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Impact behaviors of SS400 by spherical and tetrahedral solid particle through Finite Element simulation

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Erosion is a kind of material degradation, which is largely caused by solid particle impacts, so research on impact behaviors by solid particle is very important. In this study, the impact behaviors of SS400 when impact angles ranges from 10deg to 90deg was investigated by Finite Element (FE) simulation. Sphere and tetrahedron were selected as shapes of solid particles. The FE models were established in explicit dynamic software ANSYS/LS-DYNA. Erosion tests were also conducted to verify the FE results. It can be found that the Von Mises stress curve and erosion rate curve under different impact angles have same tendency, and the Von Mises stress of tetrahedral particle impact is much higher than that of spherical particle impact, with highest value occurring when impact angle is around 20~40deg.. The simulation results agrees with erosion tests results.

Keywords: *Erosion, Sphere, tetrahedron, Finite Element (FE) simulation, Erosion test*

1. Introduction

Erosion by solid particles impact has been a serious problem in many industrial fields, such as machinery, metallurgy, energy, chemistry and aviation etc.. Erosion is caused by large amount of solid particles impact on the surface of material, not caused by single particle impact, but single particle impact is fundamental for the research on erosion of material, and has been conducted widely in previous researches [1-3].

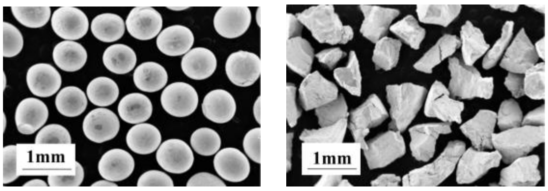
In this study, impact behaviors of ductile material SS400 by single spherical and tetrahedral particle impact was investigated by Finite Element (FE) simulation. The 3D FE model including solid particle and workpiece were established in explicit software ANSYS/LS-DYNA. Through analyzing the Von Mises stress after impacting under different impact angles, the impact behaviors of SS400 impacted by spherical and tetrahedral solid particle under different impact angles were studied. Erosion tests were also conducted to verify the FE simulation results.

2. Erosion tests

In erosion tests, spherical and angular steel grits were used as erodent particles, which were shown in Fig. 1. Test conditions were summarized in Table 1. The specimens were weighed using an electronic scale before and after tests to get the mass loss during erosion. Volumetric erosion rate was used to measure the erosion, its formula were given below:

$$E_V = (m_0 - m_1)/\rho M$$

E_V: Erosion rate, (cm^3/kg)
m_0: mass of specimen before test, (kg)
m_1: mass of specimen after test, (kg)
ρ: density of specimen, (kg/cm^3)
M: mass of erodent particles, (kg)



(a) Spherical grits (b) Angular grits

Fig. 1 Appearance of steel grits

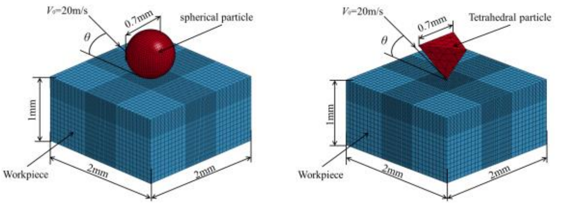
Table 1 Erosion test conditions

Test variable	Test condition
Dimensions of specimen	10×10×12.5mm
Velocity of erodent particles	20m/s
Average diameter of steel grits	700μm
Hardness of steel grits	420 HV1
Erosion angle	10, 20, 30, ～90deg.
Test duration	3600s
Test temperature	Room temperature

3. FE simulation

The FE models and its dimension are shown in Fig.2. In simulation, the impact area on workpiece was refined to improve its accuracy of simulation results. Nodes on all the surfaces of workpiece except upper surface were fixed, solid particle impacted on the upper surface of workpiece.

Bilinear Kinematic Hardening was selected as the constitutive model of SS400. The solid particle is rather harder than workpiece, so it was set as rigid body to improve the computing speed. The material parameters are listed in Table 2. The friction coefficient between solid particle and workpiece was set as 0.1. The initial velocity of solid particle is 20m/s. The impact angle θ ranged from 10deg to 90deg in an interval of 10deg. The simulation time of sphere impact and tetrahedron impact is set as 0.01ms and 0.05ms respetively.



(a) Sphere impact (b) Tetrahedron impact

Fig. 2 FE models and dimension

Table 2 Material Parameters

Parameter	Workpiece (SS400)	Particle (Rigid body)
Density(kg/m^3)	8000	8000
Young's Modulus(GPa)	210	210
Possion ratio	0.3	0.3
Yield stress(GPa)	0.2	—
Tangent Modulus(GPa)	0.2	—
Hardening parameter	1	—

4. Results and discussion

Von Mises stress of FE simulation under different impact angles are shown in Fig. 3, it can be seen that the Von Mises stress of tetrahedral particle impact is much higher than that of spherical particle impact. That is because in tetrahedral particle impact, the solid particle impacts on the workpiece with its angular point, so kinetic energy of tetrahedral particle is concentrated on a very small impact area, however in spherical particle impact, the impact area is a part of spherical surface, which is much larger than impact area of tetrahedral particle impact.

Stress is a cause to make erosion occur, the higher stress, the more erosion, therefore erosion of angular particle impact is more than that of spherical particle impact. The erosion rate under different impact angles are shown in Fig. 4.

The curves tendencies of Fig. 3 and Fig. 4 are roughly same, the curves of angular/tetraheral particles impact show much more changeable than those of spherical particles impact. The highest value of all curves occur around 20~40deg.

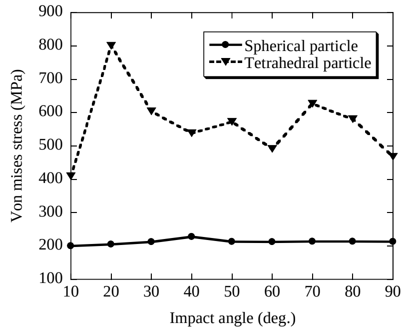


Fig. 3 Result of FE simulation

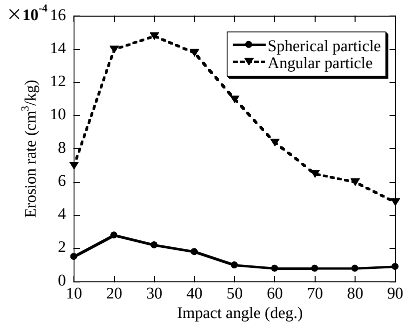


Fig. 4 Result of erosion tests

The difference between erosion tests and FE simulation comes from following reasons: (1)In erosion test, workpiece was impacted by large number of erodent particles, but in FE simulation, workpiece was impacted by single solid particle. (2)In erosion test, the shapes of angular particles was diverse, but in FE simulation, the shape of angular particle was simplified as regular tetrahedron.

5. Conclusions

The impact behaviors of SS400 impacted by spherical and tetrahedral particles were studied through FE simulation. The Von mises stress of tetraheral particles impact is higher than that of spherical particles impact, with highest Von Mises stress occurring when impact angle is around 20~40deg. The simulation results agrees with erosion tests results.

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