Design and Research of New Syntactic Foam Pressure Parts

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Abstract. With the development of materials and technology, new composite materials which can meet the requirement of new technology are produced, especially in some harsh conditions where traditional materials cannot meet the needs. In this paper, a new type of syntactic foam pressure part is studied, simulate and calculate the impact of load stress and breaking type by finite element analyze. The results of experiment are same as the calculation. A method is established in this paper to provide a reference and research ideas for the similar products.

1 Introduction

In order to meet the harsh conditions requirement and lower the cost, new syntactic foam material is applied to design and research of structural pressure parts, which gives full play to the characteristics of light weight, heat insulation and adjustable strength. Pressure parts are usually sealed together with the large structural parts, but with the impact of instantaneous load, if the preset pressure is reached, it is immediately break to remind the engineer of load conditions. It can protect the main structural parts. But so far, this kind of research is rare in China [1].

Previous research on the behaviour of syntactic foam mainly focused on the experimental research. On the one hand these researches meet the requirement of application at that time, and on the other hand, they also promote the improvement of the material preparation process. Not only the macroscopic mechanical behaviour of these new types of foams has been studied, but also the research on the microscopic failure mechanism of these materials has been paid more attention. However, the mechanical properties of the syntactic foams are closely related to the technological conditions and process level. Also the environment where the syntactic foams used is complex, so the study of this kind of new material is far from the end. Compared with the experimental research, the theoretical research work is obviously lacking. People can only use some of the existing research results in composite materials mechanics to give the estimated value of the material parameters or put forward some empirical formula.

This paper is based on the new syntactic foam products; the performance of this material is tested and the simulation software Ls-dyna is used to simulate the breaking type of the product under transient impact load. The results are verified by comparison with the experiment.

2 Material analyse

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2.1 Material introduction

At the end of the 1960s, research on syntactic foams began. DeRuntz systematically studied the mechanical behavior of syntactic foam, He experimented on the hollow cylindrical specimen and the cylindrical specimen made of hollow ball-resin syntactic foam. The experiment was carried out by pulling, pressing and twisting the uniaxial experiment, biaxial stress experiment, and triaxial stress experiment under water pressure.

In the mid-1970s, Barber and others firstly carried out the three-phase syntactic foam mechanical behavior research work, they put hollow glass microspheres in the amino rigid foam. It is obviously improved the compression and bending strength and modulus, also improved the impact resistance and the dimensional stability. Due to the addition of glass microspheres, the lower density of the syntactic foam can achieve higher density. So it provide possibility to use lighter syntactic foam in structural applications.

In the early 1980s, M. Narkis and others systematically studied the preparation of two-phase and three-phase syntactic foams and their corresponding mechanical properties. They used two different types of microspheres (phenolic and glass microspheres) to fill the foam and it showed good compression mechanics. In addition, M. Narkis and others also studied the rotational molding of thermosetting three-phase syntactic foams and the compressive strength and modulus energy of the flexible syntactic foam are given, also the temperature effect was studied for polyimide based foams and the concept of stress transfer efficiency is proposed. The Ishai and Cohen equations and the Lewis and Nielsen equations were modified by the stress transfer efficiency parameters. In order to further study the relationship between mechanical properties and density, they also studied the tensile and bending behavior of the three-phase silicone syntactic foam. The results showed that the tensile strength of the foam is lower than its bending strength and the bending strength is much lower than the compressive strength. Under the same matrix volume content, the hollow ball composite foam has a higher compressive strength but the elastic modulus of the solid spherical foam is much higher than that of the foam containing hollow spheres.

In this paper, pressure parts are made of syntactic foam. It is a new kind of structural and functional composite material which is filled with hollow microspheres and foaming agent in the resin matrix. Compared with traditional foam, the syntactic foam has a high specific strength and rigidity at low density due to the enhancement of hollow microspheres; it also has better thermal stability, insulation, corrosion resistance and etc. [2][3]

2.2 Material performance test

In order to describe the dynamic breaking behavior of the pressure parts accurately by finite element simulation, the key mechanical parameters of the material must be obtained by experiments. The syntactic foam is subjected to a quasi-static uniaxial tensile test at room temperature to measure a number of valid data. The loading strain rate is kept constant by 3mm/min and the corresponding strain rate is 0.001/s. To measure the elastic modulus and Poisson's ratio of the material, both strain values of vertical and horizontal sides should be recorded when measuring the force on the specimen. Non-contact measurement is used to avoid the interference of elastic factors caused by mechanical clamp and strain gauges, it can ensure the measurement accuracy [4][5]. As shown in Figure 1.

Figure 1. Tensile test and strain measurement experiment

2.3 Analysis of test results

There is no necking phenomenon during the process of stretching. Most of them are suddenly broken which are perpendicular to the direction of stretching. The section is flat and the material exhibits brittleness. The material exhibits linear elasticity at the initial stage of the bearing, and gradually becomes non-linear as the load increases. What the syntactic foam exhibits is following the theory of continuous elasticity in solid mechanics. After averaged the effective data of the sample, the results are shown as below: elasticity modulus is 758MPa, the Poisson's ratio is 0.329, the fracture stress is 8.05MPa, and the fracture strain is 1.22%.

