 154	
	90.2	13 831	×

[3] Kinematic energy of the projectile with crack propagation is not absorbed by fracturing of the projectile.

[4] Bending energy value, E, is proportional to the square of the wall thickness.

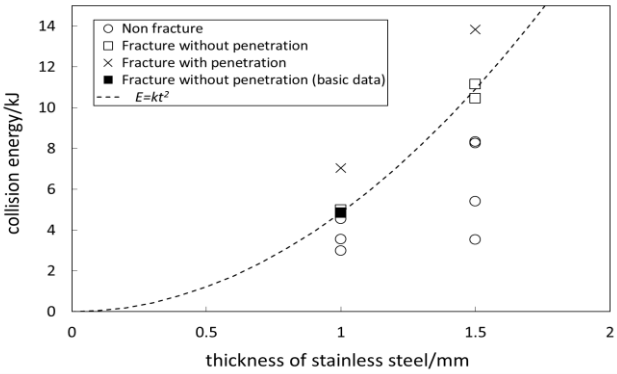

Figure 4. Effect of collision energy on wheel guard safety thickness.

Acknowledgments

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