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Study on the protection performance of a grinding wheel safety guard made of polycarbonate plate

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Abstract
When a high-speed rotating grinding wheel bursts during grinding operations, abrasive fragments will be scattered with a high speed. Work zone enclosures are one of the most important safety mechanisms for grinding machines that protects machine tool operators from the scattered abrasive fragments. Generally the most part of the enclosures are made of steel plate, and windows are made of transparent polycarbonate plate, to observe grinding condition. Although, the collision mechanism of abrasive products against polymer materials such as polycarbonate plate has not been clarified yet. The authors made collision experiments of an abrasive projectile (WA46O8V) against polycarbonate plate and investigated the collision mechanism. As the results, impact resistance of polycarbonate plate is proportional to the square of the plate thickness. In addition, the required thickness of a polycabonate plate needs to be 5 times greater than of rolled steel (SS400) plate to obtain the same impact resistance.

Key words: grinding machine, wheel cover, abrasive products, polycarbonate, collision energy, cover thickness

1. Introduction

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

Generally the enclosures are made of steel plate, and windows of the enclosures are made of transparent polycarbonate plate, to observe grinding condition. In recent years, the transparent plate area of the enclosure has been increasing for improving operability and designability. Various studies have been conducted on a polycarbonate plate as an armor material [2], and its high impact resistance has been verified. However, the collision mechanism of abrasive products against polymer materials such as polycarbonate plate has not been clarified yet, because few collision experiments using a projectile made of brittle material have been conducted.

In this study, the authors made collision experiments of an abrasive projectile against polycarbonate plate using three different thicknesses and investigated the safety performance.

2. Tensile test of polycarbonate plate

Filstly, tensile tests were conducted on polycarbonate plates (TEIJIN, Panlite L-1250) used for collision experiments to obtain the mechanical properties, which average molecular weight was 25000 g/mol. The dimensions of the test pieces were 60mm in length for the parallel part, 10mm wide and 4mm thickness, which are based on the Japanese Industrial standard K 7139. The tests were conducted three times under strain rate $5.0\times10^{-2}s^{-1}$, using an Instron type testing system (Instron 5500R).

Figure 1 shows a typical nominal stress - nominal strain diagram of polycarbonate plate. The tested plate satisfies the minimum standards of mechanical property given in ISO 16089 [1] as shown in Table 1. The polycarbonate material has good elongation property. On the other hand, the polycarbonate hardly work hardens because yield stress and tensile strength are almost the same.

3. Collision experiment

3.1. Experimental equipment

Figure 2 shows a schematic of the developed collision experimental equipment. An abrasive projectile collides roughly vertically to the center of a polycarbonate plate.Thicknesses of polycarbonate plate, *t,* were 4.0, 5.0 and 8.0mm and outer size of the cover was 750mm × 750mm, and the exposed part size was 450mm × 450mm. The dimensions of the exposed part were based on the safety evaluation criteria given in ISO 16089 [1].

Figure 3 shows the cylindrical type abrasive projectile used for the collision experiments. Size of the projectile was φ 90mm ×

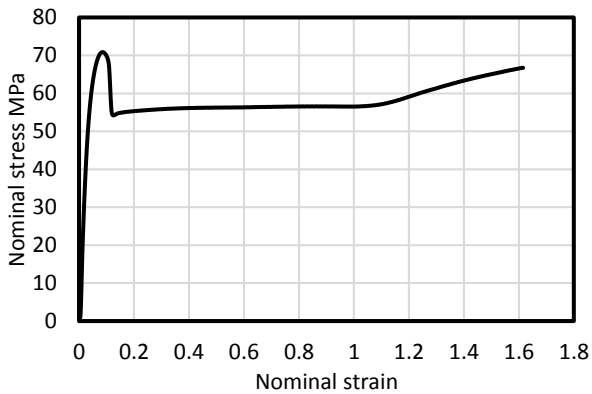

Figure 1 Stress-strain diagram of polycarbonate plate

Table 1 Mechanical properties of polycarbonate plate (*t*=4.0mm)

	Tensile strength	Yield stress	Elongation
Tensile test result	66.9MPa	70.7MPa	1.64
ISO standard [1]	>60MPa	-	>0.80

220mm. Material of the projectile is white alumina abrasive product (WA46O8V), which mass was 3.4kg.

3.2. Experimental evaluation criteria

Deformation patterns of the polycarbonate plate after the collision experiment can be classified into three patterns, plastic deformation (○), crack generation without penetration (△), and penetration (×). The impact energy under pattern (△) is defined as "border energy E_p ." In this study, the border energy is the evaluation criterion of experimental results.

