

COMPOSITES WITH RUBBER MATRIX AND FERRIMAGNETIC FILLING

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Abstract: A composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Modern composite materials are usually optimized to achieve a particular balance of properties for a given range of applications. Composites are commonly classified at two distinct levels. The first level of classification is usually made with respect to the matrix constituent. The major composite classes include organic – matrix composites (OMC's), metal – matrix composites (MMC's), and ceramic – matrix composites (CMC's). The OMC's is generally assumed to include two classes of composites: polymer – matrix composites (PMC's) and carbon – matrix composites (Peters, 1998). The composite material used in the work belongs to the PMC's and the composite is formed by the polymer matrix – rubber (sidewall mixture). As filler was used hard-magnetic strontium ferrite. Composite samples were prepared with different filler content (20%, 30%, 40%, 50%). Testing of polymer composites included: tensile test, elongation at break, hardness test and study of morphology.

Keywords: Composites, Rubber matrix, Filling, Mechanical properties, Microstructure

1. INTRODUCTION

Organic-matrix composites, or OMCs; originated through efforts in the aerospace community during World War II to produce materials with specific strength and stiffness values that were significantly higher than existing structural materials. In addition, existing aerospace structural alloys, such as those based on aluminium, were subject to corrosion and fatigue damage, and OMCs provided an approach to overcome these issues. By the end of the war, glass-fiber-reinforced plastics had been used successfully in filament-wound rocket motors and demonstrated in various other prototype structural aircraft applications. In 1970s parallel programs were also ongoing for the use of composites in military and civilian land and naval vehicles. During these years, confidence in using composite materials increased dramatically. This was also a period of great innovation in manufacturing, assembly, and repair method development (ASM Handbook, 2001).

A composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them (Meisner, 1987). Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. Modern composite materials are usually optimized to achieve a particular balance of properties for a given range of applications. However, as a common practical definition, composite materials may be restricted to emphasize those materials that contain a continuous matrix constituent that binds together and provides form to an array of a stronger, stiffer reinforcement constituent. Although composites optimized for other functional properties (besides high structural efficiency) could be produced from completely different constituent combinations than fit this structural definition, it has been found that composites developed for structural applications also provide attractive performance in these other functional areas as well. Composites are commonly classified to two distinct levels. The first level classification is usually made with respect to the matrix constituent. The major composite classes include:

- organic-matrix composites (OMCs),
- metal-matrix composites (MMCs),
- ceramic-matrix composites (CMCs).

The term organic-matrix composite is generally assumed to include two classes of composites:

- polymer-matrix composites (PMCs),
- carbon-matrix composites.

Organic matrices for commercial applications include:

- thermoplastics,
- thermosets,
- elastomers.

The second level of classification refers to the reinforcement form:

- particulate,
- whisker,
- continuous fiber,
- woven composites.

In addition to these general categories, it is possible to create fiber architectures that are combinations of two or more of these categories (Zweben, 1998).

Magnetic rubbers consist of two components, a vulcanizing rubber material containing specialized magnetic particles. Magnetic composite systems are called in general as magnetoplastics. Materials with magnetic powder, especially with ferrite, find application in various technical applications. Matrices for magnetoplastics are used natural or synthetic organic materials. For example, styrene butadiene rubber (SBR) is, quantitatively, the most important synthetic rubber. It is a copolymer of styrene and butadiene in such a ratio that its rubbery nature predominates. It is used at a very large scale in tyres for passenger cars, thanks to its excellent combination of abrasion resistance and friction on the road. In large tyres it can not replace natural rubber because of its heat development. Other synthetic material is butadiene rubber (BR). It has an excellent abrasion resistance and a very low damping. In blends with SBR or natural rubber a good compromise of properties can be obtained (Van der Vegt, 1999).

Various types of hard magnetic and soft magnetic materials, for example ferrite are used as a filling. There are basically two varieties of ferrite: soft and hard. This is not a tactile quality but rather a magnetic characteristic. Soft ferrite does not retain significant magnetization whereas hard ferrite magnetization is considered permanent. Ferrite has a cubic crystalline structure with the chemical formula $MO \cdot Fe_2O_3$ where Fe_2O_3 is iron oxide and MO refers to a combination of two or more divalent metal (i.e. zinc, nickel, manganese and copper) oxides. The addition of such metal oxides in various amounts allows the creation of many different materials whose properties can be tailored for a variety of uses. Ferrites are often produced as powder, which can be sintered into solid cores. Ferrite cores are used in electronic inductors, transformers, and electromagnets where the high electrical resistance of the ferrite leads to very low eddy current losses. Early computer memories stored data in the residual magnetic fields of ferrite cores, which were assembled into arrays of core memory. Ferrite powders are used in the coatings of magnetic recording tapes (Rigbi, 1983).

