Effect of Talc Filler Content to Short-Term Hydrostatic Internal Pressure Performance of Polypropylene Bloc Copolymer/Talc Composite Pipes

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Abstract

In this study, short-term hydrostatic internal pressure properties of micro particulate talc filled polypropylene block copolymer pipes were investigated according to the TC content. The aim of this study is manufacturing TC filled PPB pipes to achieve more rigid composite pipes and optimized Hoop stress properties. To investigate the TC filler content effect on composite PPB pipes, average particle size 13 μm TC filler content added to polymer in different ratios of 10, 15, and 17.5% volume. Short-term hydrostatic internal pressure tests applied according to ISO 1167 standards. The experimental results bring out the fact that the composites are micro particulate filled thermoplastic materials according to these standards. It was observed that the stiffness of the composite pipe was increased and the Hoop stress was decreased by the amount of the TC filler. Additionally, in order to estimate the failure mechanism, failure areas of the composite pipes were examined.

Keywords: *Composite Pipe, Talc, Hoop Stress, Internal pressure.*

1. Introduction

With physical modification of micro, nano and even hybrid thermoplastic composite materials in various particle sizes, different weight percentage (wt %) amounts, and using inorganic substances as diverse as Wollastonite [1], Kaolin [2], Talc [3], and Calcium Carbonate [4], are produced. To analyze these materials high pressurized methods are used like injection molding and hot pressing, similar to their regular production method. So the studies and information gathered on the effects of the filler amount are limited with the uniaxial test results. It's known from the experimental results that, the base material and filler interaction surface characteristic, particle size and shape[5], the filler content ratio and filler distribution is affected the performance of the micro-particulate composite materials [6]. But the hydrostatic internal pressure performance of PPB/TC composite pipes which is manufactured with single screw extrusion method, keeps the uncertainty. In this context, the aim of this work is to define the performance of the PPB/TC composite pipes according to the TC filler content ratio by using the ISO 1167 standards. In this study, outer diameter 63mm SDR (Standard Dimension Ratio) 11 pipes which were filled with average particle size 13.00 μm and TC 10, 15 and 17.5% by volume ratio tested according to the standards both ISO 1167 for hydrostatic pressure tests at 20°C water were applied. The PPB/TC pipes were investigated according to the TC filler ratio.

2. Experimental

2.1. Materials

Density of 900 kg/m^3 and mold flow index 0.30 g/min (230°C/2,16 kg) PPB material, which the commercial name is BorECO™ BEC5015 (Borealis A/S), is used. The mechanical properties tested from injection molded test specimens which 1500 MPa tensile modules, yield stress 30 MPa and 10% yield elongation are some instance information for mechanical properties given by the manufacturer product data sheet according to the standard ISO 527 (Borealis 22.01.2008 Ed.9).

To investigate the filler content effect, 13 μm average particle size and density of 2780 Kg/m^3 TC material, which the commercial name is Talk 5XH (Mikron's Mineral Endüstrisi A.Ş.), is used. The white powdered TC material producer information is given in Table 1.

Table 1. Particle Size Distribution

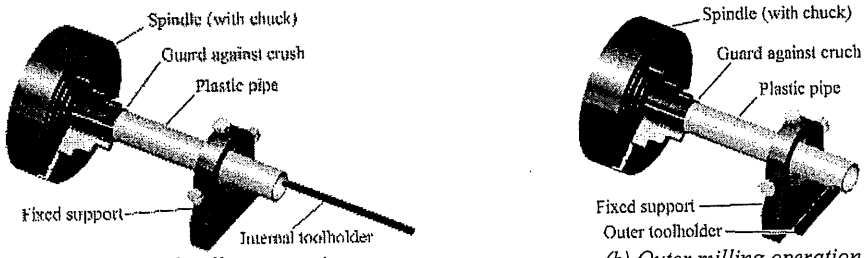
Particle Size	Method	Unit	Typical Value
Average Dia., d(0.50)		µm	13
Top Cut, d(0.97) [max.]		µm	45
Below 2 µm [min.]		%	8
Sieve 45 µm [max.]	ISO787-7	%	1

2.2. Composite Preparation

The PPB/TC composite production is performed in screw length (L/D) 38.5 and the helix length (L) 2700 mm twin-screwed extruder (Coperion Werner and Plederer ZSK 70 Mcc). TC mineral filler added in to granule form PP-B pipe raw material at ratios of 10, 15 and 17.5% by volume and extruded with a twin-screwed extruder machine, so mineral filled polyolefin compounds were obtained in granule form. The products were manufactured in a 500 kg/h extruder at -1 bars atmospheric pressure, between 240°C-260°C zone temperatures and 28°C±3°C set cooling water. Every batch was dried at 50°C for 4 hours.

