FINITE ELEMENT MODELING OF HYDRIDE COMPOSITE MATERIAL SUBJECTED TO BALLISTIC IMPACT

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Abstract

Hybrid composite materials are prepared to combine different properties of materials in order to stop the ballistic impact make consequences milder. First layer is ceramics in order to influence the projectile shape, induce plastic deformation to the top of the projectile, reduce speed, power and strength of the attack. Accomplishing its job ceramics is breaking and overhang projectile to composite layer that prevents further advancement of the projectile due to improved elastic properties. Samples are subjected to impact tests, to determine maximum speed, deep of penetration and fracture. FEM (finite element modeling) provides faster and realistic simulations of ballistic impact. Used software is Abaqus 6.10 CAE.
Key words: ballistic impact, composite material, finite element modeling

Materials subjected to ballistic impact have the aim to protect persons and goods from the sudden destruction by the projectile. The impact is important for the protection in (army) war but also in some situations where the material is subjected to the sudden collision with another object. The aim of a hybrid composite is to absorb the energy of the projectile, to deform it and to stop subject's indentation into the material. This sort of composites is usually composed of several layers each of them having a proper role (This kind of composites are made of several layers sorted with proper role).

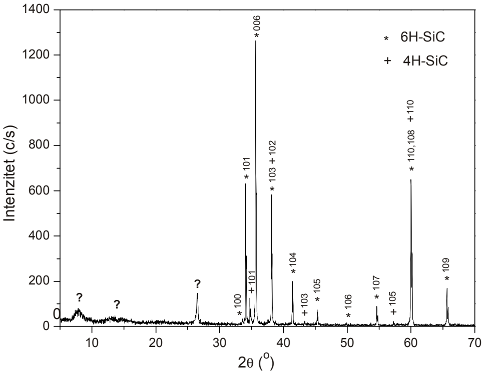
Faur-Csukat studied the mechanical and ballistic behavior of carbon, glass (E and S type), aramid and polyethylene fabric reinforced composites with different epoxies produced by hand lay-up method [1]. The ballistic performance of a composite focuses on the capacity of energy absorption of structures during a high-velocity impact. For a given target-projectile combination, the ballistic limit is defined as the lowest initial velocity of the projectile that will result in complete. The specimens were characterized by low and high velocity impact tests. They absorbed a significant part of the kinetic energy of the projectile. In low velocity impact tests (*e.g.*, in drop-weight testers) the support conditions are crucial as the stress waves generated outward from the impact point have time to reach the edges of the structural element, resulting in a full-vibration response. For common epoxy composites, the transition to a stress wave dominated impact occurs at impact velocities between 10 and 20 m/s. In high velocity or ballistic impact, the response of the structural element is governed by the 'local' behavior of the material in the neighborhood of the impacted zone.

For the protection of vehicles the composite protection often has the outer surface composed of plates made of SiC. The aim of this layer is to protect the surface from the impact, to deform the bullet and to absorb the impact energy. The commercial SiC plates were subjected to mechanical and structural testing and then the corresponding data were used in the calculation of the stress distribution in the material subjected to the impact. Both the stress and deformation of the SiC plate and the bullet are studied using the Finite element calculation of stress distribution.

Experimental

The material was subjected to characterization of the crystal structure using the XRD, to the microstructure using optical and SEM and to mechanical testing using the 3 point bending test. The obtained data gave the properties of the material that are critical for the development of the mathematical model.

The analysed specimen was approximately 4 mm high, and having good rather smooth surface. The specimen was subjected to the identification of the crystal structure using the The observed phases are □-SiC having the crysalographic definition 6H-SiC that represent aproximately 90% of the material and the other phase is defined as 4H-SiC.For both phases the narrow diffraction peaks are identified indicating the good crystalline material. The cell parameters are in accordance to the literature data[2].



