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Foreword

Alhamdulillah. First of all a big thank you and congratulations to the Editorial Board of *Esteem Academic Journal* of Universiti Teknologi MARA (UiTM), Pulau Pinang for their diligent work in producing this issue. I also would like to thank the academicians for their contributions and the reviewers for their meticulous vetting of the manuscripts. A special thanks to University Publication Centre (UPENA) of UiTM for giving us this precious opportunity to publish this first issue of volume 5. In this engineering issue we have upgraded the standard of the manuscript reviewing process by inviting more reviewers from our university as well as other universities in Malaysia. We have embarked from previous volume to establish a firm benchmark and create a journal of quality and this current issue remarks a new height of the journal quality. Instead of publishing once in every two years, now *Esteem* publishes two issues annually.

In this issue, we have compiled an array of 13 interesting engineering research and technical based articles for your reading. The first article is entitled "The Response of Tube Splitting on Circular Tubes by Using Various Types of Semi-angles Dies and Slits". The authors, Mohd Rozaiman Aziz and Roslan Ahmad investigated the axial splitting and curling behavior of aluminum circular metal tubes which was compressed axially under static loading using three types of dies with different semi-angles. The authors concluded that the introduction of slit to the specimen is necessary to initiate slitting rather than inversion.

Salina Budin, Aznifa Mahyam Zaharudin, and Sugeng Priyanto presents a model of energy conversion and impact energy generation during collision based on free falling experiment, which is closely resembles direct collision between ball and inner wall of the vial. Simulation results from the proposed impact energy model demonstrated that the impact energy generated during the collision is strongly influenced by the thickness of the work materials and reaches zero at certain value of the work materials thickness, which increases with an increase of falling height.

Salina Alias, Caroline Marajan and Mohamad Azrul Jemain wrote an article that looks at adsorption of zinc from waste water using bladderwort (*Utricularia vulgaris*). In batch adsorption studies, data show that dried bladderwort has considerable potential in the removal of metal ions from aqueous solution. The fourth article written by

Muhammad Khusairi Osman et al. looked at 3D object recognition using affine moment invariants and Multiple Adaptive Network Based Fuzzy Inference System (MANFIS). The experimental results show that Affine Moment Invariants combined with MANFIS network attain the best performance in both recognitions, polyhedral and free-form objects.

The article entitled "Construction Waste Management Methods Used by Contractors in the Northern Region" authored by Siti Hafizan Hassan, Nadira Ahzahar and Mohd Nasrul Nizam Nasri reports an ongoing study on the use of construction waste management methods by contractors and its impact on waste reduction in the Northern Region. In conclusion, the sizing and amount of materials to be ordered to reduce wastage is significant in reducing construction waste generation waste, alleviating the burden associated with its management and disposal. The sixth article by Muhammad Sofian Abdullah et al. examined on the performance of Performance of Palm Oil Fuel Ash (POFA) with lime as stabilizing agent for soil improvement. The authors concluded that POFA can be used to treat the silty soil as well as to reduce the environmental problem.

The seventh article penned by Soffian Noor Mat Saliah, Noorsuhada Md. Nor and Megat Azmi Megat Johari presents the results of an experimental study on the interfacial bond strength (IBS) of polypropylene fiber concrete (PFC). It was found that the interfacial bond strength between concrete and reinforcement bar was not affected by the inclusion of polypropylene fibers. However, concrete containing fibers exhibited no breaking of concrete and no debonding of reinforcement. The article by Juliana Zaabar and Rusnani measures, evaluates and analyzes the network link performance of fiber optic cable using OTDR. The authors suggested that the major loss for these measurements is connector loss. Preventive maintenance will increase the life time of fiber optic. From some of the findings, the PVC dust cap has been identified as a main source of contamination for the SC connector.