2.3. Composite Pipe Extrusion

To manufacture the pipe according to the SDR (Standard dimension ratio) 11, outer dia. 63 mm pipes, screw length (L/D) 30, screw dia. (D) 90 mm single-screwed extruder (Krauss-Maffei KME 1-90-30B) was used. Pure pipes were manufactured at 200°C-260°C zone temperatures and 25°C cooling bath temperature. Besides pure pipe production, the 10% filled PPB/TC composite pipes were manufactured at 160°C-170°C zone temperatures. And finally the 15 and 17.5% filled PPB/TC composite pipes were can only manufactured at 155°C-170°C zone temperatures. After the manufacturing process the pipes internal surface were rough and barbed.



(a) Internal milling operation *(b) Outer milling operation*

Figure 1. Milling operation od barbed pipes.

So, to do the experimental test on pipes, the internal and outer surfaces were milled in horizontal lathe as shown in Figure 1.

2.4. Hydrostatic Internal Pressure

Regarding to the test standard ISO 1167-2, from equation (1) where the (D_0) outer diameter and l_2 is the testing clamp length, the sample length (l_1) was calculated 575 mm.

$$l_1 = 3.D_0 + 2.l_2 + 250\text{mm} \quad (1)$$

To determine the smallest wall thickness (e) beyond the pipe length, a special fixture with 0.01mm precise measuring tool (Hi-Tech) is used. To determine the pipe sample's average outer diameter (d_e), the outer diameter (mm) where the thinner wall is the smallest and two sides diameters are 0.01mm precisely measured with a caliper (Mitutoyo).

$$P = 10 \cdot \sigma \cdot \frac{2 \cdot e}{d_e - e} \quad (2)$$

The HSP tests were done at Blue Line 1586-0212 (Institut für Prüftechnik Geraetebau GmbH & Co.KG) testing machine in Kocaeli University. Regarding to ISO 1167-1 type-A end caps were used in tests. The internal pressure (bar) applied to the pipes are calculated from equation (2) [Where (σ) indicates the Hoop

stress (MPa), (d_e) average outer dia. of pipe (mm)] Pipes are stored at least 150 hours in well-conditioned and free of sunlight. The pipes are tested at 20°C±0.2°C temperature range, at calculated nominal pressure and can be diagnosis in circumstances like 1% pressure decrease and 2% pressure rise. To determine the HSP performance of the pipes at least 5 sample is used for each test.

3. Results and Discussion

Mainly we should note in here that pure PPB, PPB/TC composite materials, were used without being exposed to the effects of the parameters used in twin-screw extrusion process. Pipes, Hoop stress-time-temperature curves plotting, pure PPB pipe damage in the first hour of Hoop stress the value of 22.1 MPa, were used as the initial base value. The PPB/TC composite pipes HSP performance is evaluated as reference of 22.1MPa = 100 %. According to this reference the composite pipes Hoop stress-time-temperature curves are plotted.
In Table 2 the measured average outer diameters and wall thicknesses of SDR 11, 63mm pure and composite pipes were shown according to test duration. It's figured out that the measured values of the pure and composite pipes were lower than the standard tolerances in ISO 15874.

Table 2. The measured values of pure and composite pipes according to test duration.

