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Effect of projectile tip shape upon safety-guard local damage of grinding machine

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Abstract
Safety of machine tools is one of the most important issues for production engineers. During grinding operations, disrupted abrasive products collide with wheel safety-guards. Not only kinematic energy but also shape and size of disrupted abrasive fragments are different. Therefore, the safety-guard material and thickness guidelines have to be indicated under scientific evidence. This paper investigates the effects of projectile tip shape upon safety-guard local damage. Adopted material of the projectile is white alumina abrasive products, WA46H8V. Three types of typical projectile tip shapes were chosen for the collision experiments: blunt type, hemispherical type and conical type in which the apex angle is 90 degrees. Rolled steel sheets for structural use with thickness of 2.3 mm were chosen for the target wall. Collision experiments were performed using the prototype collision experimental device. As a result, local damage of the target wall could be classified into three categories: bulging, through crack and complete penetration. The border between bulging and through crack is defined as the "safety border line". Experimental results showed that safety border line under the blunt and hemispherical tip shape projectiles was almost the same, on the other hand, that of the conical tip shape projectile was lower and the through crack area is distributed more widely.

Safety, machine tool, collision energy, safety guard, projectile, tip shape

1. Introduction

In recent years, the rotational speed of grinding wheels becomes faster and faster to pursue high efficient grinding. When disrupted grinding wheel fragments collide with the machine tool operators, tragic accidents will occur. Over-specification design of safety-guards results not only in increases to the manufacturing cost but also deteriorates operability of the machine tool. Therefore, machine tool safety-guard material and/or thickness guidelines based on scientific evidence must be indicated [1].

The authors built up the collision experimental device and performed collision experiments [2]. As a result, the damaged target wall can be classified into three categories: bulging, through crack and complete penetration. The border between bulging and through crack is defined as the "safety border line".

The safety border line under different wall materials and the effect of projectile speed and/or mass on local damage to the target-wall was investigated experimentally using blunt shape projectiles [3,4]. Over several experiments, it was clarified that the safety border line of target-wall thickness is proportional to the square of the target wall thickness.

This paper investigates effects of projectile tip shape upon safety-guard local damage.

2. Experimental setup

Figure 1 shows the schematic of the prototype experimental device for collision experiments. Collision energy is controlled by adjusting air pressure of the tank. Launching speed is measured by the laser sensors. Projectile orbit launched from the launcher is observed by a high-speed camera.

Material of the target-wall is a rolled steel sheet for structural use (SS400) with a thickness of 2.3 mm. Exposed size of the target-wall is 450 x 450 mm, which is rigidly tightened to the base stand using 20 bolts.

Material of the projectile is white alumina abrasive products, WA46H8V. Figure 2 represents the three kinds of typical projectile tip shapes chosen for the collision experiments: blunt type, hemispherical type and conical type in which the apex angle is 90 degrees. Projects colliding with the target-wall were launched without rotation.

Table 1 shows conditions of the collision experiments. The projectile mass change depending on the tip shape has been taken into account as kinematic energy of the projectile.

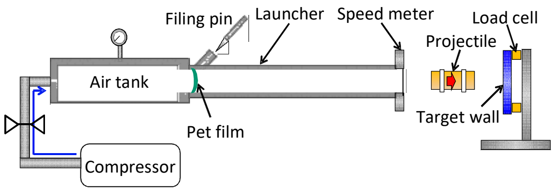


Fig.1 Schematic of experimental device for collision experiments

Table 1. Condition of the collision experiment

Material of projectile	WA46H8V
Mass of projectile [kg]	2.6-3.4
Target wall material	SS400
Target wall thickness [mm]	2.3
Kinematic energy of projectile [kJ]	0.5-14

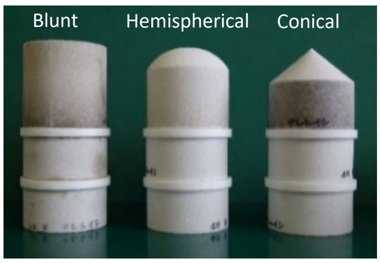


Fig.2 Projectile tip shape

3. Experimental results

3.1. Definition of "safety border line"

Figure 3 shows the effects of collision energy on the safety border line. The black-coloured symbol indicates the blunt tip shape projectile, blue-coloured symbol indicates hemispherical tip shape projectile and red-coloured symbol indicates conical tip shape projectile. The collision energy of safety border line, which is shown with the bold line in this figure, is given by the equation (1).

$$E_{pmin} = kt^2 \qquad (1)$$

Where E_{pmin} is the minimum collision energy at the safety border line, k is coefficient regarding tip shape and/or mechanical properties of the projectile and t is target-wall thickness.