The article entitled "Symbolic Programming of Finite Element Equation Solving for Plane Truss Problem" by Syahrul Fithry Senin proposed a plane truss problem to be solved by finite element method using MAPLE 12 software. The numerical solution computed by the author was almost matched with the commercial finite element software solution, LUSAS. The tenth article by Nor Azlan Othman, Nor Salwa Damanhuri and Visakan Kadirkamanathan presents a detail review of fault diagnosis in rotating machinery using pattern recognition technique. The authors proposed a solution based on artificial neural network (ANNs) which is Multi-Layer Perceptron (MLP). The authors concluded that the proposed methods are suitable for rotating machinery on fault detection and diagnosis.

The eleventh article is entitled "RAS Index as a Tool to Predict Sinkhole Failures in Limestone Formation Areas in Malaysia". Damanhuri Jamalludin et al. found that, using the RAS classification method, the prediction of sinkhole occurrences can be easily be made by simply knowing the weekly rainfall especially in areas having limestone as the bedrock. The twelfth by Muhammad Hafeez Osman et al. explores cases regarding the histories of rock slope repair and stabilization of unstable boulder along the road from Bukit Cincin to Genting Highland and along the road from Gap to Fraser Hill. The last article is "Soil Nail and Guniting Works in Pahang". The authors, Damanhuri Jamalludin et al. concluded that if the stability of the embankment needs to be improved, soil nails can be installed and embankment surface can be covered with gunite to prevent erosion.

We do hope that you not only have an enjoyable time reading the articles but would also find them useful. Thank you.

Mohd Aminudin Murad
Chief Editor
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Modeling of Impact Energy Generated by Free Falling Ball

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ABSTRACT

As a common practice in Mechanical Alloying (MA), the mixture of the work materials to be alloyed is placed in a container together with relevant milling medium. The vial and the charge materials are then moved in such a manner to create kinetic energy on the charge materials in the vial. Upon the collisions of the charge materials against each other as well as against the wall of the vial, kinetic energy is converted into impact energy. This impact energy is absorbed by the work materials which are repeatedly flattened, cold welded, fractured and re-welded – important mechanisms in MA. Since MA process utilizes energy generated by impact, it is important to understand the way on how kinetic energy of charged materials is transferred into impact energy. Four events of collision have been identified in the ball milling process: direct collision between balls, collision with sliding between the balls, direct collision between the balls and inner surface of the vial as well as collision with the sliding between the balls and inner surface of the vial. However, the most effective impact event is direct collision between the balls and inner surface of the vial. This paper presents a model of energy conversion and impact energy generation during the collision based on free falling experiment, which is the closest resemblance to the direct collision between the balls and the inner wall of the vial.

Keywords: *Mechanical Alloying, impact energy, collision, free falling*

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Introduction

Mechanical Alloying (MA) is a solid-state alloying process resulting from a repetitive cold welding and fracture of a mixture of work materials being alloyed, which is usually found in a powdery form. These repetitive cold welding and fracture of the mixture are promoted by the energy, which is created by impact (Suryanarayana, 2001; Eskandarany, 2001). MA offers a unique processing route and does not require melting. Through this process, work materials to be alloyed are synthesized at above room temperature without any additional heating. Thus, it is the most effective method to produce alloyed materials, which are previously difficult to synthesize using common metallurgical techniques. Today, the application of MA process extended to the synthesis of advance materials and nano-materials, besides being an effective technique in producing alloyed materials with interesting properties.

The process is initialized by mixing two or more different materials in a certain proportion. These materials are then loaded into a vial together with a number of suitable balls as milling medium. The mixture is subjected to high energy collisions created by the balls and the work materials as the vial moved. Due to the collisions, the work materials are flattened, cold-welded, and fractured repetitively to form layers of composites known as lamellar structures (Suryanarayana, 2001). As the process continues, cold welding and fracturing events take place leading to microstructural refinement.