	Test hour	Diameter (mm)			Thickness (mm)	
		min	average	max	min	max
Pure PPB	≤ 10	63.11	63.34	63.61	6,00	6,21
	≤ 200	63.05	63.37	63.74	5.99	6.21
10% TC filled PPB/TC	≤ 10	62.97	63.24	63.44	7.09	7.49
	≤ 200	62.97	63.19	63.42	7.15	7.46
15% TC filled PPB/TC	≤ 10	62.70	63.12	63.55	6.57	7.08
	≤ 200	62.55	63.06	63.52	6.59	7.06
%17.5 TC PPB/ TC	≤ 10	63.34	63.55	63.82	6.65	7.33
	≤ 200	63.36	63.57	63.81	6.64	7.08

In Figure.2 the short-term HSP performance of pure PPB and PPB/TC composite pipes were given. When Figure.2 analyzed, first of all it was observed that the TC filler affected the HSP properties of the pure PPB pipe. The PPB/TC composite pipe's HSP properties are slightly lower than pure PPB pipe. On the other hand, there is approximately 22.7% contraction occurs in pure PPB depending on the time from the 1 hour to 100 hour in Hoop stress values, although the contraction occurs at 10, 15 and 17.5% TC filled PPB/TC in the same order of 26.6%, 31.2% and 30.2%, which is significantly higher the pure PPB contraction.

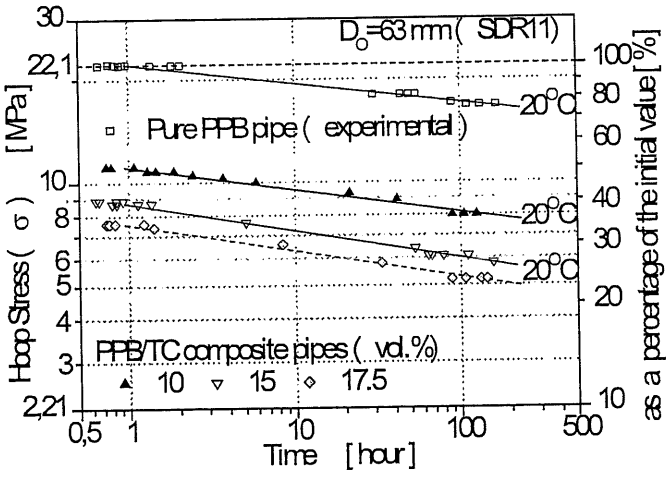


Figure 2. The Hoop stress-time-temperature curves of pure PPB and 10, 15 and 17.5% filled PPB/TC composite pipes.

Therefore it's determined that according to the pure PPB in 10, 15 and 17.5% PPB/TC pipes there is a drop occurs in 1 hour Hoop stress damage values in the same order of 49.8%, 60.6%, and 65.8%.

Similar to that, it's determined according to the pure PPB in 10, 15 and 17.5% PPB/TC pipes there is a drop occurs in 100 hour Hoop stress damage values in the same order of 52.2%, 64.9%, and 69.1%. In this context, the Hoop stress damage values rising by the increasing TC filler amount. As a result of the increasing duration of short-term HSP, this effect gets bigger. According to this experimental observation, under the HSP effect this result could be described as the TC particulates and base polymer particulates interaction surfaces were not adhere each other as required. To prepare the Hoop stress-time-temperature curves, for 20°C test temperature, regardless from the outer diameter and wall thickness of pipe, 16MPa Hoop stress value is taken as a reference from ISO 15494, at minimum required hydrostatic strength curve causes damage at 1 hour. This reference is chosen for a start value (16MPa = 100%) to demonstrate the increases or decreases by percentage in graphics. In Figure.3 the Hoop stress-time-temperature curves, minimum required hydrostatic strength curves for PP-B (ISO15494) are given together with 10, 15 and 17.5% by volume TC filled composite pipes. When Figure.3 examined, first of all it's clearly seen that the minimum required hydrostatic strength curve for 10, 15 and 17.5% TC filled by volume PP-B composite pipes Hoop stress values are significantly smaller than the minimum required hydrostatic strength curve for PP-B (ISO15494).

