Effects of Recycled Silicone Catheter Filled SMR L on Tensile Properties and Morphology

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***Abstract*—The effect of recycled silicone catheter (rSC) loading (5, 15, 25, 35 and 50phr) with two different size; fine and coarse size, on tensile properties (tensile strength, modulus at 100% elongation and elongation at break) and morphology of recycled silicone catheter filled Standard Malaysian Rubber (SMR L/rSC) vulcanizates were studied. For tensile properties, tensile strength and modulus at 100% elongation (M_{100}) for both SMR L/rSC fine and coarse vulcanizates show increment up to 15 phr and decreased gradually as the rSC loading increased. The drop might be due to the formation of agglomeration of rSC within the vulcanizates. Meanwhile, elongation at break (E_B) decreased with increasing rSC content. Comparison between SMR L/rSC fine and coarse vulcanizates indicates that SMR L/rSC fine vulcanizates has better tensile properties than SMR L/rSC coarse vulcanizates due to better dispersion and filler-rubber interaction. The results obtained also show that the morphology of SMR L/rSC fine vulcanizate is better than that of SMR L/rSC coarse vulcanizates. This attributed to better incorporation between rSC fine and SMR L rubber matrix.**

***Keywords*— SMR L rubber, recycled silicone catheter, tensile properties and morphology**

I. INTRODUCTION

In developed countries like UK, USA and Italy, it was stated that the percentage of disposable of rubber waste at landfill is higher. Therefore the government took an action to push the rubber industry towards recycling or other non-landfill alternatives like retreading or energy conversion [1]. Much of the volume of rubber waste produced annually could be recycled and reused.

As a medical device, it must be well functioning without eliciting undesirable side effects. Thus, any desirable defects on the products such as catheters; it will be rejected and considered as waste. Recycling is preferred method in handling rubber waste as they do not degrade rapidly due the presence of three dimensional networks in the rubber products [2].

For instance, in this study, the waste recycled silicone catheters were obtained from medical industry. Those wastes will undergo mechanical recycling technique such as grinding. The silicone resins can be recycled by decomposing the monomer having catalyst and active hydrogen. But for silicone materials can be grinded, crushed or recycled even though they are in different shapes [3]. The recycling of silicone rubber waste will be beneficial for both environment and human health. It is also was reported that it will increase the cash flow of economy and save energy from being wasted [4].

In this study, the effect of recycled silicone catheter loading on tensile properties such as tensile strength, modulus at 100% of elongation and elongation at break will be determined. Besides, the effect on morphology of SMR L / rSC vulcanizate also will be studied.

II. EXPERIMENTAL

A. Materials

Standard Malaysian Rubber, SMR L was used in this study. Filler used were kaolin and recycled silicone catheter (rSC). Other additives used were zinc oxide, stearic acid, sulphur and N-cyclohexyl-2-benzothiazole sulfonamide (CBS). All materials are listed along with their respective source as shown in Table I.

TABLE I. List of Material Used

Materials	Description	Source
Natural rubber	SMR L	Malaysian Testing Laboratory Sdn. Bhd.
Recycled silicone catheter (rSC)	fine (300-600μm) coarse (1-2cm)	Teleflex Sdn. Bhd.
CBS, zinc oxide, stearic acid, kaolin, and sulphur	Compounding materials	Anchor Chemical Co. (M) Ltd.

B. Preparation of Vulcanizates

SMR L was mixed will all compounding ingredients in a two-roll mill. The rubber vulcanizates were prepared with different formulations as shown in Table II. The recycled silicone catheter loading used were 5, 15, 25, 35 and 50 phr. They were prepared in two different particle size; fine and coarse size and denoted as SMR L/rSC F and SMR L/rSC C respectively.

TABLE II. Formulation for Recycled Silicone Catheter Filled SMR L Vulcanizate

Materials	phr					
	Control	**rSC 05**	**rSC 15**	**rSC 25**	**rSC 35**	**rSC 50**
SMR L	100	100	100	100	100	100
rSC	0	5	15	25	35	50
ZnO	5	5	5	5	5	5
Stearic acid	5	5	5	5	5	5
Kaolin	20	20	20	20	20	20
Sulphur	2	2	2	2	2	2
CBS	1	1	1	1	1	1
Processing oil	2	2	2	2	2	2

C. Measurement

1) Tensile

The vulcanizate test samples were prepared by hot press according to the cure time determined by the MDR 2000 at 160°C and cut into dumbbell shape for tensile test. It was conducted according to ASTM D412 using Instron machine. Tensile properties like tensile strength, modulus at 100% elongation (M100) and elongation at break (E_B) were determined.