4. Experimental result

Figure 4 shows a photo of fracture/deformation shape of the polycarbonate plate under "border energy." Deformation in the out-plane direction (*x* direction) due to the collision of the projectile reached the fixed frame, because a line shaped mark is formed on the outer edge of the exposed part. On the other hand, the surface shape of polycarbonate plate after the experiment excluding the vicinity of collided part maintained nearly original flat. Most of the deformation due to collision with a projectile is elastic deformation, and plastic deformation has generated only nearly in the vicinity of collide part.

Figure 5 shows the relationship between the collision energy of the abrasive projectiles and the polycarbonate plate thickness. The reproducibility of boundary energy E_p was confirmed at plate thickness *t* of 5 mm. As the result, the border energy is proportional to the square of the plate thickness. Therefore, the border energy E_p can be obtained by Eq. 1.

$$E_p = 53.13t^2 \quad (1)$$

where *t* is thickness of the polycarbonate plate (mm). The constant of Eq. 1 is calculated back from the experimental value of the border energy at the plate thickness of 8.0mm.

In the previous study, the effect of the cover thickness on the border energy of a rolled steel (SS400) plate can be described by Eq. 2[3].

$$E_p = 1387t^2 \quad (2)$$

From Eq. 1 and Eq. 2, in the collision of the abrasive projectile, effect of the plate thickness on border energy does not depend on whether the material is steel or polymer material. However, in order to obtain the same impact resistance as the rolled steel plate, the polycarbonate plate thickness needs approximately 5 times higher than rolled steel plate. Absorption of collision energy by a plate material largely depends on its plastic work [4], but polycarbonate plate had a narrow plastic deformation area caused by collision. For this reason, impact resistance of the polycarbonate plate is significantly lower than that of the rolled steel plate.

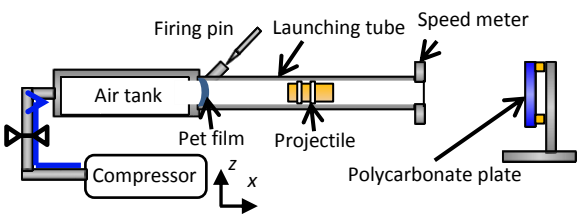

Figure 2 Schematic of developed collision experimental equipment

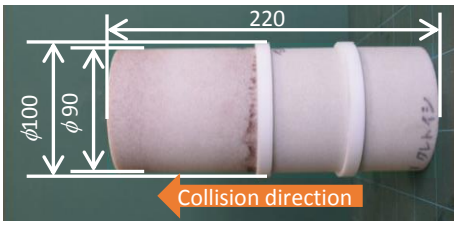

Figure 3 Photo of cylindrical type abrasive projectile used for the collision experiment (3.4kg)

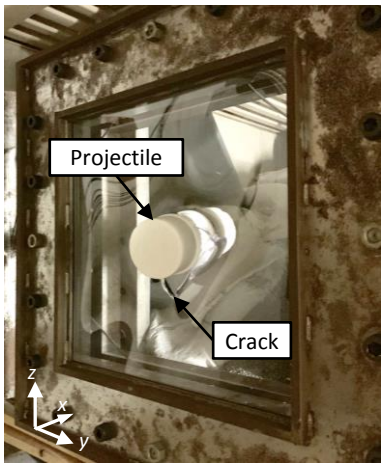

Figure 4 Fracture / deformation shape of the polycarbonate plate (*t* = 4.0mm) under "border energy"

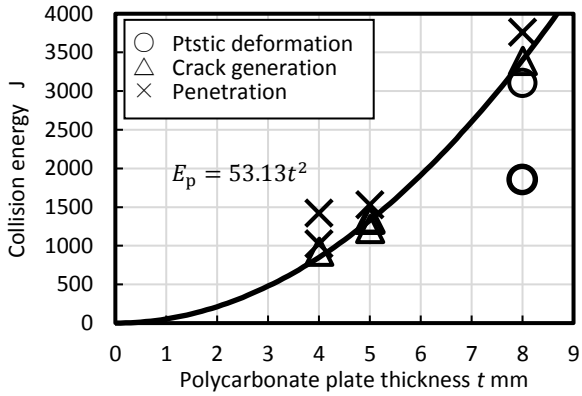

Figure 5 Effect of polycarbonate plate thickness on the border energy

5. Conclusions

The following conclusions were obtained under the collision experiments using an abrasive projectile on polycarbonate plate.

(1) The border energy is proportional to the square of the plate thickness.

(2) Thickness of polycarbonate plate needs approximately 5 times higher than rolled steel (SS400) plate.

(3) Plastic deformation of polycarbonate plate which absorb collision energy has generated only nearly in the vicinity of collided part.

Acknowledgements

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