The Effect of Adding Silica from Rice Husk Ash to CFRP Composite on Thermal Properties

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ABSTRACT

RAHMATILLAH, C. A, SUTRISNO, H. H., SARI, Y. 2022. The Effect of Adding Silica from Rice Husk Ash to CFRP Composite on Thermal Properties.

The increasing use of CFRP composites for various applications, particularly in the automotive field, emphasizes its importance in the analysis of the thermal properties. In the effort to improve the thermal properties of CFRP composites, an experiment was carried out in the form of adding silica from rice husk ash which theoretically has a high melting point and can reduce the rate of fire propagation of material. This research was conducted to determine the effect of the addition of silica from rice husk ash on the thermal stability of CFRP composites. Composite samples were made using epoxy resin, unidirectional long continuous carbon fiber, and silica from rice husk ash with various compositions: 0% (without silica), 5%, 10%, 15%, 20%, and 25%. The manufacturing process is carried out using the Hand Lay-Up method and were tested using a Thermogravimetric Analysis (TGA). The resulting thermogravimetric curve generated the data of thermal stability indicators values in the form of extrapolated onset temperature, mass change, and decomposition temperature. Based on the results of the research, it can be concluded that the addition of 15% silica from rice husk ash is the sample with the highest thermal stability value and generally, the addition of silica from rice husk ash to the CFRP composite can increase its thermal properties and can withstand ambient temperatures up to 405.9° C.
Key Words: CFRP composite, silica, thermal properties

ABSTRAK

RAHMATILLAH, C. A, SUTRISNO, H. H., SARI, Y. 2022. Pengaruh Penambahan Silika dari Abu Sekam Padi pada Material Komposit CFRP Terhadap Sifat Termal.

Peningkatan penggunaan komposit CFRP menekankan pentingnya/signifikansinya dalam analisis sifat termal. Dalam upaya peningkatan sifat termal komposit CFRP, dilakukan eksperimen berupa penambahan silika dari abu sekam padi yang secara teori memiliki titik leleh yang tinggi dan dapat menurunkan laju rambat api pada material. Penelitian ini dilakukan untuk mengetahui pengaruh penambahan silika dari abu sekam padi terhadap stabilitas termal komposit CFRP. Pembuatan sampel komposit menggunakan resin epoksi, serat karbon jenis *unidirectional long continous fiber*, serta silika dari abu sekam padi dengan variasi komposisi: 0% (tanpa silika), 5%, 10%, 15%, 20%, dan 25%. Proses pembuatan dilakukan menggunakan metode *Hand Lay-Up* dan diuji menggunakan mesin *Thermogravimetric Analysis* (TGA). Kurva termogravimetri yang dihasilkan menunjukkan data nilai indikator stabilitas termal berupa temperatur onset ekstrapolasi, perubahan massa, dan temperatur dekomposisi. Berdasarkan hasil penelitian, dapat disimpulkan bahwa penambahan silika dari abu sekam padi sebanyak 15% merupakan sampel dengan nilai stabilitas termal tertinggi dan secara umum penambahan silika dari abu sekam padi pada komposit CFRP dapat meningkatkan sifat termalnya serta mampu menahan suhu ambien hingga 405,9 °C.
Kata kunci*:* komposit CFRP, silika, sifat termal

INTRODUCTION

The increasing use of CFRP composites for various applications, especially in the automotive field, emphasizes their importance/significance in the analysis of the thermal properties of engineering systems. This is because thermal properties are closely related to the material's resistance to heat/high temperatures which will affect the strength of the material. Results of research conducted by Nguyen, et al. [1] showed that the mechanical performance of the tested CFRP composites decreased as the temperature increased. So it can be concluded that the higher material's ability to maintain its mechanical properties at high temperatures, the better the thermal properties of the material.

Apart from mechanical properties, the thermal properties of materials are also closely related to fire and combustion. In the automotive field, it is very important to prevent fires in vehicles, especially in vehicle materials that come into direct contact with humans and can endanger their safety. Like the incident that occurred at the international motorbike racing event, Mandalika MotoGP in March 2022, namely the burning of a motorbike that used CFRP composite as its fairing component material while being ridden. This incident is one of the reasons for this research to study and improve the thermal properties of CFRP composite materials. This is based on the theory that the better the thermal properties of a material, the higher the material's ability not to burn.