The direct impact between a ball and a vial is an important event and has been extensively studied. The coefficient of restitution, reflecting the capacity of the contacting bodies to recover from the impact and the extent of energy losses during impact, the impact force and characterizing the severity of impact have been the focus of the studies conducted (Harris, 2002). A number of models related to the impact and collision events have been developed. Benjamin (1992) modeled a single collision based on material response of the powder, which was treated as one or more particles of 100 μm height and diameter. The collision times were then calculated. In another model, Lu, Lai and Zhang (1995) declared that the deformation of powders between two balls or between a ball and the inner wall of the container during collision events is alike to that in an upset forging between two parallel plates. Because of work hardening of the powders, the yield shear stress is actually a function of deformation strain.

Magini, Iasonna and Padella (1996), simplified the impact events into two different elemental mechanical actions: collision when milling is conducted with a limited number of balls and attrition when milling is carried out in a container filled with balls. The kinetic energy dissipated during the impact event is mainly transferred into heat, which increases the temperature of the work materials and the milling tools. A minor fraction of it is stored in the materials as structural disorder.

Lu and Man (1998) had reviewed the impact between two balls having the same radius and concluded that the deformation strain of the work materials depended upon the value of the center-to-center approach of the balls. Based on the work, the greatest strain must be at the circumference of the particle where the edge fracture is initiated and the greatest strain is at the centre of contact where the crack inititiation takes place. In another study, they have modelled a collision involving powder entrapped between grinding media. They observed that a collision between grinding balls coated with powder was similar to a Hertzian collision between uncoated balls.

Huang, Dallimore, Pan and McCormick (1998) measured the loading experienced by powder during a ball vial collision using free falling experiment. They concluded that the impact force is an important parameter to evaluate the impact with milling condition such as impact velocity, ball size and powder thickness. It was also found that the impacts are significantly influenced by the presence of powders. Reichardt, Adam and Wiechert (2005) introduced collision response model and compared it to classical approaches and concluded that the energy dissipation during collision and the coefficient of restitution are velocity independent.

In other simulation work, Mio, Kano, Saito and Kareko (2002, 2004) reported that the grinding rate is well correlated with the specific impact energy. It is observed that the normal component of this impact force is a key factor for estimating mechanical milling (MM) yields. Consequently, high frequency impact has to be employed to generate high impact energy.

In this work, free falling experiment using milling ball was used to model the energy conversion and impact energy generated during the collision. Energy which was lost mainly due to ball bouncing and friction between the work material particles was also considered. Based on the theoretical modeling developed, the influences of the thickness of work materials and the falling height on the impact energy generated during the collision for various sizes of milling balls were studied and analyzed.

Modeling of Impact Energy

The schematic illustrating the free falling apparatus is shown in Figure 1. A milling ball with mass, m, is placed at height, h. The ball is then released to freely fall into a stainless steel container containing work materials.

At the height of h, the potential energy, E_u, of the ball is,

$$E_u = mgh \tag{1}$$

where g is gravity acceleration. When the ball is released from its platform, the ball will freely fall and travel towards the surface of work materials. The potential energy diminishes due to the decrease of h while the kinetic energy of the ball increases due to the increase of the velocity of the ball. When the ball is just about to hit the surface of the powder mix ($h \sim 0$ mm), the potential energy of the ball approaches zero. At this situation, the kinetic energy of the ball is in its maximum value. The energy conversion can be expressed as:

$$E_u = E_k \tag{2}$$
$$mgh = ½\, mv^2 \tag{3}$$

where v is the velocity of the ball.