3 Simulations

3.1 Pressure part model

Draw a 3D model of pressure part in Solidworks and divide it, as shown in Figure 2 and 3：

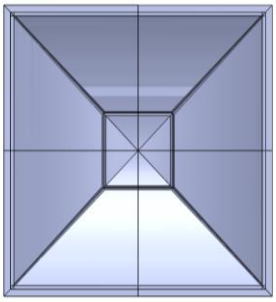

Figure 2. Bottom view

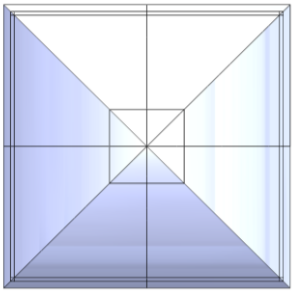

Figure 3. Top view

3.2 Unit selection and meshing

Select the solid 3D solid164 module and do the hexahedral and tetrahedral meshes. As shown in figure 4 and 5.

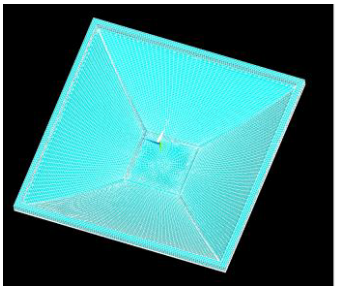

Figure 4. Overall grid

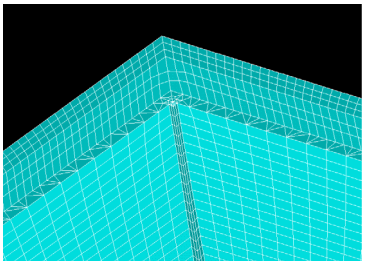

Figure 5. Local grid

3.3 Boundary conditions

According to the real situation, constrain the pressure part.

3.4 Apply the load

Apply impact load on the pressure part and the instantaneous impact load is P=0.075MPa.

3.5 Calculation

The pressure part is subjected to an instantaneous impact load and the broken position is the location of the fracture groove and the part is completely broken into 5 blocks. As shown in figure 6 and 7.

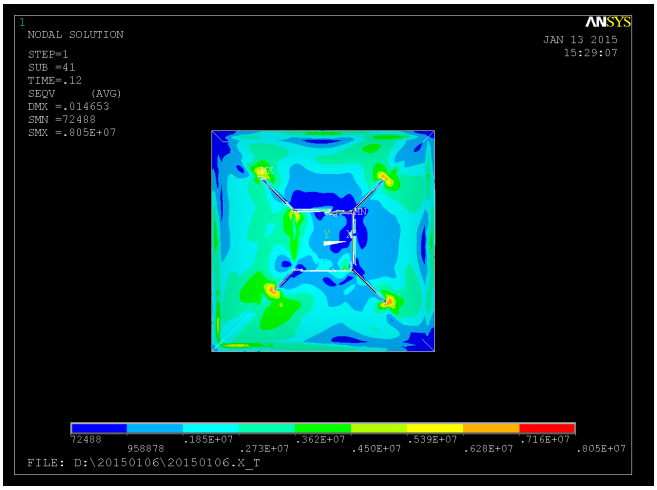

Figure 6. The stress distribution of the moment of cracking

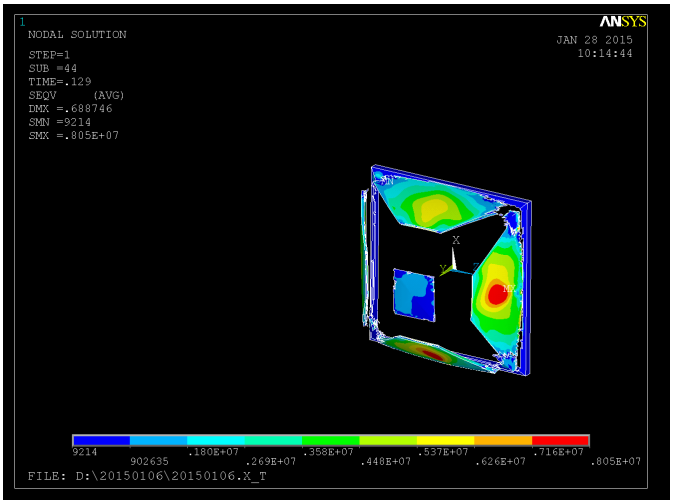

Figure 7. Debris distribution of the pressure part

4 Impact breaking test

In order to verify the validity of the simulation, an impact breaking test is carried out. The pressure part is fixed on the left and there is a gas tank with high pressure gas on the right. To compare results with the simulation, there are three pressure sensors in the chamber, to monitor pressure change during the test process. When the test begins, valve will be opened quickly, then, high pressure gas released. Under the action of the impact load, the pressure part is quickly broken and the whole process of the experiment is finish.

To ensure the accuracy of the experiment, the test was repeated several times. Four times' experimental data are shown in table 1.

Table 1. Test data

No.	Breaking strength（MPa）	Fractures and pieces	Discrete rate
1	0.072	Break along the trench, 5 pieces	-4.16%
2	0.077	Break along the trench, 5 pieces	2.59%
3	0.067	Break along the trench, 5 pieces	-11.94%
4	0.07	Break along the trench, 5 pieces	-7.14%

5 Calculation and results analyze

In this experiment, a total of four impact breaking tests were carried out, the breaking forms of all the pressure parts were broken along the trench and broken into 5 pieces. Compared the results with the simulation, the theoretical calculation and experimental results are almost same in broken form, fragment size, and fragment shape.

6 Conclusions

Simulate the transient impact of the syntactic foam pressure parts by finite element simulation software, insert the data to Ls-dyna and calculate the broken form, fragment size and fragment shape Then, complete the impact breaking test and compare the results with the simulation and the results show they are almost same. The calculation can be drawn that this new syntactic foam material can meet the requirement of design and working conditions well, also the producing process of the material is simple and the cost is low. The simulation method and results are established in this paper to provide a reference and research ideas for the syntactic foam pressure parts.

References

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