In an effort to improve the thermal properties of materials, several studies are used as references. Research conducted by D.A.Wati [2], R. Wirawan, et al. [3], and H.H. Sutrisno, et al. [4] The background for this research was to conduct experiments with the addition of silica to CFRP composites. The results of these studies show that there is a positive relationship between the addition of silica from rice husk ash to the thermal properties of the material.

When silica is used as a coating material, the material will ultimately have a high flash point. [3] This is based on the theory of a very high melting point of silica (1600-1700 °C). Therefore, silica is a commonly used filler to modify the properties of epoxy resins. [5]

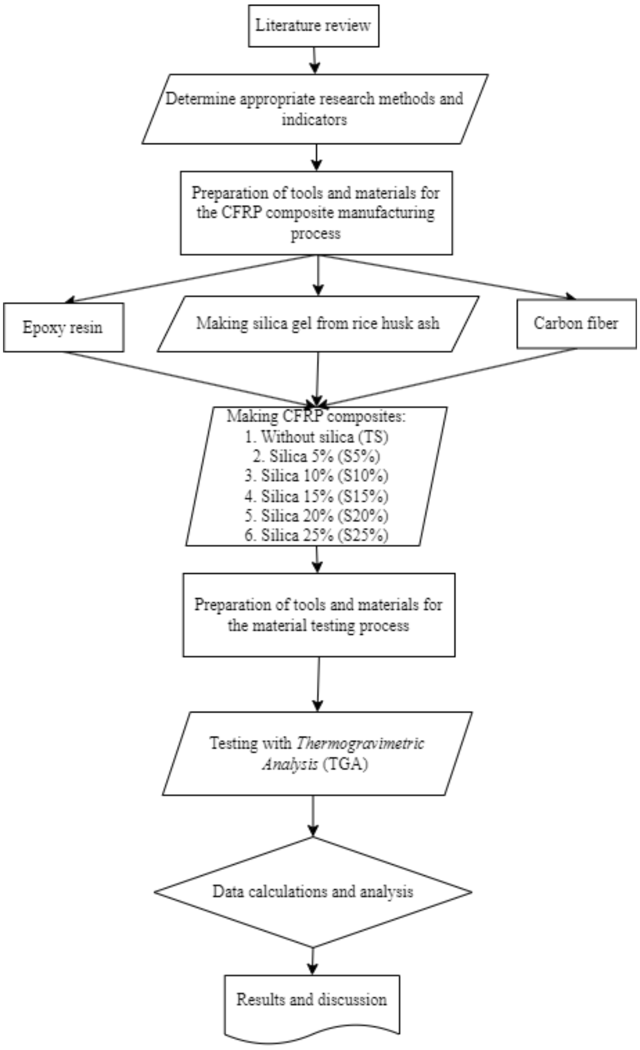
In producing silica, rice husk ash is an alternative source. Rice husks are a lignocellulosic material like other biomass but contain high levels of silica. The chemical content of rice husk consists of 50% cellulose, 25–30% lignin, and 15–20% silica. [6] Even rice husks that have been burned to become rice husk ash (Rice Husk Ash/RHA) show a much higher silica composition, namely 86 – 97.30%. [7] Based on this theory, chemically, rice husk ash can be used as an alternative material for making silica.

Furthermore, previous research related to the addition of silica to CFRP was carried out by Hanif [8] and Huzaefah [9], which focused on its effect on the fire properties and mechanical properties of CFRP, showing a positive relationship between the addition of silica to the fire properties and mechanical properties of CFRP. Therefore, further research needs to be carried out regarding the relationship between the addition of silica to CFRP and its thermal properties.

MATERIALS AND METHODS

The following is a flow diagram of the research conducted.

Figure 1. Research flow diagram



Materials

The materials used in making of CFRP samples in this research include:

1. Silica extracted from rice husk ash
2. 0.5 M KOH (used in making of silica)
3. Epoxy resin and hardener
4. Carbon fiber

Methods

The ensuing section outlines the procedural methodology employed in making and testing of CFRP samples within the scope of this research.

