

Macro and micro modelling of the composite materials behaviour using FEA analysis

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The paper presents some applications of the Finite Elements Analysis (FEA) on the research and design of the composite materials. If the ordinary FEA modeling is now something indispensable for the mechanical design, then the micro models which we propose in this paper are less usual in the general FEA modeling and for the study of the composite materials. Their applications have very important perspectives for the future of the composite material design.

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1. Introduction

In this paper, are present two fundamental types of composite materials modeling with finite elements method. The first type, the structural macro models, is already used in the FEA modeling of the composite materials. All the usual FEA software contains finite elements which can be used to simulate the composite materials behavior. The original contribution of this paper, consists in the development of structural micro models, which are accomplished with different types of finite elements. These elements simulate the behavior of the composite materials components: the matrix, the strong fiber and other components.

2. FEA macro models for the composite materials

Through FEA macro models of the composite materials we understand the FEA model which is mashing with finite elements of the FEA software, which can simulate the composite materials behavior, but we can not include separately the components of the composite materials: fibers, matrix, etc. The finite elements which mash the composite materials are included in the FEA software finite elements library. The finite elements used for the mash macro models, simulate the composite materials behavior through the materials properties, which are different on the different directions and for different layer of the composite materials. The macro models are which simulate globally the composite materials behavior [3], [2]. These finite elements can not mark out the micro structural phenomena which occur at micro scale, for example the fiber or matrix behavior. For instance, we choose a typical structure for the structures which now frequently build by composite materials, a tank. The model

of the tank is shown in the Fig. 1. This model is valid for both structures: the one is made by homogeneous material (steel plate) and the other one is made by composite material.

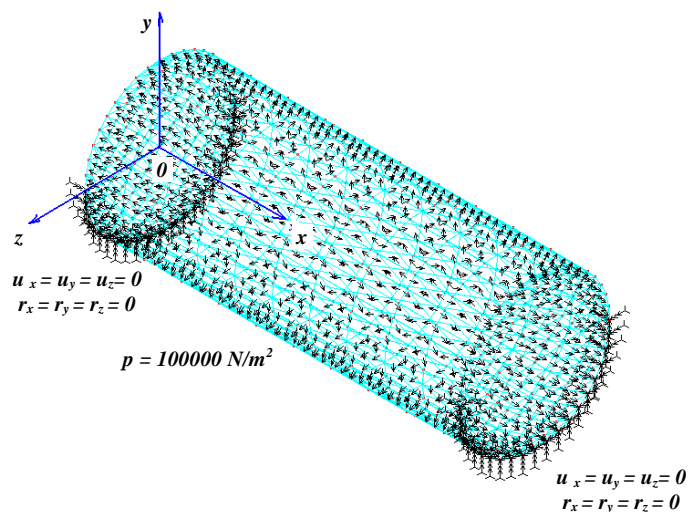


Fig. 1. Structural model of the tank.

The circular cylindrical tank has the 0.2 m diameter and the 0.5 m length. This tank contains a fluid which exerts a uniform pressure on the tank walls with 100000 Pa value. The metallic tank is build by steel plate with 2 mm thickness. The yield stress of the steel is 220 MPa. The tank walls are made from 10 composite layers, each with 0.5 mm thickness, the odd layers (numbering from the interior of the tank) having fibers oriented in the long of the tank and the even layers have the fibers oriented perpendicular of the fibers orientation of the odd layers. The materials properties are the same like the beam material, used for the first example. The tank is embedding in two semicircular zones (see fig. 1). The model was

mashed for the homogeneous material with SHELL3 finite elements and, for the composite material, with SHELL3L finite elements both type of finite elements is included in the finite elements library of the FEA, [3].

Among charts of the state parameters of the structures is shown only one for each structure, considered the best one for evidencing differences in behavior.

These charts are shown in the Figs. 2 and 3 and represent the distribution of the u_y component of the displacement field. We remark that the metallic tank elongation is greater than the composite tank (approximately with 43%), on the direction of the Ox axis (direction of the tank length).

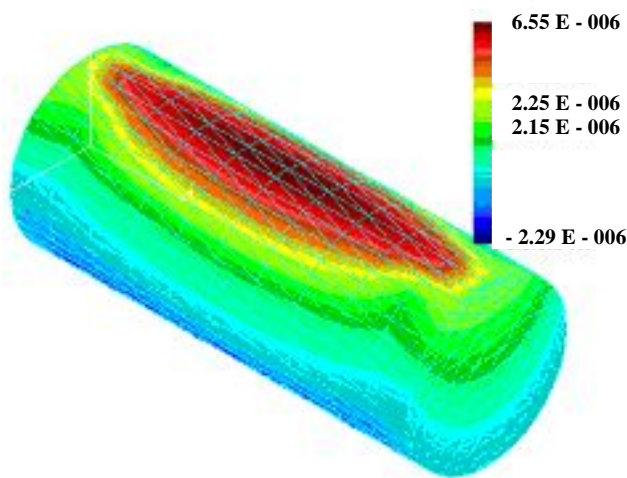


Fig. 2. The chart of the u_y displacement distribution in the metallic tank.

