PREPARATION AND INVESTIGATION OF CARBON FIBER REINFORCED ELASTOMERS

Doktori (Ph. D.) értekezés tézisei

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Introduction and objectives

The primary task of applied materials science is to utilize professional knowledge and results elaborated in scientific laboratories in the construction technology. The scientific project "Synthesis and investigation of mechanical properties of carbon fiber reinforced composites made from elastomer matrices" belongs to this topic. One of the important scientific areas of applied chemical sciences is the preparation of new-type materials which correspond the environmental (degradable materials) and energy saving (lighter structural materials) requirements. Various kind of composites are used in many kind of areas of life. A variety of composites is assured by different matrices and various reinforcing fibers. New-type materials – composites - can be produced by combination of these compounds. Composites possess excellent properties by unification of advantageous properties of components, e.g. resistance to splitting or wear resistance. According to the associate materials, composites can be granular, fibrillar, lamellar materials and covered with surface layer. Properties of composites are determined by the type of matrices and reinforcing fibers. Strength of reinforced composites can be intensified by load transmission of matrices to the fibers. The essential condition of strength transmission is the good adhesion between the matrix and fiber. Improvement of resistance of materials is very often accompanied by the disappearance of other properties. Modification of plastics properties is variable, but it is limited, too. Mechanical properties of composites are determined by type, amount, diameter, length and arrangement of fibers. One of the basic compounds of the produced and examined composites is polyurethane (PUR). I prepared polyurethane-based composites from polyols, polyglycols and toluene diisocyanate under laboratory conditions. The other matrix was polyvinylchloride (PVC). It is also an elastomer. Carbon fibers with different cover and placed the total length of the specimens were used as a reinforcing agent. According to the literature, polyurethane matrices have excellent elasticity, wear resistance, cold resistance and hydrolysis resistance. The other matrix was the soft PVC, and according to the amount of softener agent it got excellent flexibility, cold resistance, impact resistance than hard PVC, but possesses less chemical resistance**,** tensile strength and hardness. The embedded component was the carbon fiber, it got high tensile strength and elasticity modulus, low density, good heat resistance and excellent vibration resistance. My aim was to determine the quality of connection between the matrices and fibers and the mechanical properties of the carbon fiber reinforced composites.

I. Applied methods and equipment

I. 1. Applied materials, compounds

Toluene diisocyanate (TDI) and polyether glycols (with using ratio), soft PVC granulates (LE 411/009) and PVC powders with different softener content (1720/1, 1720/2, 1720/3) were industrial products provided by BorsodChem ZRT, Hungary.

Flexane 60 L polyurethane was PENTAgroup Bt., a Hungarian product. The carbon fibers in staple were CF 48K signed and the products of ZOLTEK VISCOSA Rt. Hungary. Lines of cotton, glass fibers and flax fibers were commercial products.

I. 2. Applied methods

I have designed a standard teflon mould for the preparation of specimens (5 specimens) of the composites to the tensile test. The tensile tests were obtained by using an INSTRON 4302 machine according to the MSZ ISO 527-1 standard. Tensile strength, Young’s modulus and elongation at rupture of composites were determined by this machine. I also qualified the composites. I determined the stress-strain curves, too.

Based on MSZ 13571: 1980 standard I have designed a flexural loading fatigue testing machine to compare the folding resistance of basic and fiber reinforced elastomers.

A JEOL JSMT-220 A scanning electron microscope was applied to study the surface failure of the composite after break.

The Shore A hardness was determined with a ZWICK 3114.01 Hardness Tester according to the Hungarian standards (MSZ ISO 868)17.

Dynamic mechanical analysis (DMA) was used to determine the glass transition temperature (Tg) of the PVC-CF composites. A REOMATRIX DMTA MK was applied at 1Hz frequency, and 2 K/min. heat velocity.

