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Effect of grinding wheel safety guard thickness in the collision of a conical projectile

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When a rotating grinding wheel bursts during grinding operation, abrasive fragments are scattered. Grinding wheel safety guard is one of the most important safety mechanisms for grinding machines that protect machine tool operators from the scattered abrasive fragments. The guard thickness is specified by ISO16089, however, the collision phenomenon of brittle material such as an abrasive product has not been clarified yet. In the previous study, the authors have conducted collision experiments using an abrasive projectile. In the case of using a cylindrical abrasive projectile, regardless of the material both projectile and guard, the effect of safety improvement by increasing the guard sheet thickness is proportional to the square of the thickness. However, it has not been clarified whether the same is true when the tip shape of a projectile is different e.g., conical shape with high penetration. In this study, the authors conducted collision experiments of the conical abrasive projectile against the rolled steel sheet guard with four types of thickness. The result revealed the effect of guard thickness on impact resistance is affected by the mechanical properties of a projectile in the case of collision of a conical projectile. When the thickness of the rolled steel sheet guard is 4.0mm or less, the effect of guard thickness for collision safety is approximately the square of the thickness.

Key words: grinding machine, wheel guard, abrasive products, collision energy, guard thickness, conical projectile

1. Introduction

A grinding wheel safety guard is one of the safety mechanism that is defined by the ISO standard for grinding machines [1]. Guards hold scattered abrasive fragments in the work zone when a high-speed rotating grinding wheel bursts. Therefore, a guard needs to have appropriate impact resistance for the safety of a machine tool operator.

The impact resistance of the grinding wheel guard is affected by the thickness. In the case of expected translational energy of the abrasive fragment is high, such as high-speed grinding, the grinding wheel guard should be thicker. In the guard thickness specification of the ISO 16089, which is the standard of a machine tools safety for stationary grinding machines, the impact resistance of a guard is calculated by the 2.7th power of a guard thickness and multiplying a factor for each guard material. In the author's previous study, the impact resistance in the collision of a cylindrical abrasive projectile is proportional to the square of the guard thickness and a multiplication factor for each guard material and abrasive product[2]. From these calculations, under the same experimental conditions, the effect of guard thickness on impact resistance does not appear to be affected by mechanical properties of guard and projectile. This is, however, is not examined in detail.

In the author's other previous study, the impact resistance in the collision of a conical abrasive projectile made of a white alumina abrasive product WA46H8V having 68 MPa compressive strength σ_m is approximately the 4th power of the guard thickness[3]. However, it has not clear the relation between a guard thickness and the impact resistance is affected or not by the compressive strength of a conical abrasive projectile.

In this study, the authors conducted collision experiments of a more hardened conical abrasive projectile against the rolled steel sheet guard with four types of thickness and investigated the safety performance of guards.

2. Tested materials

The white alumina abrasive product WA46O8V was selected for the material of the test projectile. Table 1 shows the relevant mechanical properties of this abrasive product. The density of WA46O8V is 2400 kg/m^3. This density is the same as ISO 16089's reference abrasive product of a guard thickness standard. The compressive strength of WA46O8V tested by Split - Hopkinson pressure bar method is 171 MPa under strain rate 250 s^{-1}.

The hot rolled steel sheet SS400 was selected for the test guard material. SS400 is a material commonly used as a guard in Japan and classified as the same guard material group as cold rolled steel sheet DC01 in the ISO 16089. Table 2 shows the relevant mechanical properties of SS400. These properties meet the requirements of guard material in ISO 16089.

3. Collision experiment

3.1. Experimental equipment

Figure 1 shows a schematic picture of the developed collision experimental equipment. An abrasive projectile collides roughly vertically to the center of the SS400 sheet. The thicknesses of

Table 1 Mechanical properties of abrasive product

	Density	Compressive strength
WA46O8V	2400 kg/m^3	171 MPa
WA46H8V [3]	2100 kg/m^3	68 MPa
ISO standard [1]	2400 kg/m^3	-

Table 2 Mechanical properties of guard material

	Tensile strength	Yield stress	Elongation
SS400(Hot rolled steel)	479 MPa	314 MPa	0.39
ISO standard [1]	>340 MPa	>215 MPa	>0.17

the SS400 sheet were 2.3, 3.2, 4.0 and 4.5 mm. The outer dimension of the test guard including a fixed area was 750 mm × 750 mm, and the exposed area dimension was 450 mm × 450 mm. The dimension of the exposed area was based on the safety evaluation criteria given in ISO 16089.

Figure 2 shows the conical abrasive projectile used for the collision experiments. The size of the projectile was ⌀ 90 mm × 220 mm. The conical angle was 90 degrees. The mass of the projectile was 2.8 kg.

3.2. Experimental evaluation criteria

Deformation patterns of the SS400 sheet after the collision experiment can be classified into three patterns, plastic deformation (○), crack generation without penetration (△), and penetration (×). The minimum impact energy under pattern (△) is defined as "minimum cracking energy E_{pmin}." In this study, the minimum cracking energy is the evaluation criterion of experimental results.