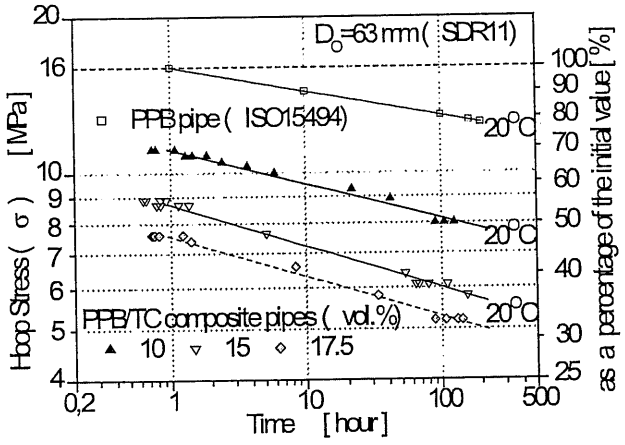


Figure 3. According to ISO15494 min. required hydrostatic strength time temperature curve for 10, 15, 17.5% TC filled by volume PPB composite pipes.

From the reference standard according to the allowed value for 1 hour Hoop stress, 10, 15 and 17.5% TC filled by volume PP-B composite pipes Hoop stress values which occurs damage are decreases in the same order of 30.6%, 45.7% and 52.8%. Similarly to this context, from the reference standard according to the allowed value for 100 hour Hoop stress, 10, 15 and 17.5% TC filled by volume PP-B composite pipes Hoop stress values which occurs damage are decreases in the same order of 36.8%, 53.5% and 59.1%. In Figure.4 shows the damages occurred under 1 - 100 hour short-term HSP effect. When the figures examined depended on time, ductile fractures are observed (<1 hour) in pure PPB pipe, by increasing time there were no changes in the fracture type. On the contrary the composite pipes failure shape was start with ductile (<1 hour) and later indicate a brittle failure (>1 hour).

4. Conclusion

In this study, 1-100 hour short-term HSP performances of PPB/TC composite pipes affected by 10, 15 and 17.5% TC filler content. But it's determined that the Hoop stress damage values rising by the increasing TC filler amount. And the increasing duration of short-term HSP, this effect gets bigger. It was recorded that the TC filler in PPB pipe by volume 10% has a significant decrease in pipes mechanical performance, also its observed that by increasing TC content the effects were increased. Performance of composite pipes, for the standard associated with PPB pipes, within the same durations stipulated by the minimum performance, were found to be lower. Also, 10, 15 and 17.5% by volume TC-filled composite pipes, between the same durations (1-100 hours), in the same order of about 26.6%, 31.2% and 30.2% change in performance, for the standard associated with PPB pipes, as reference to the predict value in standard 19.4% were also detected

higher. From the Hoop stress-time-temperature curves it should be stated that the decrease in Hoop stress value of PPB/TC composite pipes under HSP stress during time is higher than the required decrease from the associated standard. Finally it's recommended to use lower and/or modified TC filler amount, besides small TC particulate size in future PPB/TC composite pipe research. It also recommended using different extrusion process parameters.

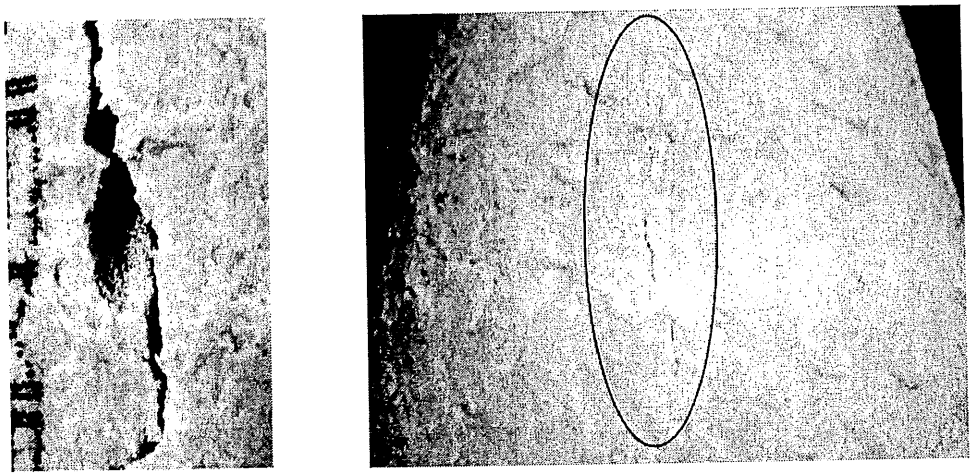


Figure 4. Failure modes depend to time.

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