

Investigation of Mechanical Properties of Vinylester Composites Reinforced with Boron Nitride Particles

İlyas Kartal*, Yalçın Boztoprak*

*Department of Metallurgical and Materials Engineering, Marmara University, İstanbul, 34722, Turkey
Corresponding author: ilyaskartal@marmara.edu.tr

Abstract

In recent years polymer matrix composites reinforced with inorganic particles have been widely used to develop new materials. Many of the studies in recent years on this subject have focused on hybrid materials obtained by the addition of inorganic structures to polymer materials. In this work, boron nitride particle reinforced vinyl ester composite materials were produced. The reinforcing material was boron nitride particles having an average size of 70 nm. The mechanical properties such as tensile, stiffness and impact of specimens prepared from the vinyl ester composite obtained by the addition of boron nitride at different ratios were investigated. The vinyl ester resin was used because it combines the properties of epoxies and unsaturated polyesters as matrix material and is easy to use at room temperature. Silicone was preferred as a mold material to prepare tensile and impact samples. The reaction used 50% active methyl ethyl ketone peroxide as initiator and 6% cobalt naphthalate as accelerator. In the sample preparation process, the mixture was stirred for 30 minutes in an ultrasonic mixer by addition of MEG (mono ethylene glycol) in an amount of 5 times the amount of the particles to provide homogeneous distribution of the boron nitride particles and to prevent agglomeration. Subsequently, 80 g of vinyl ester resin was added to this homogeneous mixture and stirring was carried out in an ultrasonic mixer for 30 minutes to obtain a homogeneous mixture. 3% methyl ethyl ketone peroxide was added as a hardener to the resulting mixture, and 6% cobalt naphthalate was added as an accelerator after thorough mixing. Once a homogenous mixture has been obtained, the mixture is poured into a silicone mold which is placed on a smooth surface and balanced with a water balance. The silicone mold was left at 85 ° C for 10 minutes and the cured samples were removed from the mold. In this way, sample preparation was repeated in the same manner for all sample ratios. Tensile and elasticity modulus and impact values increased by 1% mixture. Hardness values increased up to 1.5% mixture and a constant value was observed after this ratio. A decrease in bending properties was observed.

Composites have taken the place of metals and other engineering materials in almost all engineering applications. The reason behind such a great growth is the wide range of applications they find. Polymer matrix composites are the fastest growing engineering materials due to their high specific strength and specific modulus. Applications are available in a wide range of venues such as automobiles, space and civic buildings. For example, use in automobiles can reduce its weight and improve fuel economy [1-2]. The mechanical properties of the polymer matrix composites can be improved by reinforcing the particles. These properties can be designed by selecting the appropriate matrix and reinforcement material [3]. In general, the mechanical properties of particle-reinforced polymer composites depend on the shape, size and distribution of the reinforcement, and also on the adhesion between the matrix and the particles [4]. Numerous inorganic fillers such as fly ash, aluminum and silicon carbide are used as reinforcing polymer matrix.

Of the micro-scale particles commonly used as fillers / reinforcers, submicron particles have a higher specific surface area. This high specific surface area requires high surface interaction between the long chain polymer matrix and the reinforcement. It is well known that the distribution state of the submicron particles in the composite structure directly influences the properties of the polymer composites. If the agglomeration of these submicron particles can be controlled, both the mechanical and electrical properties of the composite can be improved [5-7].

Vinyl ester resins have more hydroxyl terminal reactive double bonds than other resins. Due to their long chain structure they are more flexible than other epoxy resins. Unlike unsaturated polyester resin, which has reactive double bonds entirely in the chain, it only has reactive double bonds at the end of the chain. This double bond nature and toughness allows the production of vinyl ester resin composites. When using vinyl ester resins, both cure speed and reaction conditions can be easily controlled. These make vinylester resin more versatile than other epoxy resins. Vinyl ester resins are one of the predominantly used thermosets and provide excellent toughness, thermal stability and chemical resistance [8].

It is widely used in electrical components, military and aviation applications. It is frequently used in boat hulls and wind turbine wings [9-10].

In this work, vinyl ester resin is preferred as matrix material because it combines the properties of epoxies and unsaturated polyesters and is easy to use at room temperature.

Experimental

In the sample preparation process, the mixture was stirred for 30 minutes in an ultrasonic mixer by addition of MEG (mono ethylene glycol) in an amount of 5 times the amount of the particles to provide homogeneous distribution of the boron nitride particles and to prevent agglomeration. Subsequently, 80 g of vinyl ester resin was added to this homogeneous mixture and stirring was carried out in an ultrasonic mixer for 30 minutes to obtain a homogeneous mixture. 3% methyl ethyl ketone peroxide was added as a hardener to the resulting mixture, and 6% cobalt naphthalate was added as an accelerator after thorough mixing. Once a homogenous mixture has been obtained, the mixture is

poured into a silicone mold which is placed on a smooth surface and balanced with a water balance. The silicone mold was left at 85 ° C for 10 minutes and the cured samples were removed from the mold. In this way, sample preparation was repeated in the same manner for all sample ratios. Tensile and elasticity modulus, impact and hardness values increased by 1% mixture. A decrease in bending properties was observed.