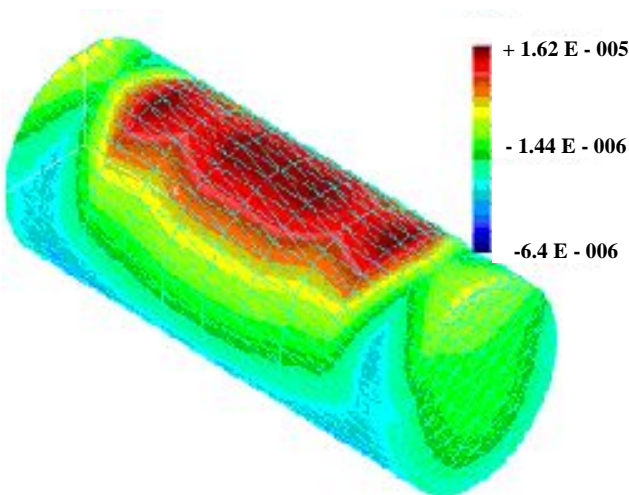


Fig. 3. The chart of the u_y displacement distribution in the composite tank.

The radial displacements are very small, but are different for the two structures. The radial displacement has greater values at the composite tank than the metallic tank. For a good appreciation of the stress state in the layers of the composite tank, results of the analysis is given in Fig. 4.

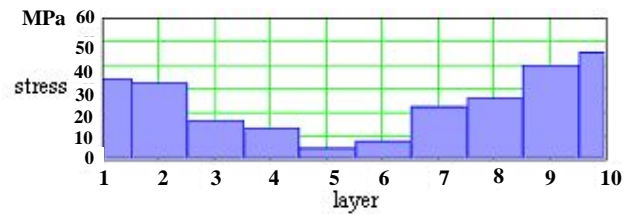


Fig. 4. The stress distribution on the layers of the composite material tank.

It is noted that the maximum value of the Von Mises stress on the layer is maximum on the exterior layers (1 and 10 layer). Working in linear elastic domain, if we increase the load, the stress in the layers increase in proportion. If the pressure increases at 200000 Pa, then in the 10th layer, the stress value became 90.22 MPa. On this way is possible to estimate the limit load such as maximum value of the stress to be smaller than the yield (if there is this limit for the composite material) or breaking stress. The advantage of using composite materials, also, the decrease of the structure mass, for example the metallic tank has 5.911 kg and the composite tank has 3.388 kg.

3. Structural micro models for the composite materials

The structural models of the composite materials, that allow to deduce some macro properties (elasticity modulus, yield and breaking stress and strain limits, the material curve, etc.), all for many directions, if are knowing the same properties for the components of the composite materials, are different by the macro models of same materials because in the micro models is included separately, each component of the composite material. For the macro models, the same properties are determined experimentally. In the FEA micro models of the composite materials, the fibers and the matrix are introduced by the finite elements from the FEA library, elements not especially used for composite materials. So, for fibers are using, for example, elements TRUSS and for the matrix can using 2 or 3-dimensional finite elements (SHELL, SOLID). Each type of finite elements will be described by its material properties and specific constants. The different types of finite elements will be connecting in the composite structural micro model using the nodal network of the model. In conclusion the FEA micro models are hybrid models. This means that the models contain many types of finite elements. From example a FEA micro model can be built using 2-dimensional finite elements (SHELL) for the matrix, and 1-dimensional finite elements (TRUSS) for the fibers. We can complicate the model using 3-dimensional finite elements (SOLID) for the matrix and 1-dimensional or 2-dimensional finite elements for the fibers. Finally, it is possible to consider only 3-dimensional finite elements for matrix and fibers but these micro models present serious problems in the building process and also in the solving process. Different

materials, which can be included in the composite materials, can be introduced in the micro models by others elements, except the fibers and the matrix. First example is a FEA micro model for a composite material, which includes the matrix, meshed by 2-dimensional elements (SHELL4) and the fibers that are introduced by 1-dimensional elements (TRUSS3D). The model is shown in Fig. 5.

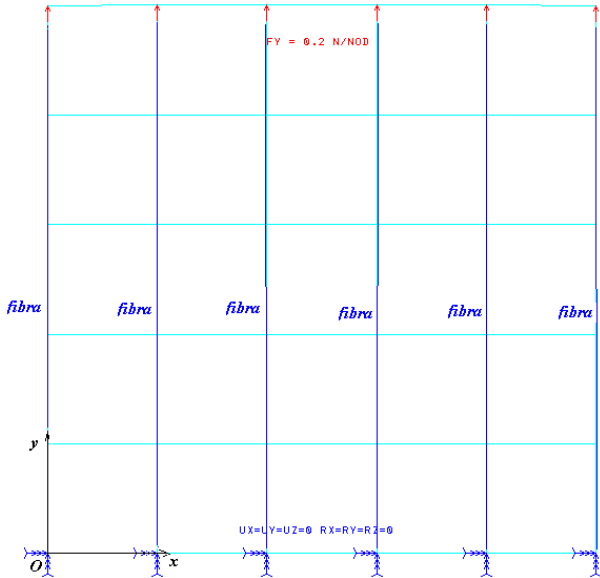


Fig. 5. The model for a composite material zone loaded on the fibers direction.