Phase	Unite cell parameters (Å) Experimental	Literature	
6H-SiC	*a* = 3,081 *c* = 15,119	*a* = 3,081 *c* = 15,125	*
4H-SiC	*a* = 3,080 *c* = 10,119	*a* = 3,073 *c* = 10,053	**

ICSD is the Inorganic Crystal Strucutures Database

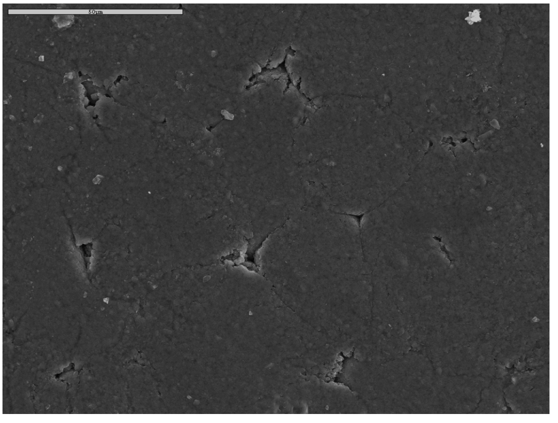
**156190-ICSD*

***24170-ICSD*

Figure 14 Diffraction pattern of the examined SiC specimen. The observed phases are □-SiC having the crysalographic definition 6H-SiC that represent aproximately 90% of the material and the other phase is defined as 4H-SiC.

The microstructure was examined using the optical and scanning electron microscope Jeol JSM 5800, working voltage was 20 keV. The characteristic images are given in Figure 2 showing the presence of surface defects that were than characterized using the image analysis. The corresponding distribution of the size of surface defects is given in the same figure.

Finally, the mechanical testing gave the flexural strength gave the main value of 313 MPa having values that were ranging from 250 to 430 MPa. The data used in the numerical simulation are given in table.



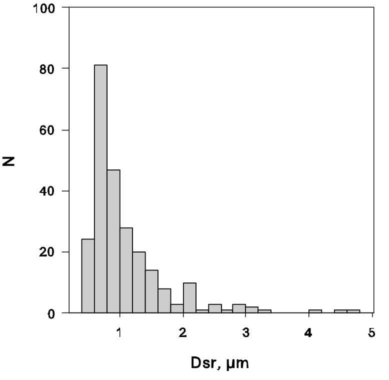


Figure 15 The surface of the specimen characterized using the SEM and the corresponding distribution of the main diameter of the defect observed.

Finite element modeling (FEM)

Software used for finite element modeling is Abaqus CAE 6.9. Impact conditions with hard contact are modeled in Abaqus/Standard with the assumption that, at the time of impact, the two impacting surfaces instantaneously acquire the same velocity in the direction of the impact. An explicit dynamic analysis is used due to its computationally efficiency for the analysis of large models with relatively short dynamic response times and for the analysis of extremely discontinuous events or processes. Model is made of 2 parts: target and projectile. Target consists of 4 layers. Upper one is silicone carbide; next three layers are made of steel with different Young's modules. Parts are divided on hexagonal elements. Structure and assembly are shown at Figure 3

The simulation of the impact of the steel object on the surface of the material consisting of the layer od SiC is given. Velocity of impact is 200 m/s . Projectile is made of steel with following properties: density 7800 kg/m^3 , Young modulus 210 GPa, Poisson koefficient 0,3. First layer of target is made of silicone carbide with next propeties: density 3120 kg/m^3, Young modulus 410 GPa, Poisson koefficient 0,2. Next layers of steel differ in Young module, upper is with 210 GPa, lower 200 GPa and the lowest with 190 GPa. Other properies are the same with projectile. According to Figure 4 stress distribution is shown with different colors depending on level of stress in material. Stress in ceramics is 150 MPa at target. Stress in projectile is 1,8 GPa which caused deformation as it can be seen. At this stress level the ceramic material is stil not destroyed as this level is under the measured level of strength.