Making Silica from Rice Husk Ash

1. Rice husk ash is dried in the sun for 4 (four) days so that the water content contained in it evaporates
2. Rice husk ash is filtered
3. Rice husk ash with 0.5 M KOH solvent added is heated at 85°C for 15 minutes
4. Add KOH again after the heating process to dissolve the rice husk ash
5. Ensure that the solution is in liquid/gel form to later be used in making composite materials.

Making CFRP

The process of making composite materials is carried out using the Hand Lay-Up method. The Hand Lay-Up process is a manual fiber lamination process, which is the first method in making composites. The Hand Lay-Up method is emphasized for making simple products and only requires one side to have a smooth surface. [10] This study uses a matrix: reinforcement volume ratio of 7:3. Following are the stages of the process:

1. Cutting carbon fiber into certain sizes
2. Mix the resin and hardener in 6 (six) containers (for making the six samples) with a volume ratio of resin: hardener of 2:1. Then the mixture of the two ingredients is stirred until evenly mixed using a stir stick
3. Preparation of rice husk ash silica. Variations in silica percentage 5%, 10%, 15%, 20%, and 25%)
4. Mixing rice husk ash silica with resin + hardener solution. Silica is poured into the solution using a dosing syringe
5. Spraying release agent on the mold
6. Pour the mixture of resin, hardener and silica (matrix) into the mold using a measuring syringe then spread it evenly on the surface of the mold using a brush
7. Layer a sheet of carbon fiber on top
8. Glue the carbon fiber laminate to the matrix using a roller.
9. Carry out steps 6, 7, and 8 alternately until 2 (two) sheets of carbon fiber are used and end with smearing the matrix
10. Wait for the composite to harden completely, after that the CFRP material is released from the mold.

Testing with TGA

The material testing technique used in this research is using Thermogravimetric Analysis (TGA). The following are the stages of the testing procedure.

1. Activate and prepare the operation of the TGA machine, the NETZSCH Proteus Thermal Analysis application on the PC, and nitrogen gas in the cylinder
2. Cutting material to a mass of ±20 mg. Weighed using a digital scale
3. The sample chamber cover is opened and the crucible is removed
4. The sample material is placed on the crucible using tweezers
5. The crucible is put back into the sample chamber and the sample chamber cover is closed again
6. Fill in the material data and other data required in the application
7. Set the heating temperature limit (initial temperature and final temperature), namely from 25 °C (room temperature) to 800 °C (maximum engine combustion chamber temperature)
8. Set the nitrogen flow speed to 20 ml/minute
9. Set the heating rate to 40 °C/minute
10. The testing process is carried out until the final temperature is reached and the machine automatically stops the process. This process takes approximately 20 minutes
11. TGA graph is generated.

RESULTS AND DISCUSSION

Extrapolated Onset Temperature

The extrapolated onset temperature is the point of intersection of the initial mass baseline and the tangent line to the TGA curve at the point of maximum gradient. [11] In short, the extrapolation onset temperature indicates the temperature at which the sample mass decrease begins.

