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Study on Mechanical Properties of Silicone Rubber Talc RTV 497-Talc Composite as Shoe Insole Material Fabricated by Vacuum Mixing Technique

[1]Dwi Basuki Wibowo, [2]*Agus Suprihanto, [3]Ojo Kurdi

[1,2,3]Mechanical Engineering Department, Diponegoro University, Semarang, Indonesia
*Corresponding Author's E-mail: agusm90@yahoo.com

***Abstract* - Silicone rubber is a biocompatible elastomeric material. Its elastic properties enable it to absorb impact loads, such as those experienced by the foot during walking or running. In order to achieve desired mechanical properties, silicone rubber can be blended with talc to form a composite material. This study investigates the influence of talc addition on the mechanical properties of silicone rubber RTV 497. The mixing process involves adding talc in percentages ranging from 5% to 30%. To minimize trapped air, the mixing process is conducted under vacuum conditions. The resulting mixture is then used to create specimens for tensile and compression testing. The test results demonstrate that the tensile strength and compressive strength significantly increase with higher percentages of talc addition. Thus, the percentage of talc added can be tailored to meet the requirements for an insole material that provides optimal comfort.**

Keywords: silicone rubber RTV 497, talc, composite material.

I. INTRODUCTION

Fast walking and running are popular athletic activities among the community due to their health benefits, affordability, and minimal equipment requirements. As a result, the popularity of these sports continues to grow (McCarthy & Jones, 2007). However, these activities also pose a risk of foot injuries caused by impact forces when the foot strikes the ground (Baumann, 1987). To prevent such injuries, specially designed shoes are used to provide comfort and reduce the potential for injuries. One approach is the development of materials for shoe components, including insoles and midsoles (Mishra et al., 2020). A suitable material for this purpose is an elastic and biocompatible material like silicone rubber.

Silicone rubber is an elastomeric material based on high molecular-weight linear polymers (Boonstra et al., 1975; Han et al., 2022). Its main polymer chain consists of polydimethylsiloxane, composed of Si-O units with two methyl groups attached to each silicone atom.

The mechanical properties of silicone rubber can be modified by incorporating it into composite materials. Its strength and hardness can be adjusted by varying the reinforcing materials. Talc is commonly added filler in silicone rubber to enhance its mechanical properties. Talc is a hydrated magnesium silicate that is insoluble in water (Barbosa & Castillo, 2023). The addition of talc to silicone rubber transforms it into a composite material, which can affect its mechanical properties.

Thus, the mechanical properties of silicone rubber-talc composites can be tailored to meet the requirements of insole materials for absorbing impact loads during walking and running.

The production of silicone rubber-talc composites is typically conducted under atmospheric pressure. However, this method has the drawback of trapping air within the material, resulting in air voids. This makes it challenging to accurately predict the mechanical properties. To avoid trapped air, the air is minimized during the mixing process using vacuum techniques. This study investigates the tensile and compression strength of silicone rubber-talc composites produced under vacuum conditions.

II. METHODOLOGY

The silicone rubber used in this study is RTV 497. The addition of talc powder is varied at percentages of 5%, 10%, 15%, 20%, 25%, and 30%. The mixing process involves stirring the silicone rubber and talc in a sealed container connected to a vacuum pump for 10 minutes. The vacuum pump used is a Free Air Displacements model VE160N with a capacity of 7.0 CFM and a maximum vacuum pressure of 150 mmHg. Figure 1 illustrates the schematic of the silicone rubber-talc mixing apparatus.

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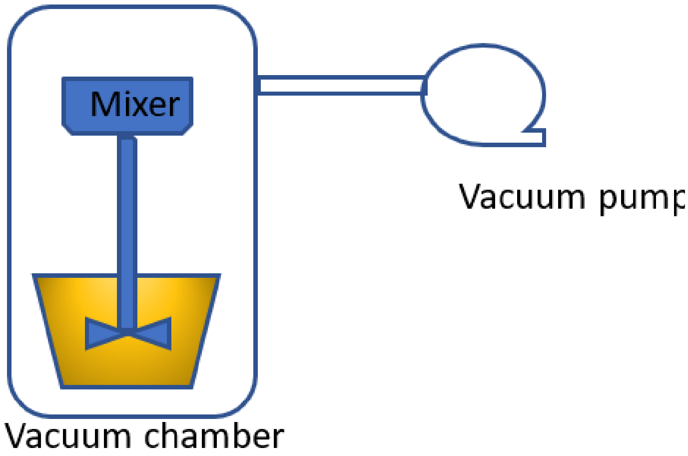