2) Morphology

Morphology of the tensile fracture surface of the test sample was carried out by using scanning electron microscopy (SEM). The sample surface were mounted on aluminium stubs and sputter coated with a thin layer of a gold about 2nm thickness prior to analyze to avoid electrostatic charging and poor resolution.

III. RESULTS AND DISCUSSION

A. Tensile Properties

It can be seen in Fig. 1 and 2 that the tensile strength and M_{100} of both SMR L/rSC fine and coarse vulcanizates increased up to 15phr of rSC loading but then drop gradually. The initial increase in tensile strength and M_{100} is because of the reinforcement effect of the rSC and also increased in crosslinking density. The drop might be due to the formation of agglomeration of filler that resulted in poor interaction between adjacent aggregates and leads to the reduction in reinforcement of rubber [5, 6].

The tensile strength and M_{100} of SMR L/rSC F vulcanizate is higher than that of SMR L/rSC C vulcanizate because finer rSC has larger surface area than the coarse one. This can contribute to more uniform dispersion of rSC within the rubber matrix and gives better reinforcement to the SMR L/rSC F vulcanizates. This contributes to an efficient stress transfer in the SMR L/rSC F vulcanizates, thus resulted in higher tensile strength [7,8].

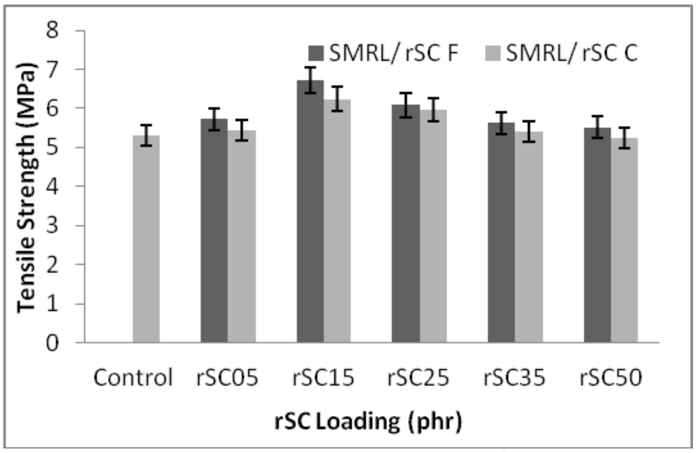


Fig. 1. Effect of rSC Loading on Tensile Strength of SMR L/rSC Vulcanizates

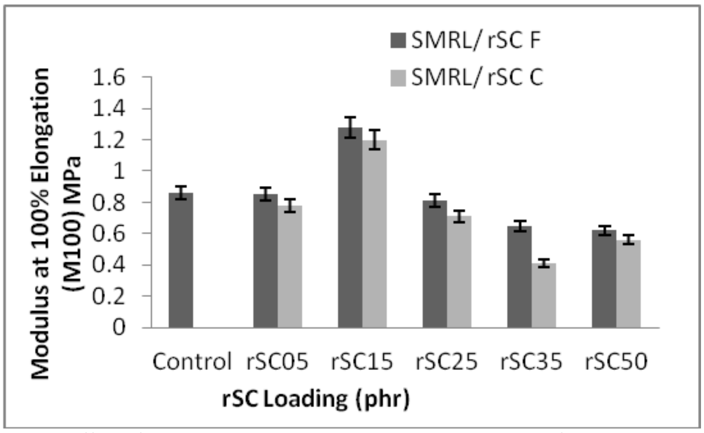


Fig. 2. Effect of rSC Loading on Modulus at 100% Elongation of SMR L/rSC Vulcanizates

On the other hands, the E_B of SMR L/rSC vulcanizates was decreasing when the rSC loading increased as shown in Fig. 3. It is believed that the reinforcement effect took place in which the vulcanizates became stiffer, thus restrict the rubber chain movement and tend to break when stretching [8]. Due to better dispersion and filler-rubber interaction, the E_B of SMR L/rSC F vulcanizates was higher compared to the SMR L/rSC C vulcanizates at similar loading of rSC. Therefore, it provided higher extensibility and able to elongate at higher strain [7].

