

## Effect of reinforced particle shape on the failure behavior of TiC/AZ91 Composites

Shao Letian<sup>1,a</sup>, Yao Junping<sup>2,b</sup>, Hu Qiyao<sup>3,c</sup>, Huang Kaixin<sup>4,d</sup>, Sun Zhong<sup>5,e</sup>

(School of Aeronautical Manufacture Engineering, Nanchang Hangkong University ,

Nanchang 330063)

Slt-6535@outlook.com

yyyjpsz@126.com

**Keywords:** Finite element simulation; Magnesium matrix composites; Failure

**Abstract :** Using image processing, recognition technology and edge extraction technology, the real particle morphology and distribution of TiC/AZ91 composites are obtained, and the finite element numerical calculation model with different particle shapes is constructed. With the help of ANSYS finite element software, the stress distribution and the maximum strain value of TiC/AZ91 composites under the shape of different reinforced particles were studied, and the influence rules and mechanism of the material on the failure behavior of the materials were discussed. The results show that compared with the round particles, the square particles are prone to plastic damage and lead to failure of magnesium matrix composites.

### Introduction

Particle reinforced metal matrix composites have high specific stiffness and high specific strength and are widely used in aerospace, automobile and other fields [1]. A large number of experimental studies have found that reinforced particle properties of metal matrix composites has a great impact on the mechanical properties, such as reinforced particle shape, distribution and volume fraction, so need to reinforced particle microscopic characteristics and macro performance simulation studies combined.

Studies on the effect of reinforced particles on the mechanical properties of metal matrix composites have shown that many scholars have oversimplified the microstructure of composites and simplified irregular particles into ideal and regular shapes. For example Azra Rasool, j.s. egurado simplifying the SiC particles to round 2 D finite element model is established, under static tensile loading is studied the damage mechanism of SiC particles and aluminum matrix, but the study of reinforcing particles be simplified as the ideal shape, randomly distributed particles position, ignores the true microstructure features, reinforcing particles leads to the simulation results with the actual result differs [2,3]. At present, more advanced treatment methods are based on the real microstructure of composite materials, and the corresponding finite element model is established to realize two-dimensional or three-dimensional simulation. Such as Li Yugang [4] using ImageJ, WinTopo Pro software such as complex image processing and edge detection, a complete reflects the original particles morphology, and to establish a finite element model of real microscopic, uniaxial tension simulation, studied the A356 / TiB2 composite materials mechanics performance. Bowen Liang[5] et al. established the finite element model with real microstructure, and analyzed the influence of SiC/Al composite microstructure on its mechanical properties based on the micro-reconstruction algorithm of this model.

Micro particles of metal matrix composites reinforced failure law research is currently a research focus at home and abroad [6], for the most part but the metal substrate is aluminium alloy, magnesium alloy as the metal substrate, the studies of the microscopic failure of the reinforced particles rule, has not been reported.

Based on similar methods with the help of image processing and recognition technology and edge extraction technology, build the TiC/AZ91 composites real microstructure of two-dimensional finite element model, and set up the material failure criteria, to research and reinforced particle

shape of TiC/AZ91 composite failure behavior, the influence mechanism, so as to optimize TiC/AZ91 provide theoretical basis for the mechanical properties of composite materials.

### Experimental materials

Considering the TiC has high melting point, high hardness, good chemical stability and corrosion resistance, excellent comprehensive performance and is one of the ideal reinforcing particles in the magnesium matrix composite, the magnesium alloy AZ91 magnesium alloy is widely used in industry, this paper choose the TiC as reinforced phase, AZ91 magnesium alloy as the matrix material. The basic parameters of AZ91 magnesium alloy and TiC particles are shown in table 1.

**Table 1** basic parameters of AZ91 magnesium alloy and TiC particles

materials	Ep	Poisson's ratio	Yield strength	Density
AZ91	45GPa	0.35	121MPa	1.8g/cm <sup>3</sup>
TiC	460GPa	0.15	280MPa	4.93g/cm <sup>3</sup>

### Establishment of finite element model

**Image processing and edge extraction.** In this paper, in situ autogenous TiC/AZ91 composites were obtained through experiments, and TiC particles did not react with magnesium alloys, and the strengthening phase was closely bound to the matrix, and no intermediate phase was formed. Appearance in order to more clearly reflect the particles and matrix, the experiments for organization chart, using only two kinds of grey value, had a higher degree of differentiation, guarantee the particles and matrix does not display the constitution diagram of  $\alpha$ -Mg and  $\beta$  phase, as shown in figure 1 (a). Due to the TiC particles irregularity, the finite element modeling can lead to greater difficulties, in order to guarantee the accuracy, this paper Matalab image processing software for testing, using Roberts operator and Sobel operator edge detection and make the necessary boundary pruning. Due to the identification problem of finite element software, the TiC/AZ91 composite material should be vectorized through Adobe Illustrator to obtain the TiC/AZ91 composite material vector diagram, as shown in figure 1(b).