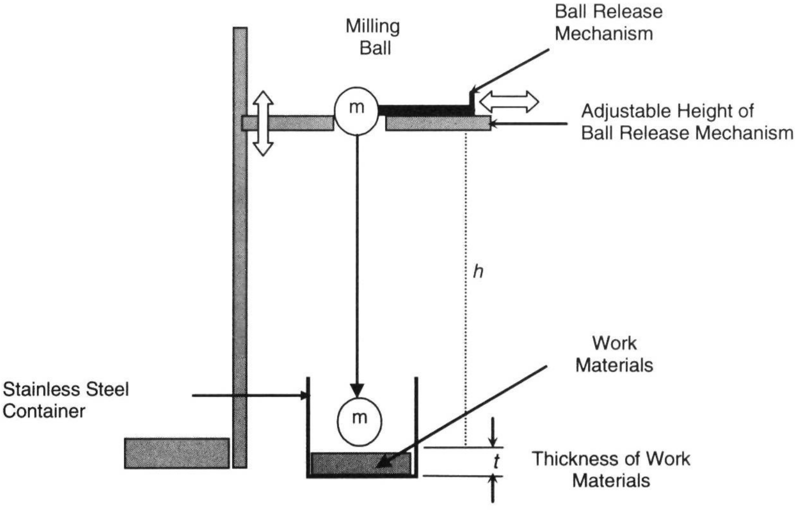

Figure 1: The Schematic Illustration of Free Falling Ball Apparatus Setup

Collision Without the Present of Work Materials

Consider stainless steel container without the present of work materials. When the milling ball is released from height, *h*, collision will occur between the ball and the base of stainless steel container, as illustrated in Figure 2.

During the collision, the kinetic energy of the ball will be converted to impact energy. However, only a partial of the kinetic energy is converted into impact energy (Misra, 2003; Kwon, Gerasimov & Yoon, 2002) while the rest is lost mostly due to ball bouncing. The energy conversion can be expressed as:

$$\tfrac{1}{2} mv^2 = E_i + E_{bb} \tag{4}$$

where E_i is the impact energy and E_{bb} is the energy lost due to ball bouncing. E_{bb} can be expressed in terms of coefficient of restitution, *e*, whereby

$$E_{bb} = e^2 E_k \tag{5}$$

Thus, the impact energy, E_i can be determined by the equation

$$E_i = E_k(1 - e^2) \tag{6}$$

Assuming that the collision is perfectly elastic with no deformation occurred on the stainless steel container base, E_i is finally dissipated as internal vibrations and waves in the stainless steel container (Brach, 1991).

Collision with the Presence of Work Materials

In contrast, consider the stainless steel container containing work materials. At height *h*, a milling ball will experience potential energy

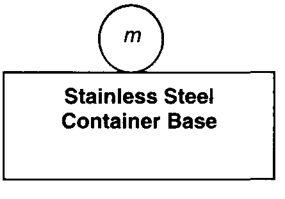

Figure 2: Illustration of Collision between the Ball and the Base of Stainless Steel Container

similar to equation 1. When the ball falls freely, potential energy will be converted to kinetic energy as expressed in equation 3. At $h = 0$, the ball will start to be in contact with the work materials. Since the work materials contains an infinite number of tiny particles which is similar to a loose and non-cohesive granular medium, the ball would be able to move and penetrate through the work materials causing the splashing and flowing of the work materials. The model of the collision process can be illustrated as Figure 3.

During the motion of the ball falling through the work materials, a partial of the work materials is trapped between the ball and the base of the stainless steel container as shown in Figure 3(b). The trapped work materials will continuously be pressed to the base of the stainless steel container. As the ball moves in the work materials, the velocity of the ball will decelerate due to the frictions between the ball and the work materials and drag force which acts on the opposite direction. At the end of the collision process, the trapped work materials is finally agglomerated as shown in Figure 3(c) and form a 'powder flake' as shown in Figure 4. During the process, some of the kinetic energy of the ball will be converted to impact energy and the remaining is lost mostly to due to the friction, drag and ball bouncing. The impact energy would be absorbed by the flake which is repeatedly flattened, cold welded, fractured and re-welded, deformed and re-welded.