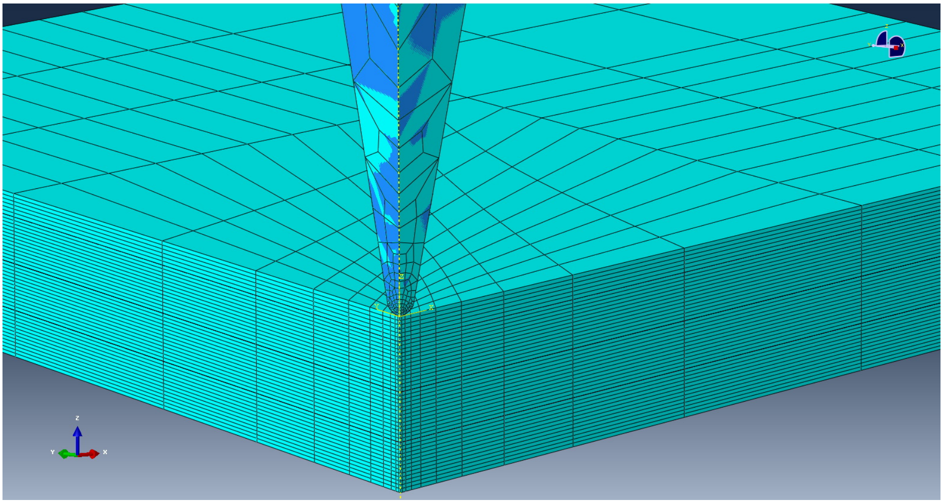


Figure 3. Hexagonal elements used to define parts in FEM model

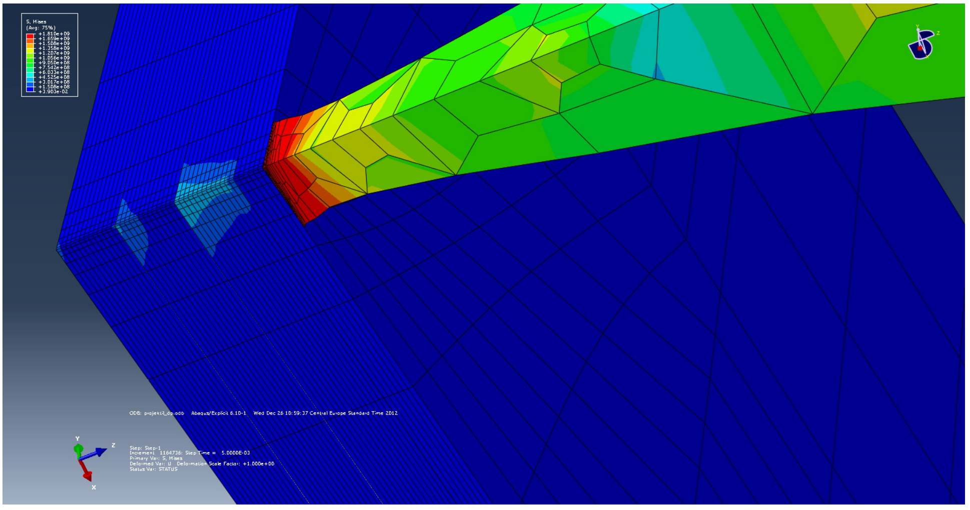


Figure 4. Deformation of projectile impacting target

Conclusion

Material used as shield protection for vehicles is analyzed. The microstructure is crystalline and is composed of two most commonly seen phases of SiC. The lattice parameters are in accordance with the literature values. Surface is characterized with SEM and reveals the surface pores that are up to 5 μm in diameter, but most of them is having the mean diameter under 1 μm. Flexural strength of the material give the value of 313 MPa and this was the parameter for the evaluation of the material behavior simulated using the FEM technique. The simulation of the impact explaines the main purpose of the ceramic material layer and illustrates the deformation of the projectile in contact with the surface. The stress level in the composite material in the simulation is lower than the level indicated by flexural strengths and therefore the material exhibits only small elastic deformation up to this moment of the simulation.

Acknowledgements

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References

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