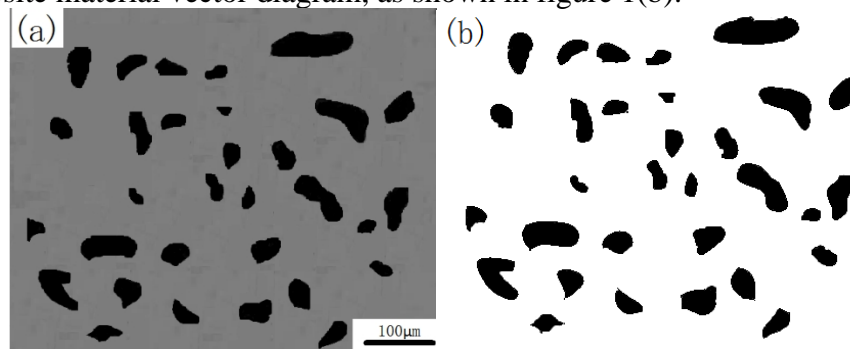


Fig. 1 TiC/AZ91 composite microstructure diagram (a) vector diagram (b)

**Grid division of finite element model.** Boselli found in his research that the free boundary would have a great impact on the numerical simulation process. At present, the ideal method is to use  $r/w$  parameter to evaluate the effect of free boundary on it. The  $r/w$  value of this article is mainly concentrated between 0.006 and 0.009. The vector graph was imported into CAD software, and the CAD model as shown in figure 2(a) was obtained by trimming simply the lines, closing the broken lines and drawing the boundary of the matrix. And through CAD format conversion, and imported into the finite element software ANSYS, to the grid as shown in figure 2 (b), the model contains 24881 units, according to the theory of composite material, the strength of, the Failure Criteria set in the TiC/AZ91 composite material Failure Criteria.

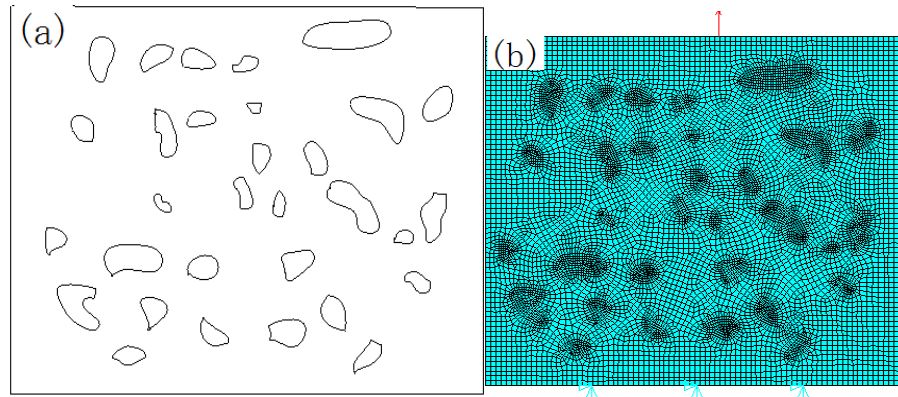


Fig. 2 CAD model (a) and finite element mesh model (b) of TiC/AZ91 composite materials

Because magnesium has a dense six-sided cell structure, its atomic coordination number is 12. No unit types with a matching in ANSYS, and considering the model in this paper for the TiC/AZ91 composite two-dimensional finite element model, so this article use plane eight node isoparametric element.

Second strength theory: no matter what stress state the material is in, once the maximum tensile strain exceeds the limit value that the material can bear, the material will break. Maximum tensile strain expression:

$$e_1 = [s_1 - m(s_2 + s_3)] / E \quad (1)$$

$e_1$  is maximum tensile strain;  $s_1, s_2, s_3$  is three main stresses respectively;  $E$  is elastic modulus. In the finite element analysis of composite materials, AZ91 magnesium alloy is a homogeneous material, and its elastic-plastic stress-strain relationship satisfies the Johnson cook material model:

$$s = (A + B e^n) (1 + C \ln e^*) \quad (2)$$

$s$  is Quasi-static flow stress;  $e$  is equivalent strain;  $e^*$  is relative equivalent plastic strain rate;  $n$  is hardening index.

## Results and discussion

Figure 3 shows the stress-strain curves of the simulated TiC/AZ91 composites with different particle shapes. Figure 5 is the stress cloud diagram of circular particle model, irregular shape particle model (original model) and square particle model. As can be seen from figure 5, compared with the original model and the circular particle model, the stress predicted by the square particle model is higher. The stress distribution inside and around the particle is also different with different particle shape. See from figure 5, no matter what kind of model, the stress distribution in the matrix is relatively uniform, but inside the particles exist stress concentration phenomenon, of the TiC particles carrying TiC/AZ91 composites most tension, this is because the material stress, matrix will force to particles. Due to the yield flow of magnesium matrix, severe stress concentration occurs at the sharp Angle of the square particles, causing extensive damage to the matrix and particles, thus reducing the failure strain of TiC/AZ91 composite materials.