Mathematically, the energy conversion in the collision process can be written as:

$$E_k = E_{il} + E_{bbl} + E_f + E_s \tag{7}$$

$$E_i = E_k - E_{bbl} - E_f - E_s \tag{8}$$

where, E_{il} is the impact energy generated in the collision; E_{bbl} is the energy lost due to ball bouncing; E_f is the energy lost due to friction

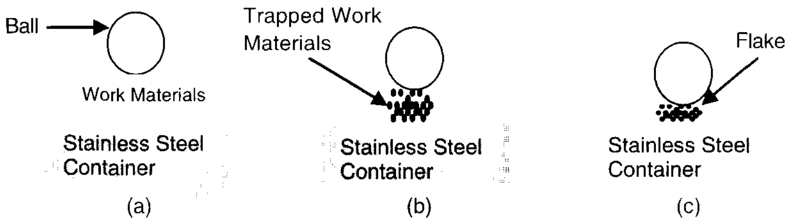

Figure 3: Model of the Collision Process

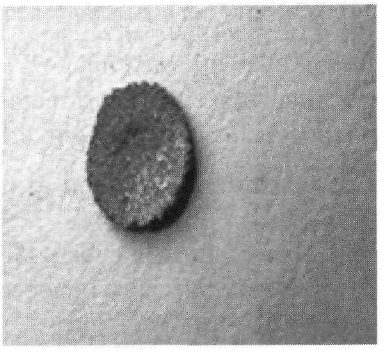

Figure 4: Powder Flake

between the ball and work materials; and E_s is the energy lost due to inertial drag of the ball during the penetration motion of the ball through the work materials.

The energy lost due to ball bouncing, E_{bbl} can be determined by:

$$E_{bbl} = E_k (1 - e_1^2) \tag{9}$$

where e_1 is the coefficient of restitution at specific work materials height, t. The energy lost due to friction and drag can be established based on Poncelet model (Cimarra, Lara, Lee & Goldman, 2004; Tsimring & Volfson, 2005; Katsuragi & Durian, 2007). The force acting on the ball which passes through the work materials can be expressed by:

$$\Sigma F = - mg + F(z) + mv^2/d_1 \tag{10}$$

where mg is the force due to gravity; $F(z)$ is the friction force (F_f); mv^2/d_1 is the inertial drag force (F_s); v is the impact velocity of the ball; and d_1 is the impact penetration. The friction and inertial drag force can be simplified as:

$$F_f = c\mu\rho_g g D_b^2 \tag{11}$$

$$F_s = \sqrt{(1 - e_1^2)}\ \rho_g v^2 D_b^2 \tag{12}$$

where c is a contant; μ is the coefficient of friction; ρ_g is the density of work materials; D_b is the ball diameter; and e_1 is the coefficient of restitution at specific work materials thickness. Thus, energy loss due to friction and drag between the ball and work materials, E_{f+s}, can be represented as:

$$E_{f+s} = (F_f + F_s)t \tag{13}$$

where t is the thickness of the work material.

In formulating the model, the energy lost mainly by ball bouncing, friction and drag is taken into consideration with the assumption that:

1. No deformation occurred to the ball and to the base of stainless steel container.
2. No energy is transferred to the work materials as kinetic energy. Thus splashing of work materials does not occur.

Computer Simulation

Table 1 lists the parameters and their values or variation ranges used in the simulation. The simulation was conducted using Matlab 6. The milling balls used in the study are made of stainless steel in various sizes which are commonly used in mechanical milling. The falling height varies from 0.5 m to 2.0 m to obtain impact velocities of 3.13 ms^{-1}, 4.43 ms^{-1}, 5.42 ms^{-1} and 6.26 ms^{-1} respectively. The density of the work materials are obtained by measuring the mass of the work materials in 10 ml volumes.

Table 2 shows the coefficient of restitution used in the simulation for various work materials thickness. The values were determined by the parameter fitting method reported previously (Huang et al., 1998). Previous studies have shown that the coefficient of restitution decreased as the impact velocities which is represented by falling height increased (Mangwandi, Cheong, Adam, Hounslow & Salman, 2007). However, to simplify, the coefficient of restitution listed in Table 2 remains unchange at various falling height.