Figure 1: Schematic diagram of the silicone rubber-talc mixing device

The silicone rubber-talc mixture is then removed from the sealed container and poured into molds for the preparation of tensile and compression test specimens. The dimensions of the tensile test specimens follow ASTM D412 standards, while the compression test specimens are disk-shaped with a diameter of 30 mm and a thickness of 20 mm. Figure 2 illustrates the tensile and compression test specimens. The test specimens are removed from the molds after 24 hours.

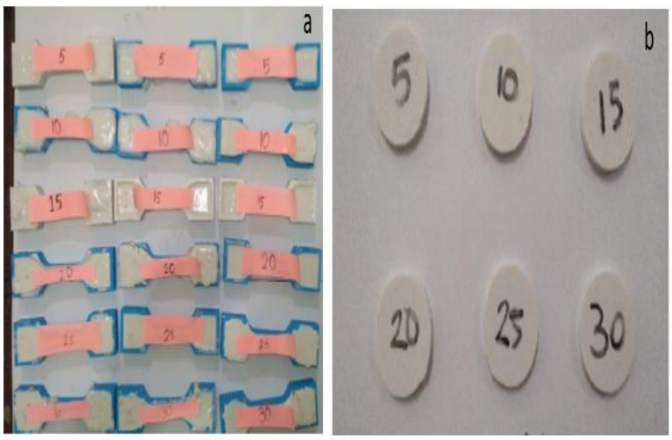

Figure 2: Test specimens a) for tensile testing and b) for compression testing

Tensile testing was conducted to determine the tensile strength of the specimens. The testing was performed using a GD 1100 Universal Testing Machine with a maximum tensile force set at 100kg. The pulling speed was set to 20mm/minute.

Compression testing was carried out using a DME 220H model machine. The maximum compressive force was set at 500kg, and the compression speed was set to 1mm/minute. The purpose of the compression testing was to obtain data on the change in diameter and the magnitude of the compressive force when the specimens were compressed to distances of d = 2mm, 4mm, 6mm, and 8mm from their initial thickness.

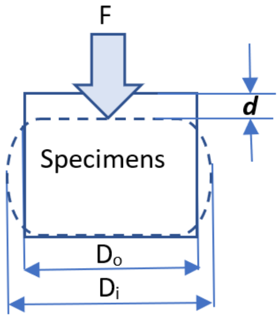

Figure 3: Schematic diagram of compression testing

III. RESULTS AND DISCUSSION

Figure 4 shows the data of tensile testing results. It can be observed that the tensile strength of the specimens increases with the increasing percentage of added talc. This is attributed to the fact that talc acts as a reinforcement in the silicone rubber-talc composite material. Therefore, a higher addition of talc leads to an increased tensile strength.

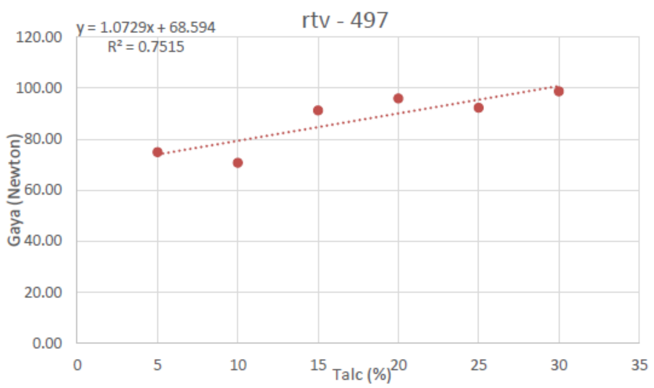

Figure 4: Tensile Strength vs Talc Percentage Graph

The effectiveness of the reinforcing material on the mechanical properties of elastomers depends greatly on its shape, size, and distribution (Kumar et al., 2023). A homogeneous distribution is more capable of improving the overall mechanical properties compared to an uneven distribution. This proves that the mixing process under vacuum conditions is capable of achieving a uniform dispersion of talc powder in the silicone rubber matrix (Ahmadjonov et al., 2023).