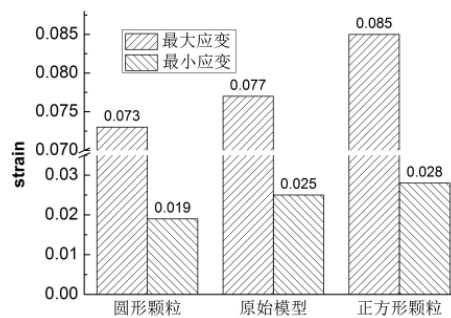
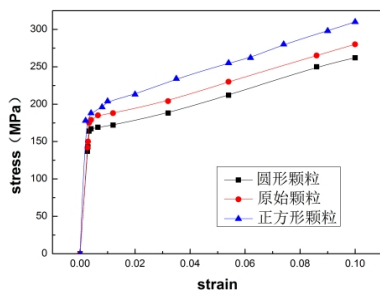


Fig. 3 stress-strain curves of different particles Fig.4 strain results of different particle shapes

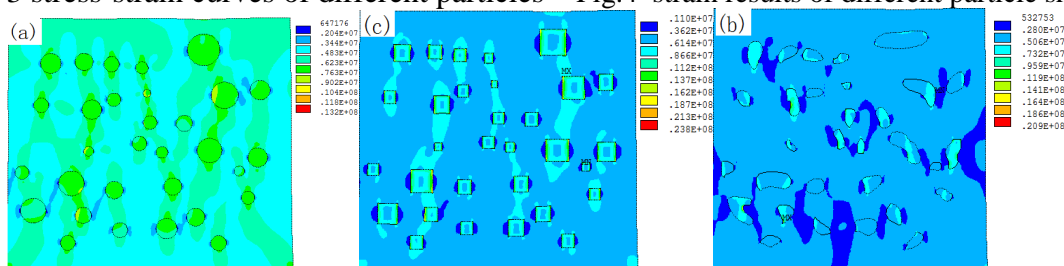


Fig. 5 stress clouds of circular particles (a), original models (b) and square particles (c)

Compared with circular particles, square particles contain more sharp angles, which cause more stress concentration of composite materials, and composite materials are more likely to fail. Figure 4 is set after composite material failure criterion of strain in the case of simulation for different particle shape as a result, it can be seen that the boundary conditions in the same square particle composites have a more strain, once, as the change of the load bearing ahead of circular particle composite material failure, the reason is that particles pointed at high stress concentration, easy appear holes nucleation, resulting in composite material failure. This conclusion is consistent with the research results of Helmut[7] et al.

## Conclusion

- (1) For TiC/AZ91 composites, the square particles can cause large area damage to the matrix and particles, which easily leads to failure of composite materials.
- (2) Same boundary conditions, the maximum strain of the square particles is 0.085 larger than that of the circular particles 0.073, and the TiC particles are square, which is more likely to cause failure of magnesium matrix composites.

## Acknowledgements

This work was financially supported by the National Natural Science Foundation of China (51164027,51661024); key scientific and technological project of Jiangxi Provincial Department of Education (GJJ14502)

## Reference

- [1] Hu Qiyao, zhao donghai, ge jilong. Microstructure and properties of B4C(SiCp)/A356 composite materials prepared by stirring [J]. Special casting and non-ferrous metals, 2015, 35(11):1213-1216.
- [2] J.Segurado,C.Gonzalez.A numerical investigation of the effect of particle clustering on the mechanical properties of composites[J].Acta Materialia 51(2003) 2355-2369.
- [3] Hai Qing .Automatic generation 2D micromechanical finite element model of silicon-carbide/aluminum metal matrix composites:Effect of the boundary conditions[J] Materials and Design 44(2013)446-453.

- [4] Li Yugang, wang fei-fei, li jianfeng, et al. Finite element models of nano-particle reinforced metal matrix composites [J]. *Materials guide B*, 2011.7(25):134-138
- [5] Bowen Liang, Anand Nagarajan, Soheil Soghrari. Numerical quantification of the impact of microstructure on the mechanical behavior of particulate Al/SiC composites in 2D [J]. *International Journal of solids and structures*. 117(2017)91-103.
- [6] Qin Qun, hua jianjie. Preparation of SiCp reinforced Al matrix composites by powder metallurgy and its properties [J]. *Special casting and non-ferrous metals*, 2017.37(4):411-414.
- [7] Helmut, J, Bohm. Effect of particle shape on the thermoelastoplastic behavior of particle reinforced composites [J]. *International Journal of solids and structures* 87(2016) 90-101.