Figure 2. TG curve and extrapolated onset temperature of 6 samples

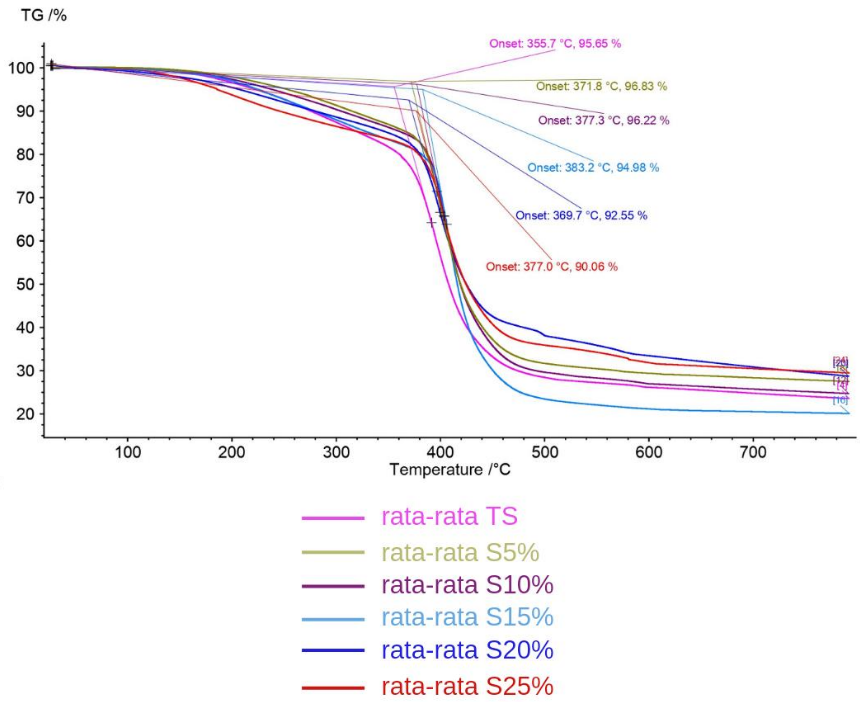
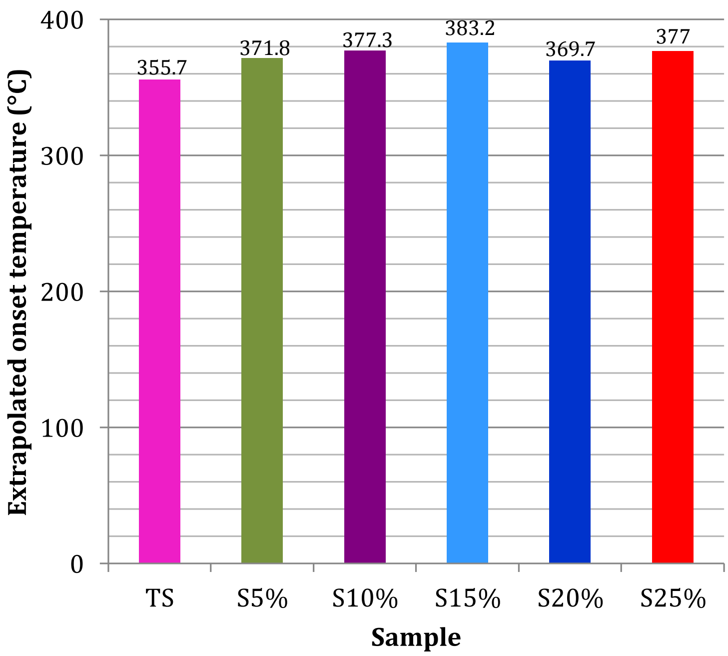


Figure 3. Extrapolated onset temperature values of the 6 samples



Based on these data, the highest temperature value was produced by the S15% sample, namely 383.2 °C. Meanwhile, the lowest value was produced by the TS sample, namely 355.7 °C. From the variation of the first sample to the fourth sample (TS – S15%), it shows that the higher the silica concentration given to the sample, the higher the extrapolated onset temperature value. However, in the fifth sample (S20%), the resulting temperature was lower than the previous samples (which contained silica), namely 369.7 °C. Even so, this value is still higher than the TS sample which is CFRP without silica content. Then in the last sample (S25%), the temperature again rose to 377 °C, which is automatically also higher than the TS sample.

Mass Change (∆m)

Mass change data collection is carried out by limiting the temperature range, namely from the initial heating temperature to the extrapolation onset temperature, then continuing from that temperature to the final heating temperature so that the mass change data obtained is divided into 2 (two) stages, according to the decomposition stages that occur in the composite. CFRP. The remaining mass at the final temperature is also identified.