From the experimental results, k under the blunt type, the hemispherical type and the conical type is given 1204, 1191 and 314, respectively. The safety border line under the conical tip shape projectile is the lowest. This means that, the conical type fragment is the most dangerous.

Each coloured region belt shows distribution of collision energy under the experiments. Collision energy of the conical type projectile is widely distributed compared to the blunt and/or the hemispherical type projectile. The reason for this is that, during the collision process, contact area between projectile tip and target wall is increasing. The projectile will charge until energy balance between the projectile fractured and the target wall strength are equal. The projectile fracture energy increases with the increase of contact area. When the projectile fracture energy becomes larger than target wall strength, the target wall will be entered and cracks.

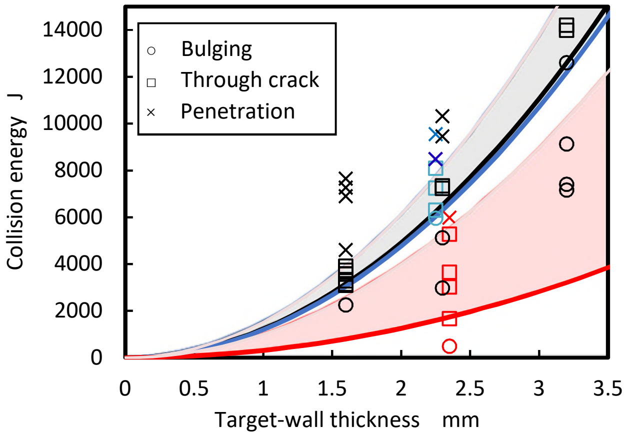
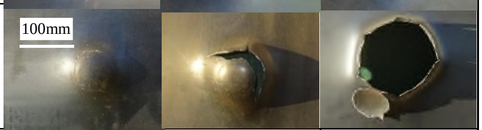


Fig.3 Collision energy and target-wall safety thickness (Hemispherical and Conical projectile)

Table 2 Target wall damage (Conical tip shape projectile)

Damage grade	Bulging (○)	Though crack (□)	Penetration (×)
Collide surface			
Back surface			
Kinematic energy	1660 J	3664 J	5272 J

Table 3 Target wall damage (Hemispherical tip shape projectile)

Damage grade	Bulging (○)	Though crack (□)	Penetration (×)
Collide surface			
Back surface			
Kinematic energy	6300 J	7241 J	9554 J

3.2. Observation of target wall local damage

Local damage of the target-wall using different tip shape projectiles can be classified into three categories: bulging (○), through crack (□) and complete penetration (×). Tables 2 and 3 show target-wall typical damage after the collision experiments using conical and hemispherical tip shape projectiles. As shown in Table 2, even the conical projectile with smaller kinematic energy results in larger damage to the target wall. That is, conical tip shape type projectile collision energy under the safety border line is smaller than that of the blunt type and/or the hemispherical tip shape projectile.

4. Comparison of the previous study under right projectile investigation of collision energy

Dr. Ohote investigated the effect of projectile tip shape on target-wall damage using solution treatment stainless steel projectiles (SUS304) [5]. Under experimental and theoretical investigations, the safety borders are affected by the projectile tip angle. The coefficient of collision shape factor is given as shown in the lower line of Table 4 when blunt shape projectile number is 1.

The authors investigate projectile tip shape effect using the experimental results. Obtained results are almost same as Dr. Ohote's paper. That is, collision energy of safety border line using abrasive products projectile is affected by the tip shape.

Table 4. Coefficient of collision shape factor

	Blunt	Hemispherical	Conical
k	1204	1191	314
Experiments	1	0.99	0.26
Equation [2]	1	1	0.15

5. Conclusions

The following conclusions were obtained under collision experiments using different tip shape types of projectiles on a rolled steel sheet for structural use. Collision energy under blunt and hemispherical tip shape type projectile is almost the same; on the other hand, conical tip shape type projectile is smaller. Range of safety border under conical type projectile is widely distributed.

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