Table 1. Tensile test results

% Boron Nitride (by weight)	Tensile Strength MPa	Elasticity Modulus MPa	% Elongation
0	40	2200	7
0,5	40,5	2300	6,8
1,0	42	2600	6,2
1,5	22	1100	5,4
2,0	15	700	5,2

Table 2. Change in bending test results

% Boron Nitride (by weight)	Maximum Stress at Bending, MPa	Modulus of Elasticity at Bending, MPa	% Elongation
0 (Saf)	43	280	21
0,5	36	250	20
1	35	240	15
1,5	20	220	15
2	16	200	12

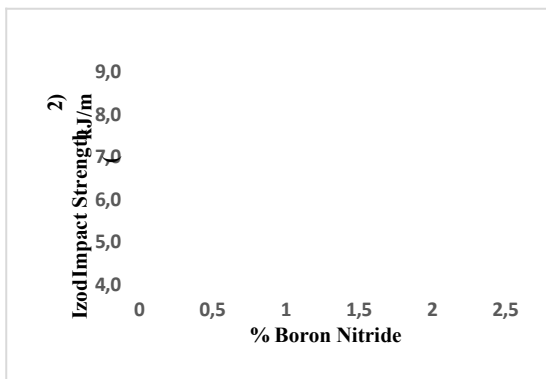


Figure 1. Change in impact strength depending on the amount boron nitride

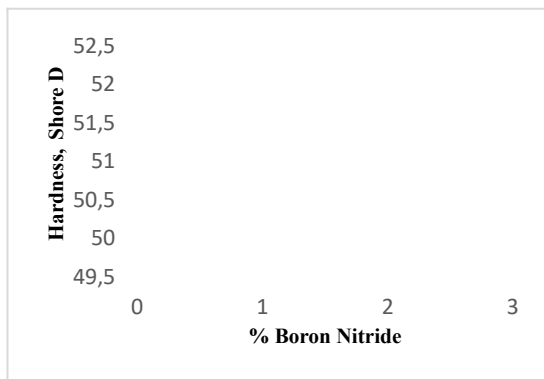


Figure 2. Hardness change values depending on the amount of boron of nitride

Addition of nano-sized boron nitride to the vinylester resins resulted in an increase in tensile strength and impact strength as expected of the composite specimens obtained. However, the ideal values were obtained with the addition of 1% boron nitride. Hardness values increased up to 1.5% and a constant value was observed after this ratio. The bending properties were reduced as expected. When we examine the vinilestart matrix with 1% by weight of the sample, very little of the volume is composed of boron nitride. A very small addition to the nano size has caused significant changes in mechanical properties. This method is recommended for producing parts with small dimensions and recessed protruding geometries, which are reinforced in the independent direction.

References

1. Chauhan SR and Thakur S. Effects of particle size, particle loading and sliding distance on the friction and wear properties of cenosphere particulate filled vinyl ester composites. *Mater. Des.* 2013; 51: 398–408.
2. Labella M, Zeltmanna SE, Shunmugasamy VC, et al. Mechanical and thermal properties of fly ash/vinyl ester syntactic foams. *Fuel* 2014; 121: 240–249.
3. Tagliavia G, Porfiri M and Gupta N. Analysis of flexural properties of hollow-particle filled composites. *Compos B Eng* 2010; 41: 86–93.
4. Kulkarni MB and Mahanwar PA. Effect of methyl methacrylate–acrylonitrile–butadiene–styrene (MABS) on the mechanical and thermal properties of poly (methyl methacrylate) (PMMA)-fly ash. *J Miner Mater Charact Eng* 2012; 11: 365–383.
5. Deepthi MV, Sharmab M, Sailaja RRN, et al. Mechanical and thermal characteristics of high density polyethylene–fly ash cenospheres composites. *Mater Des* 2010; 31(4): 2051–2060.
6. Kolay PK and Singh DN. Physical, chemical, mineralogical, and thermal properties of cenosphere from ash lagoon. *Cem Concr Res* 2001; 31(4): 539–542.
7. Shunmugasamy VC, Pinisetty D and Gupta N. Electrical properties of hollow glass particle filled vinyl ester matrix syntactic foams. *Mater Sci* 2014; 49: 180–190.
8. Mallick P. *Fiber-reinforced composites: materials, manufacturing and design*. Boca Raton: CRC press, 2007.
9. Sathesh Raja R, Manisekar K, Manikandan V, et al. Study on mechanical properties of fly ash impregnated glass fiber reinforced polymer composites using mixture design analysis. *Mater. Des* 2014; 55: 499–508.
10. Prabhu BK, Dudse S and Kulkarni SM. Statistical analysis of flexural modulus of cenosphere reinforced recycled poly (ethylene terephthalate) using Taguchi method. *J Elastom Plast* 2014; 47(6): 611–622.