II. New scientific achievements

1. Synthesis of new composite from polyurethanes

Moulded polyurethane composites were synthesized under laboratory conditions from industrial basic materials such as polyether polyols and toluene diisocyanate. I prepared different composites with continuous carbon fibers to improve a new type, flexible structural material for industrial application with high strength and high wear resistance. Low amount of carbon fibers (from 0,1 w/w% to 3 w/w%) was encased in elastomer specimens in their total length. The mechanical properties of the composites with various amount of carbon fibers were determined. According to the tensile, fatiguing and hardness tests, reinforced composites possess better mechanical properties than the native ones. I have proved that carbon fibers stick to the PUR matrix very well. It is very excellent, because the matrix and the carbon fibers collaborate with each other, so the matrix can be handed over the load to the fibers.

I have established that the native carbon fibers in the matrix reinforced the composites better than the covered fibers. According to the electron microscope investigation (SEM) the rough surface of native carbon fiber adheres to the PUR matrix better than the covered ones. The arrangement of the carbon fibers affects the value of strength of composites significantly. Firstly, I put the carbon fibers in staple into the matrix, than I increased the amount of the carbon fibers in the specimens. In the second examination I put them in the total length of the specimens uniformly. Based on the tensile test the arrangement of fibers in the total length of the composites has insured better reinforced products than fibers in staples. The reason for better results is that the matrix can flow among the fibers better than in the other case, so the linkage is stronger between the fiber and matrices and the load transmission is better.

2. Mathematical modelling of the tension behaviour of the carbon fiber reinforced polyurethane composites

The polyurethane matrix is suitable for the Poynting-Thomson model (see equation 1.), but stress-strain curves of the carbon fiber reinforced polyurethane composite can be appreciated by the Maxwell one (see equation 1.).

$$\sigma = a_1[\varepsilon + a_2(1 - e^{-a_3\varepsilon})] \qquad (1)$$

$$\sigma = b_1(1 - e^{-b_2\varepsilon})] \qquad (2)$$

Where, σ: tensile strength, ε: elongation per unit length.

a_1, a_2, a_3, b_1, b_2 are parameters which contain the Young's modulus of Hook's springs of the model and the viscous coefficient of viscous liquid. They were controllable parameters.

3. Synthesis of new composites from PVC with low carbon fiber content

Native carbon fibers were embedded into PVC matrices with different softener content. Carbon fibers were put into the matrices longitudinally, in cross direction and working into the matrix. According to tensile test, DMA analysis and hardness, the test carbon fibers adhere to the PVC matrix very well, too. The long carbon fibers reinforced the PVC matrix measurably and I synthesized new composites. Based on the stress-strain curves, application of sort carbon fibers is advantageous at low deformation.

4. PVC composites with planning mechanical properties

Effective improvement of mechanical properties, e.g., tensile strength and Young's modulus of soft PVC was carried out by using countinous carbon fibers. By the increase of the carbon fiber content of PVC - based composites the tensile strength and Young's modulus increase linearly.

$$\sigma_{max,comp} = w_{CF}(\sigma_{max,CF} - \sigma_{max,m})\rho_m/\rho_{CF} + \sigma_{max,m} \quad (3)$$

$$E_{comp} = w_{CF}(E_{CF}-E_m)\rho_m/\rho_{CF} + E_m \quad (4)$$

where: σ: tensile strength, w: weight, ρ: density, E: Young's modulus.

I could synthesize carbon fiber reinforced PVC composites with well-defined properties. The adhesion between the matrix and fibers were suitable. PVC-randomly placed sort carbon fiber composites were also investigated. Increasing of the carbon fiber content in the PVC matrix the Young's modulus and hardness also increase, but the tensile strength did not change. By a significant increase of hardness the glass temperature increased less.

III. Some aspects of possible applications of the results

In the future, carbon fiber reinforced composites can be used as technical plastics (constructional engineering). Composites are also resisted for fatiguing stress and abrasion, and they will meet the requirements of industry.