Table 1: Input Parameters of the Computer Simulation

Parameters	Values or variation ranges	
Ball size (mass & diameter)	D_b = 23.8 mm	m = 55.03 g
	D_b = 25.3 mm	m = 66.77 g
	D_b = 26.3 mm	m = 73.27 g
	D_b = 28.5 mm	m = 95.1 g
G	9.81 m/s^2	
H	0.5 m, 1.0 m, 1.5 m, 2.0 m	
C	100	
$\grave{I}$	0.5	
ρ_g	575 kg/m^3	
T	1, 2, 3, 4, 5, 6, 7, 8, 9, 10 mm	

Table 2: Coefficient of Restitution for Various Work Materials Thickness

Work materials thickness, t	Coefficient of restitution, e_1
1	0.28
2	0.19
3	0.14
4	0.10
5	0.09
6	0.08
7	0.07
8	0.06
9	0.06
10	0.05

Results and Discussion

Influence of Ball Mass

Figure 5(a) shows the the impact energy generated obtained from computer simulation as a function of work materials thickness for falling height, 0.5 m. For all the sizes of the ball used in the simulation, the magnitude of the impact energy decreases with an increase of work materials thickness. When the ball crashes into the work materials, the natural characteristic of the work materials, which behaves like a fluid, allows the ball to penetrate through the work materials. During the penetration, the ball will experience deceleration on the velocity due to the friction and drag force that occur between the ball and work materials. Increasing the thicknesss of the work materials will increase the friction and drag and thus reduce the impact energy generated. This finding correlates with previous simulation conducted by Feng, Han and Owen (2004), which found that the presence of the metal work reduces the impact forces and extends the impact duration. In addition, Huang et al. (1998), reported that the increase of the powder thickness will reduce the impact force which leads to the decrease of impact energy because some of the impact energy is used to rearrange and slide the grains in the powder at the onset of impact (Alkebro, Colin, Mocellin, Warren, 2002).

A further discussion of the results of the simulations is the impact energy generated by various sizes of ball. As shown in the Figure 5 the trend remains valid for different sizes of ball. However, the magnitude