4. Experimental result

Figure 3 shows the relationship between the collision energy of the conical abrasive projectile made of WA46O8V (σ_m = 171 MPa) and the SS400 sheet thickness. The curve of the minimum cracking energy E_{pmin} was calculated by the least-square method using the minimum impact energy under pattern (△) of 2.3, 3.2 and 4.0mm thickness. As a result, E_{pmin} can be obtained by Eq.1.

$$E_{\text{pmin}} = 230.3 \cdot t^{1.75} \quad (1)$$

where t is thickness of the SS400 sheet (mm).

In the previous study, E_{pmin} of the conical abrasive projectile made of WA46H8V(σ_m=68 MPa) could be obtained by Eq.2 under the same guards thickness and calculation method as Eq.1[3].

$$E_{\text{pmin}} = 48.98 \cdot t^{4.28} \quad (2)$$

According to Eq.1 and Eq.2, the effect of guard thickness on minimum cracking energy is affected by projectile compressive strength. The effect of guard thickness in Eq.1 is approximately the square of the thickness. This value is almost equal to using cylindrical projectiles[2].

However, Eq.1 is incompatible with the results of 4.5 mm thickness. Figure 4 shows the fracture shape of the collided projectile. When the guard plate thickness was less than or equal to 4.0mm and the only plastic deformation occurred, the damage is only caused the top of a conical. This suggests that the crack of the guard is caused before the conical surface contacts. On the other hand, in the case of the impact energy is higher than Eq.1 at 4.5 mm thickness, the projectile is damaged not only on the top but also on the conical surface. This suggests that the crack of the guard 4.5 mm thickness or more is caused after the conical surface contacts. Therefore, the collision mechanism differs between 4.0 and 4.5 mm, and the safety improvement by increasing the guard thickness becomes more effective.

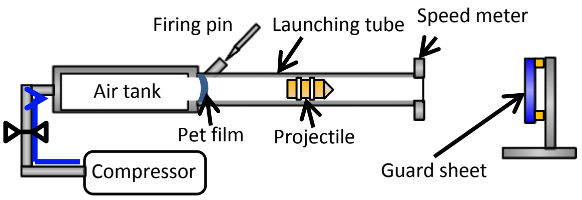

Figure 1 Schematic of developed collision experimental equipment

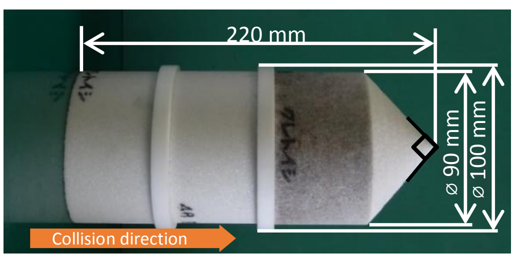

Figure 2 Photo of the conical type abrasive projectile used for the collision experiment (2.8 kg)

5. Conclusions

The following conclusions were obtained under the collision experiments using a 90 degrees conical abrasive projectile on SS400 sheet.

(1) The effect of safety improvement by increasing the guard sheet thickness is relatively small with a harder abrasive projectile.
(2) The minimum cracking energy is proportional to the approximately square of the guard thickness.
(3) The collision mechanism is different for guard thickness of 4.5mm or more, and the safety improvement by increasing the guard thickness becomes more effective.

Acknowledgements

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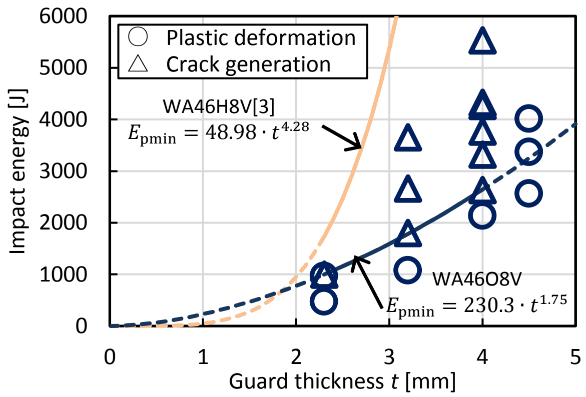
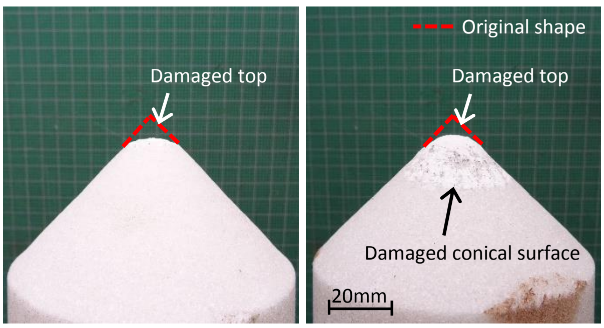


Figure 3 Effect of guard thickness on the minimum cracking energy



(a) t = 3.2 mm(1074 J) (b) t = 4.5 mm(4009 J)

Figure 4 The fracture shape of the collided projectile under pattern(○)