Figure 4. TG curve and ∆m of TS

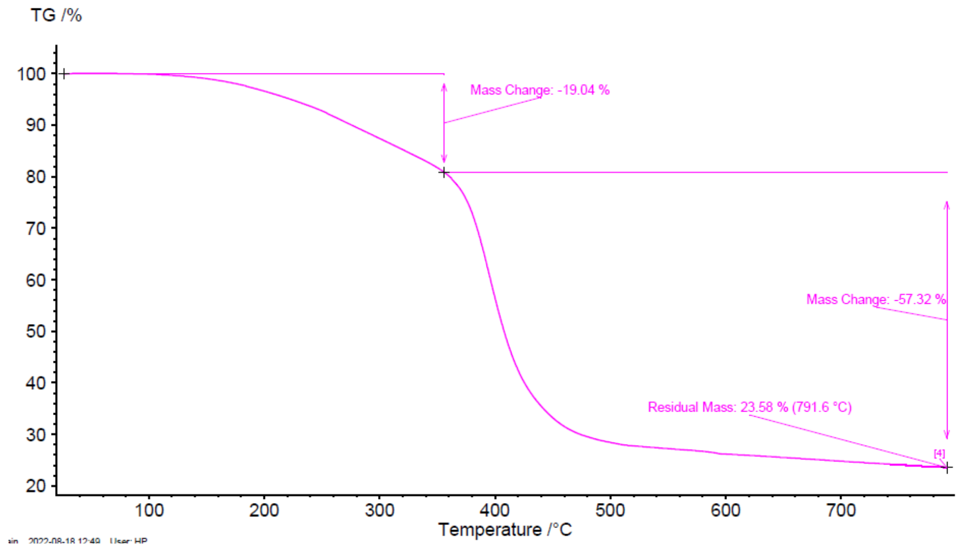


Figure 5. TG curve and ∆m of S5%

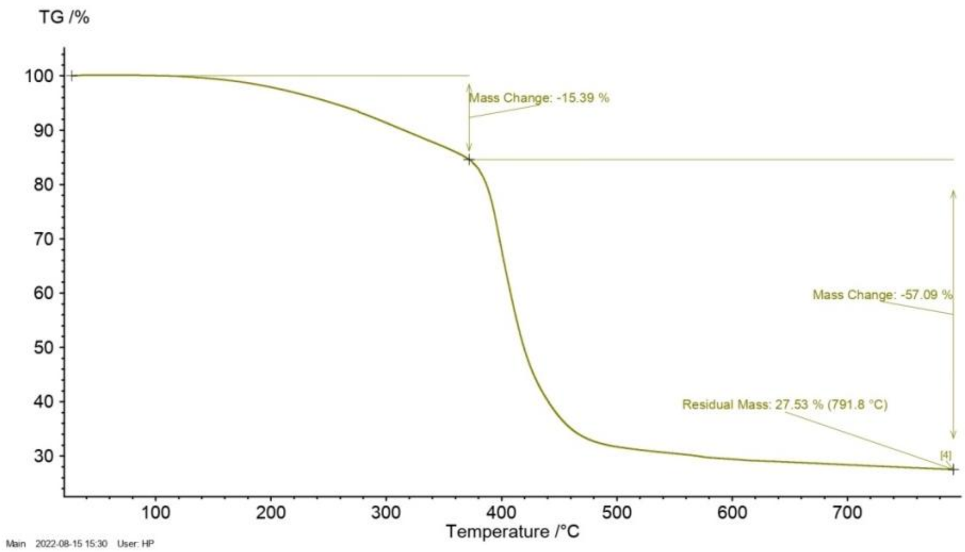


Figure 6. TG curve and Δm of S10%

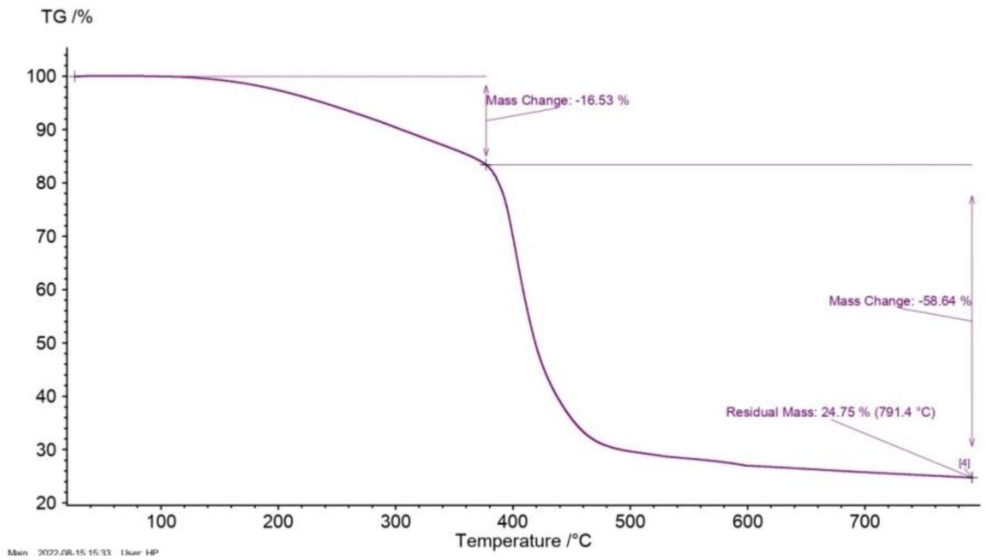


Figure 7. TG curve and Δm of S15%

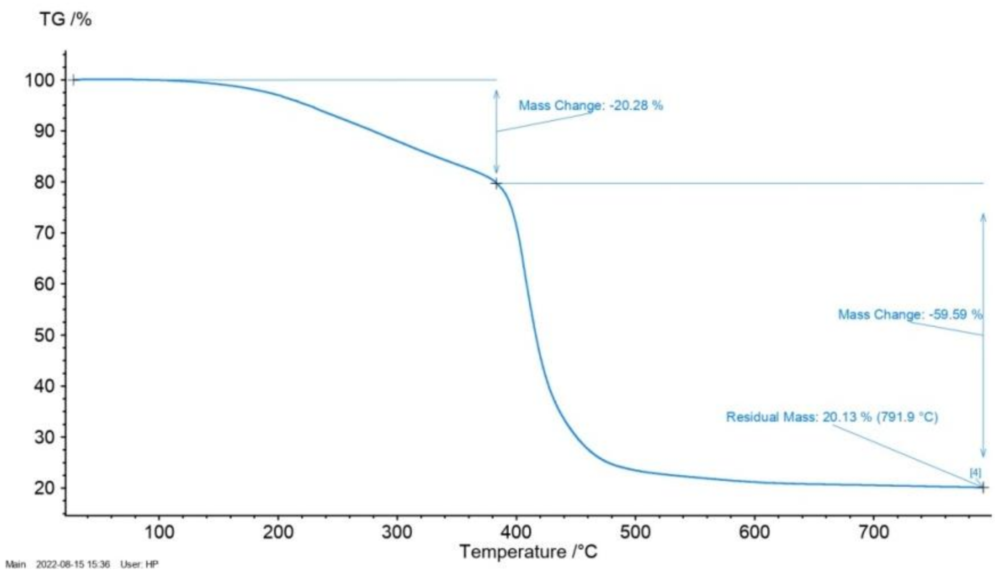


Figure 8. TG curve and Δm of S20%

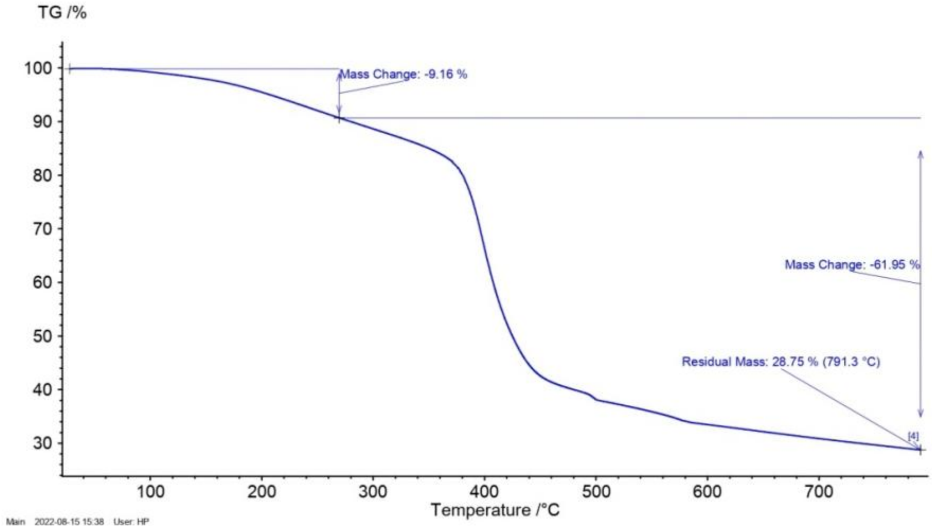


Figure 9. TG curve and Δm of S25%

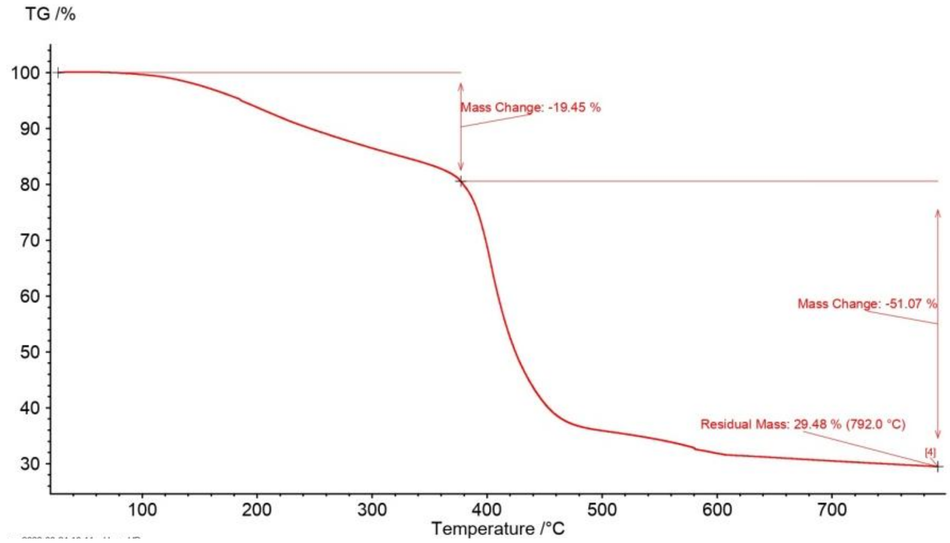


Table 1. Δm of 6 samples

Sample	Colour	Mass loss (%)	Residual mass (%)	Final temperature (°C)
TS		76,36	23,58	791,6
S5%		72,48	27,53	791,8
S10%		75,16	24,75	791,4
S15%		79,89	20,13	791,9
S20%		71,11	28,75	791,3
S25%		70,52	29,48	792,0

Four of the five samples with silica content, namely S5%, S10%, S20%, and S25% had smaller mass loss percentage values than the TS samples. The smallest percentage value of mass loss was produced by the S25% sample, which was 70.52% of the initial mass. Based on this, it proves that in general the addition of silica to the tested CFRP samples can reduce the decomposition of the samples at high temperatures, which means increasing their thermal stability.

Decomposition Temperature (T_d)

The first derivative of the thermogravimetry (DTG) curve from the TG curve allows us to obtain the value of the thermal decomposition temperature. The T_d value can be considered as the temperature point at which the mass loss of the CFRP composite reaches its peak (the peak point of the DTG curve).