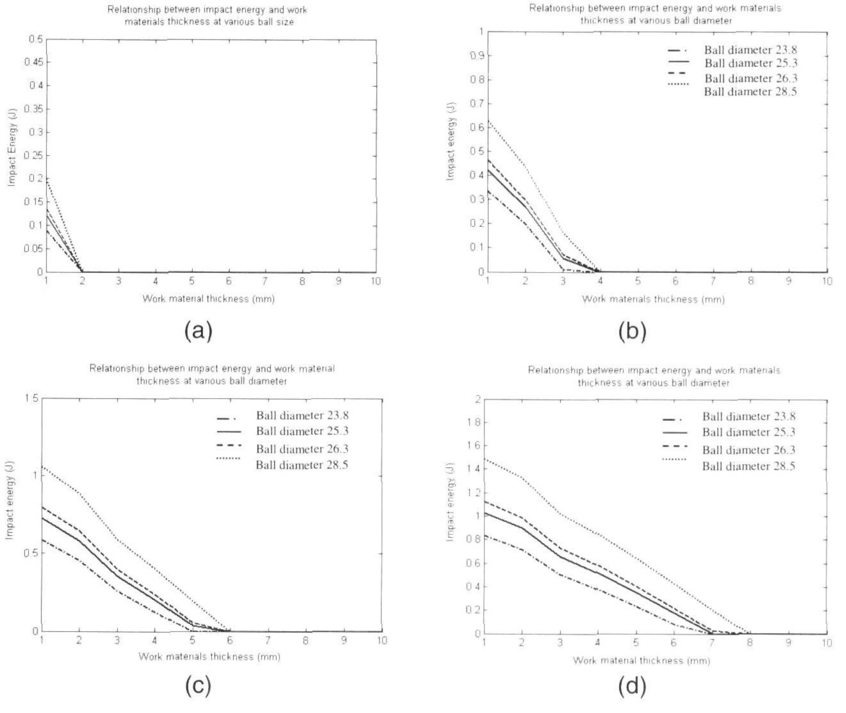

Figure 5: Impact Energy as a Function of Work Materials Thickness for Various Falling Heights: (a) 0.5 m (b) 1.0 m (c) 1.5 m (d) 2.0 m

of the impact energy increases with the increase of the ball sizes. As the size of the ball increases, the weight of the ball increases and more impart energy is generated (Suryanarayana, 2001). Although the magnitude of impact energy generated differs for different ball sizes, the impact energy decreases and reaches zero at the same point, namely when the thickness of work materials is at 2 mm. When the thickness increases above 2 mm, most of the kinetic energy of the milling ball is used to overcome the friction and drag between the milling ball and work materials. The milling ball no longer possesses the necessary energy to break the work materials. Breakage and/or deformation will not occur and the work materials will only undergo compaction process.

Influence of Free Falling Height

Similar trend is observed at falling heights of 1.0 m, 1.5 m and 2.0 m as shown in Figure 5(b)-(d) whereby the impact energy decreases with an increase of work materials thickness. However the magnitude of the impact increases as the falling height increases. For example, for a ball with the diameter of 28.5 mm, the impact energy on work materials with a thickness of 1 mm is approximately 0.19 J, 0.62 J, 1.1 J and 1.5 J for the falling heights of 0.5 m, 1.0 m, 1.5 m and 2.0 m respectively. At higher falling height, potential energy of the ball is higher and collision will occur at higher impact velocity. Thus, high impact energy could be produced.

It was also observed that, the impact energy will reach zero at higher work materials thickness as the falling height increases. At the falling height of 0.5, the impact energy will reach zero at work materials thickness of 2 mm. However, the value increases to 3 mm (for ball diameter 23.8 mm) and 4 mm (for ball diameter 25.3 mm, 26.3 mm and 28.5 mm) for falling height of 1.0 m. The summary of work materials thickness at where the impact energy reaches zero is listed in Table 3.

Based on the simulation output, the optimized condition for mechanical milling can be achieved by keeping the work material thickness minimum. However, if the work materials is very low, the amount of work materials trapped between the ball and the stainless steel container will be minimum, resulting in low breakage output. The effect will be more dominant if the impact velocity is higher. In addition, the work materials could be excessively splash out and less or no work materials will be trapped in the collision and resulted in unnecessary collision between ball and stainless steel container. Thus, the possibility of wear on the stainless steel container can increase and affect the quality of the processing work materials due to contamination from worn material.

Table 3: Thickness of the Work Materials When the Impact Energy Reaches Zero

Falling height (m)	Thickness of the work materials when the impact energy reaches zero
0.5	2 mm
1.0	3 mm (for ball diameter 23.8 mm) 4 mm (for ball diameter 25.3 mm, 26.3 mm and 28.5 mm)
1.5	5 mm (for ball diameter 23.8 mm) 6 mm (for ball diameter 25.3 mm, 26.3 mm and 28.5 mm)
2.0	7 mm (for ball diameter 23.8 mm and 25.3 mm) 8 mm (for ball diameter 26.3 mm and 28.5 mm)

Conclusion

This paper describes some computer simulation results related to mechanical milling and illustrate the complex role of work materials thickness in generating an impact during collision. Simulation results from the impact energy model proposed demonstrated that the impact energy generated during the collision is strongly influenced by the thickness of the work materials. It reaches zero at certain value of work materials thickness which increases with an increase of the falling height. At this stage all supply energy is completely dissipated to overcome friction and drag. Maximum impact could be gained at low work material thickness.

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