2. EXPERIMENTAL MATERIAL

Elastomeric matrices was use like experimental material (tyre sidewall mixture) and magnetic filling (strontium ferrite – $Sr \cdot 6Fe_2O_3$, magnetically hard granulate). Specimens were prepared of introduced materials. Specimens are different in carbon black content 10, 20, 30 % and ferrite filling content 20, 30, 40 and 50 weight %.

Filler was used hard-magnetic strontium ferrite labeled FD 160S. Sr ferrite powder coated with a PVAL which provides spherical particles (Fig. 1).

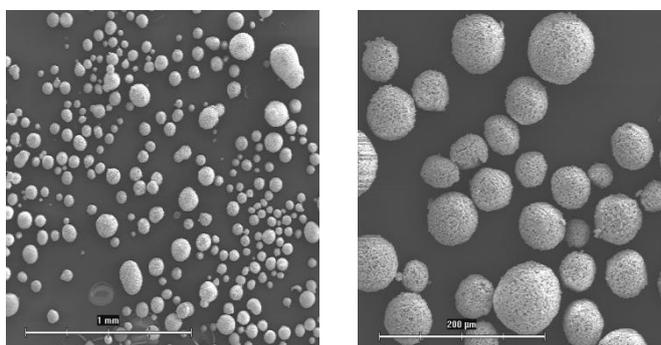


Fig. 1. Sr ferrite particles

In order to clarify particle size and structural characteristics of the individual ferrite fillers we followed the specific surface area and porosity filler mercury porosimetry method. In addition to the determination of pore size, this method allows to determine the pore volume inside the particles, the particles and the total porosity. The measurement results are shown in Table 1.

Table 1

Structural characteristics of ferrite filler

	Sr ferrite
Pore volume greater than 10 μm (cm^3/g)	5.10
Pore volume greater than 1 μm (cm^3/g)	5.02
Total specific surface (m^2/g)	2.11

Total porosity (%)	72.09
The total pore volume (cm ³ /g)	0.22
Apparent density (g/cm ³)	1.51

3. EXPERIMENTAL PROCEDURE

Tensile strength test and elongation – tensile strength was measured in accordance with STN ISO 37. The samples were cut into dumbbell shaped specimens using a die. Parameters, namely tensile strength, modulus, and elongation at break were measured on defined speed of strain 500 mm.min⁻¹.

Hardness test SHORE – hardness was measured in accordance with STN ISO 868. The SHORE scleroscope measures hardness in terms of the elasticity of material. A diamond-tipped hammer in a graduated glass tube is allowed to fall from a known height on the specimen to be tested, and the hardness number depends on the height, which the hammer rebounds, the harder the material, the higher the rebound. SHORE hardness, using either the Shore A or D scale, is the preferred method for rubber (elastomers) and is also commonly used for softer plastics such as polyolefins, fluoropolymers and vinyls. The Shore A scale is used for softer rubbers while the Shore D scale is used for harder ones.

Scanning Electron Microscopy – the structure and morphology magnetic composite materials were observed by SEM. We did not prepare metallographic plane cut from listed material the structure was observed in brittle failure. The brittle failure was prepared absorption in liquid nitrogen. We obtained brittle failure and we can observe morphology and filling distribution (Markovičová, 2004).

4. EXPERIMENT RESULTS AND DISCUSSION

Results of mechanical properties of rubber compound are presented in Table 2.

Table 2

Mechanical properties of sidewall compound

	Ferrite (weight %)	Stress at break (MPa)	Elongation at break (%)	ShoreA
Sidewall mixture	0	18.35	478	61

The mixture was made by the particular prescriptions. A tensile test was performed using the device WDW 20. The speed of moving jaw was set at 500 mm.min⁻¹ with. The sample was pinned to the jaw and force was exercised in the longitudinal axis until the sample break. We measured the maximum force required to break the test samples. From the acquired data, we calculated the stress at break. Results of mechanical properties of magnetic composite are summarized in Table 3. Composites contain different filler content (carbon black, ferrite powder). From the measured values we can see that the carbon black content does not have a significant effect on the tensile strength. The increasing content of the ferrite filler has been shown to decrease the stress at break. The elongation at break is reduced depending on the increasing content of carbon black and the increasing content of the ferrite filler.

Table 3
Mechanical properties of composites

Filling – Sr ferrite	Carbon black (%)	Ferrite (weight %)	Stress at break (MPa)	Elongation at break (%)	ShoreA
	10	20	13.22	616.6	43
	10	30	11.70	573.0	45
	10	40	10.44	525.0	48
	10	50	9.28	479.0	49
	20	20	12.99	537.5	46
	20	30	13.03	540.9	48
	20	40	11.26	494.9	50
	20	50	9.69	436.9	56
	30	20	14.01	490.9	48
	30	30	12.28	442.9	52
	30	40	10.45	388.9	53
	30	50	9.98	378.0	55

On the contrary, the hardness grows slightly with the increasing content of carbon black and ferrite filler.