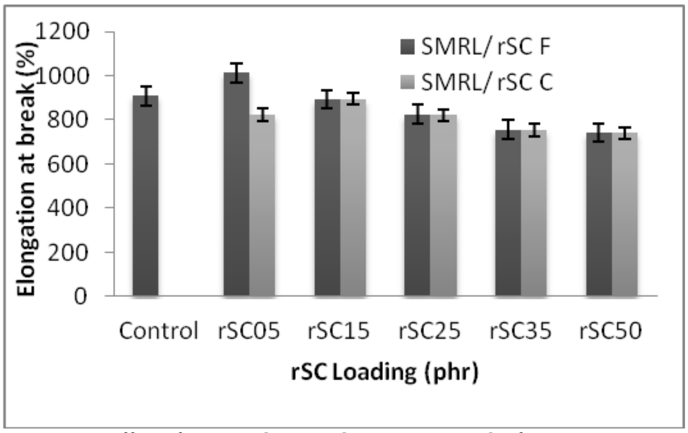
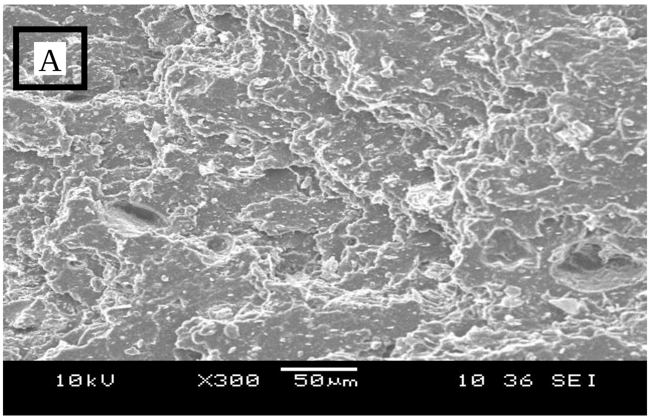


Fig. 3. Effect of rSC Loading on Elongation at Break of SMR L/rSC Vulcanizates

B. Morphology

Fig. 4 (A) and (B) illustrate the tensile fracture surfaces of both SMR L/rSC fine and coarse vulcanizate with 15phr of rSC loading at 300X magnification. It can be seen that Fig. 4(A) shows filler detachment of rSC in the rubber matrix. This indicates low adhesion between phases and contributed to poor stress transfer. Moreover, rougher surfaces with less tear lines also observed. It means that less energy is needed to break the sample which resulted in lower tensile properties [7]. There was also observed in Fig. 4(B) that more tear line with filler well bonded in the SMR L matrix which contribute to more stress transfer across the interface [7]. Thus, it results in higher tensile properties for SMR L/rSC F vulcanizate.



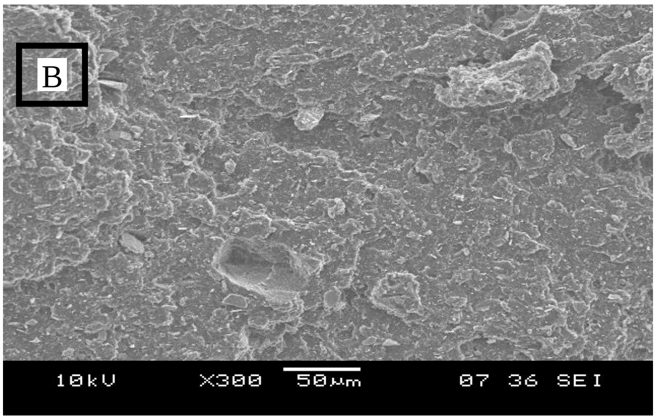


Fig. 4. SEM Micrographs of Tensile Fracture Surface of SMR L/rSC F (A) and SMR L/rSC C (B) Vulcanizate with 15phr of rSC Loading at 300X Magnification

IV. CONCLUSION

As the conclusion, the tensile strength and M_{100} of SMR L/rSC vulcanizate increased up to 15 phr but E_B decreased as the rSC content increased. SMR L/rSC F vulcanizate shows higher tensile strength, M_{100} and E_B compared to SMR L/rSC C vulcanizate at similar blend ratio due to the larger surface area and better dispersion of fine rSC in SMR L/rSC F vulcanizate. Therefore, 15 phr is optimum loading for SMR L/rSC vulcanizate as it imparts better properties. From the morphological study, it was observed that SMR L/rSC F vulcanizate shows more tearing line with filler well embedded into the matrix.

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