IV. Tudományos közlemények / Scientific publications

IV. 1. Az értekezés témájához kapcsolódó közlemények / Publications in the field of the dissertation

1. Jenő Borda, Ildikó Bodnár, **Istvánné Ráthy**, Miklós Zsuga:
Synthesis and investigation of the mechnaical propertis of the polylactic acid-toluene diisocyanate – polethylene glycol/polypropylene glycol copolymers
Polymers for Advanced Technology, 14, 1-7, 2003.

2. Jenő Borda, Sándor Kéki, **Istvánné Ráthy**, Ildikó Bodnár, Miklós Zsuga:
Novel polyurethane elastomer-continous carbon fiber composites: preparation and characterization
Journal of Applied Polimer Science, 103 (1), 287-292, 2007.

3. **Ráthy Istvánné**-Dr.Borda Jenő –Dr.Horváth Róbert-Dr.Zsuga Miklós :
Szénszálerősítéses poliuretán kompozitok előállítása és mechanikai tulajdonságainak vizsgálata
Debreceni Egyetem, *Műszaki Tudományos közlemények,* Debrecen, p.273-285, 2000.

4. Tiba Zsolt- **Ráthy Istvánné**:
Egyedi fárasztógép tervezése kompozit anyagok vizsgálatához
Gép, 12. P32-35/2004.

5. Kéki Sándor, Ráthy Istvánné, Borda Jenő, Deák György, Kuki Ákos, Zsuga Miklós:
Preparation and characterization of poly(vinyl chloride)- continous carbon fiber composites
Közlésre előkészítve

IV. 2. Lectures in the field of the dissertation

1. **Ráthy Istvánné**, Budai Zoltán, Borda Jenő, Deák György, Kéki Sándor, Horváth Róbert, Zsuga Miklós :
   Szénszálerősítéses poliuretán kompozitok előállítása és mechanikai tulajdonságainak vizsgálata
   VI. Vegyészkonferencia, Kolozsvár 2000. nov. 17-19.

2. Budai Zoltán, **Ráthy Istvánné**, Borda Jenő, Deák György, Kéki Sándor, Horváth Róbert, Zsuga Miklós :
   Szénszállal erősített polipropilén kompozitok fizikai vizsgálata
   VI. Vegyészkonferencia, Kolozsvár 2000. nov.17-19.

3. **Ráthy Istvánné**, Borda Jenő, Horváth Róbert, Zsuga Miklós
   Szálerősített kompozitok előállítása és vizsgálata
   VII. Vegyészkonferencia, Félixfürdő, 2001. nov. 16-18.

4. György Deák, Zoltán Budai, Sándor Kéki, **Ráthy Istvánné**, Róbert Horváth, Miklós Zsuga: Polypropylene composites
   Studia Universitas „Vasile Goldis” Arad, 2001./11 (p. 24-30.)

5. **Ráthy Istvánné**, Borda Jenő, Bodnár Ildikó, Horváth Róbert, Zsuga Miklós :
   Új tipusú kompozitok előállítása
   XIII. *Műanyagok műszaki alkalmazása és feldolgozás-technológiája c. konferencia,* Mechanoplast 2002. Gyula, 2002. március 12-14.

6. **Ráthy Istvánné**, Borda Jenő, Bodnár Ildikó, Horváth Róbert, Zsuga Miklós,
   Erősített műanyagok előállítása és vizsgálata
   „FUTURE AVIATION TESHNOLOGIES” 1-st INTERNATION SYMPOSIUM
   Szolnok, 2002. ápr. 12-14. Repüléstudományi Közlemények 2002., 155-156. old.

7. **Ráthy Istvánné**, Borda Jenő, Bodnár Ildikó, Zsuga Miklós:
Moulded polyurethane based composites
6. International Scientific-Technical Conference for PhD Students
Presov- Herlany 2-4. 5. 2005.

8. **Ráthy Istvánné**, Marossy Kálmán, Borda Jenő, Zsuga Miklós,
Szénszálak viselkedésének vizsgálata lágyított PVC-ben,
XI. Nemzetközi Vegyészkonferencia, Kolozsvár 2005. nov.11-13.