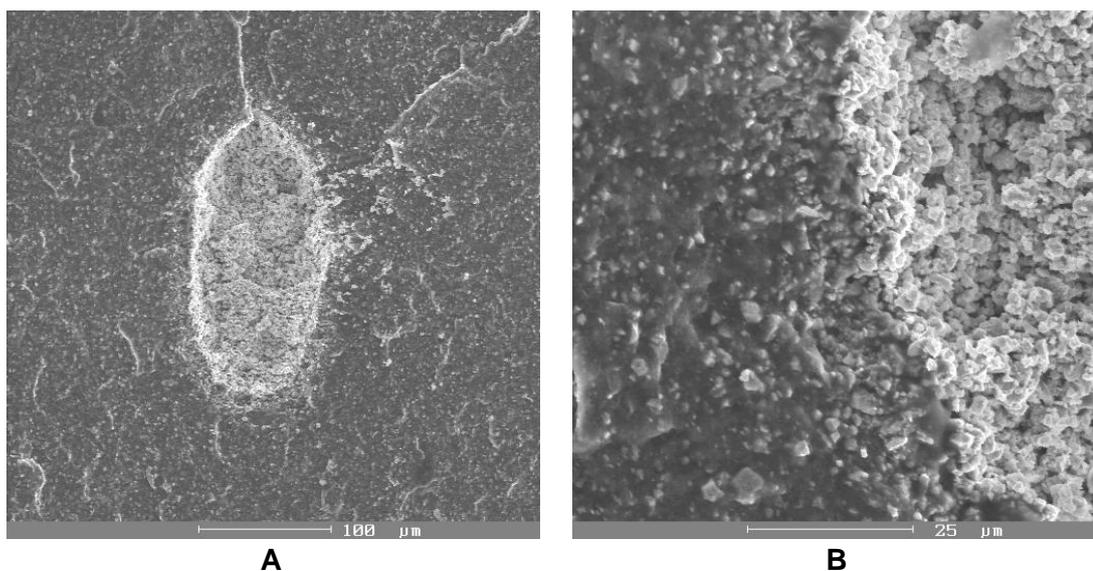


Fig. 2. Composit 50 % Sr ferrite: a) detail of agglomerate of ferrite particles, b) interface between matrix and filler

From the point of view of the structure, the ferritic particles, their shape and the character of the interface between the matrix and the filler, were studied (Fig. 2.). Ferrite particles form clumps in which they do not fill the volume perfectly. The ferritic particles are porous, as a result of which such a filler contains a high percentage of air. The air enclosed in the cavities of the ferritic particle aggregates adversely affects the coherence of the matrix and the filler (Markovičová, 2004). Figure 2B shows decaying agglomerates of ferritic particles and a sharp interface between the matrix and the filler.

5. CONCLUSION

Results from evaluation of mechanical properties of composite are that change in properties is followed by increasing filling content in mixture. From experimental works we can see that:

- increase of filling content lead to decrease of stress at break and elongation at break,
- increase of carbon black and ferrite filling content lead to increase of SHORE A hardness.

Following the results from fracture surface morphology evaluation with increasing ferrite filling content the number of ferrite particles aggregates in sphere shape increased. Higher ferrite filling content was followed by sharp transition between matrix and ferrite particles aggregates. At lower ferrite filling content the matrix inside of ferrite particles aggregates was observed. Moreover, the distribution of ferrite particles were more uniform in specimens with lower ferrite filling content, which was caused by better mixed-up matrix with ferrite filling.

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REFERENCES

- Peters, S. T., 1998. *Handbook of Composites*. 2nd ed., Chapman & Hall, London, 1998.
- ASM Handbook:Composities*. vol. 21, USA, 2001.
- Meisner, B., Zilvar, V., 1987. *Fyzika polymerů*. Praha, 1987.
- Zweben, C., 1998. *Composite Materials and Mechanical Design*. Mechanical Engineer's Hansbook, 2nd ed., New York, 1998.
- Van der Vegt, A. K., 1999. *From polymers to plastic*. DUP Blue Print, Netherlands, 1999.
- Rigibi, Z., Jilkén, L., 1983. *The responce of an elastomer filled with soft ferite to mechanical and magnetic influences*. Jour. Magn. Mat., vol. 37, 1983.
- Markovičová, L., Mintách, R., 2004. *Hodnotenie mechanických vlastností magnetických kompozitov*. VII. Letná škola únavy materiálov, 2004.