In Fig. 6 is given, comparatively, the charts of Von Misses stress for the composite material loaded on fibers direction, and loaded on the direction perpendicular on the fibers direction. On the charts of Fig. 6 can be read the values of the Von Misses stress in each location of the composite sample.

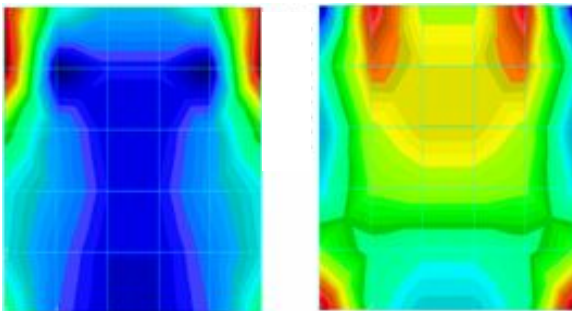


Fig. 6. Comparison between the charts in the composite loaded on the fibers direction (left) and in the composite loaded perpendicular on the fibers direction (right).

The stress can be read separately only on the fibers, like in Figs. 7 and 8. Another application of the micro models is the estimation of the effects of some imperfections in the composite materials. A micro model for the simulation of the presence of an imperfection consists in a breaking glass fiber.

Using the same models is possible to estimate the effects of imperfections in composite material and it is possible to appreciate the tolerance limits with the aim to use the composite material to build structures with different safety degree. Obviously, it is possible to simulate others imperfection types as absence of some matrix portions and the deviation from the ideal geometry for the fibers. These types of imperfections can be combined and their effects can be estimated in function of their spatial extending.

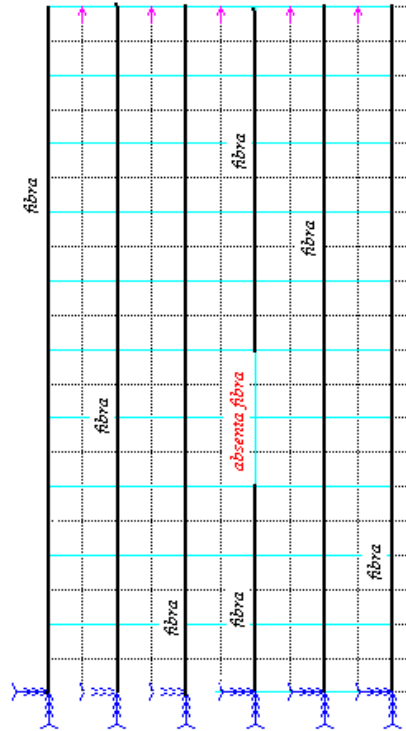


Fig. 7. Composite micro model with imperfection.

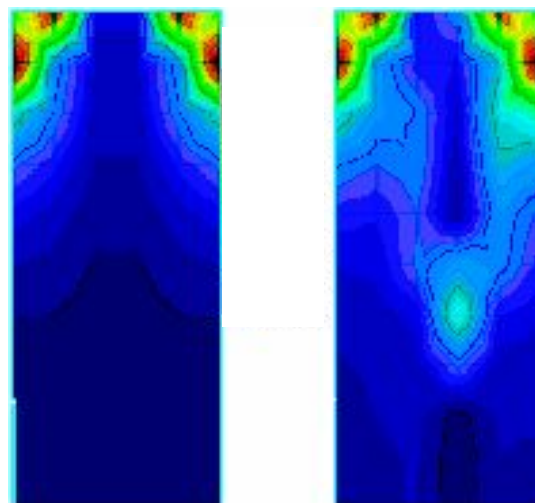


Fig. 8. Stress chart in the perfect composite (left) and in the imperfect composite (right).

4. Conclusions

We have shown that the structural modeling can be used in the design activity in many technical domains which use the composite materials. For these categories of users is recommended the structural macro models of the composite materials. In addition at the macro models, we recommend the use of the structural micro models for the composite materials design, but their results must be experimentally verified.

Using the structural micro models, is possible to improve the composite material qualities through varying the fibers geometry and arranging them in the matrix, the alternation of the different fibers in the matrix, etc.

The simulation of the composite materials behaviour, which is obtained using the design with the micro models assistance, allows to obtain the multilayer composite materials, possible with different properties in the layers. These results must be experimentally validated. Optimized results can be obtained for the composite materials using both the macro and micro structural models.

The micro models are helpful for the investigation on the boundary effects and also for the behavior of the composite materials at the contact with others materials. Finally we remark that the simulation of the composite behavior on the micro and macro structural models can be used for the investigation of the failure mechanisms in the composite materials and, accordingly, to find the cause of the failure of the composite structures.

References

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