Table 1 presents the results of the compression testing. Generally, as the value of the diameter d of the specimen increases, the diameter *Di* also increases. Under a compression of *d* = 2mm, the change in the value of *Di* for each variation of talc composition percentage is not significantly different. Differences start to appear when the compression reaches 4mm to 8mm. The largest change in diameter occurs at a compression of 8mm, with the maximum *Di* value observed at a talc composition percentage of 15%.

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Table 1: Diameter and Compression Force

% Talc	*d* (mm)	D_i (mm)	*F* (kg)
5	2	30.92	25.46
	4	34.56	50.84
	6	39.68	139.12
	8	40.24	552.03
10	2	32.96	24.90
	4	34.74	52.61
	6	44.90	183.38
	8	54.22	840.27
15	2	32.69	28.79
	4	37.14	74.85
	6	44.12	305.34
	8	55.61	1544.63

% Talc	*d* (mm)	D_i (mm)	*F* (kg)
20	2	32.52	26.14
	4	35.62	55.70
	6	42.51	146.97
	8	50.12	522.44
25	2	32.62	23.64
	4	35.51	51.57
	6	40.12	122.65
	8	49.13	434.05
30	2	32.62	27.16
	4	38.12	60.28
	6	42.14	171.46
	8	51.16	632.17

The compression force generally increases with the increasing depth of compression, d. The maximum measured compression force occurs at a compression depth of 8mm. Similar to the value of Di, the maximum compression force occurs at a talc composition percentage of 15%. The graph showing the changes in the value of Di with the compression depth, d, is depicted in Figure 5.

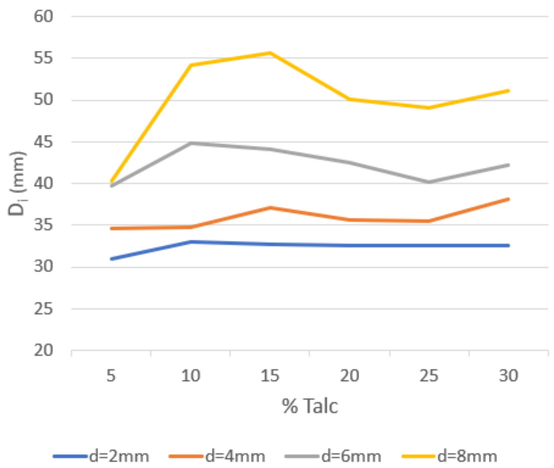

Figure 5: Changes in the value of *Di* with the compression depth, *d*

Figure 6 the relationship between the compressive force, F, and the compression depth, d. Generally, the compressive force, F, for compression depths of 2mm and 4mm does not differ significantly among the talc composition percentages. Differences become apparent at compression depths of 6mm and 8mm. Similar to the changes in Di values, the highest compressive force also occurs at a talc composition percentage of 15%.

The tensile test results indicate that the highest tensile strength is obtained at a talc composition percentage of 30%. However, the maximum Di value and compressive force, F, occur at a talc composition percentage of 15%. This may be due to the bonding between talc powder and the silicone rubber matrix reaching its maximum at a talc composition percentage of 15%. With talc composition percentages exceeding 15%, the high deformation causes the bond between talc and the silicone rubber matrix to weaken, resulting in a decrease in the compressive strength of the composite.

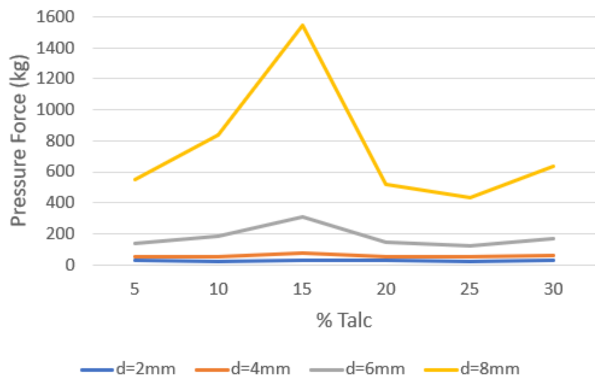

Figure 6: Variation of compressive force, F, with compression depth, d

IV. CONCLUSION

The mechanical properties of silicone rubber can be modified by adding talc as reinforcement. The use of silicone rubber-talc composite as a material for shoe insoles requires not only high tensile strength but also the ability to withstand deformation under impact loads during walking and running. The desired level of deformation can be optimized by adding talc to the silicone rubber.

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