Figure 10. DTG curve of TS

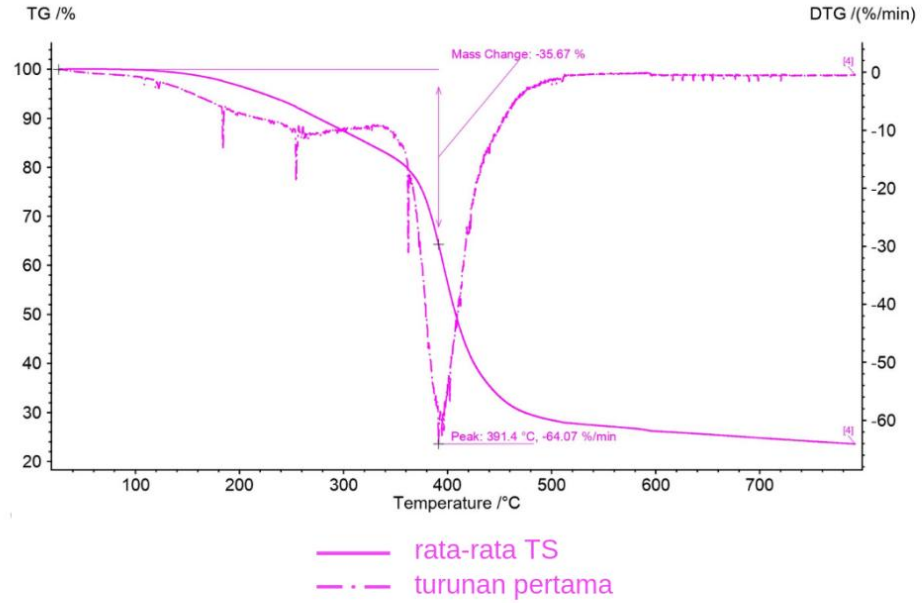


Figure 11. DTG curve of S5%

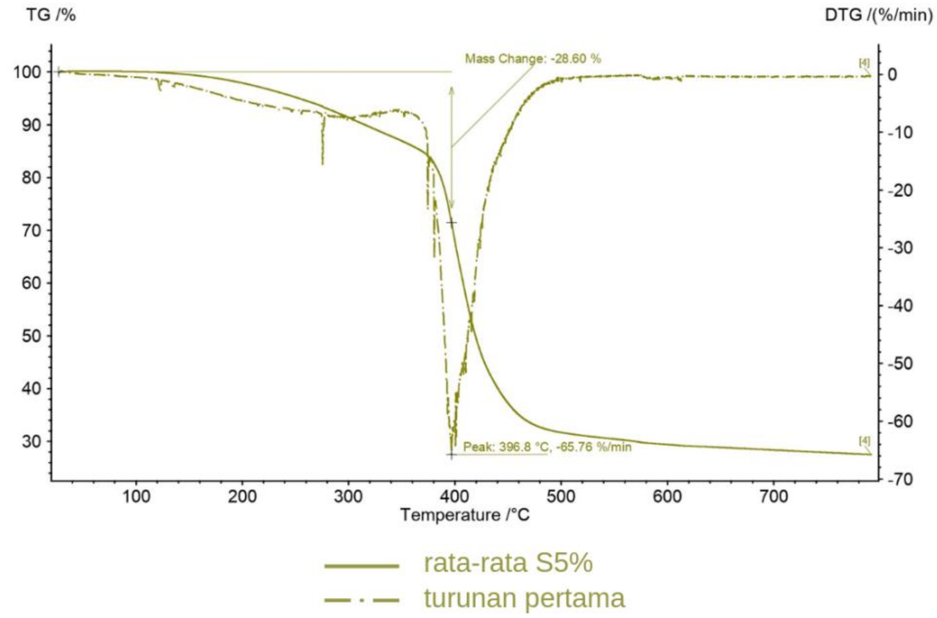


Figure 12. DTG curve of S10%

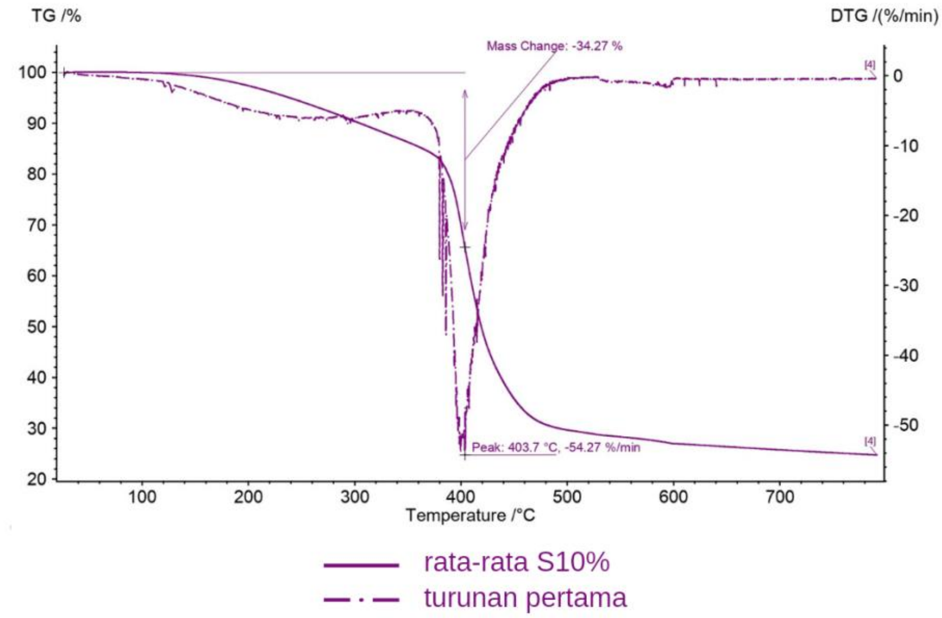


Figure 13. DTG curve of S15%

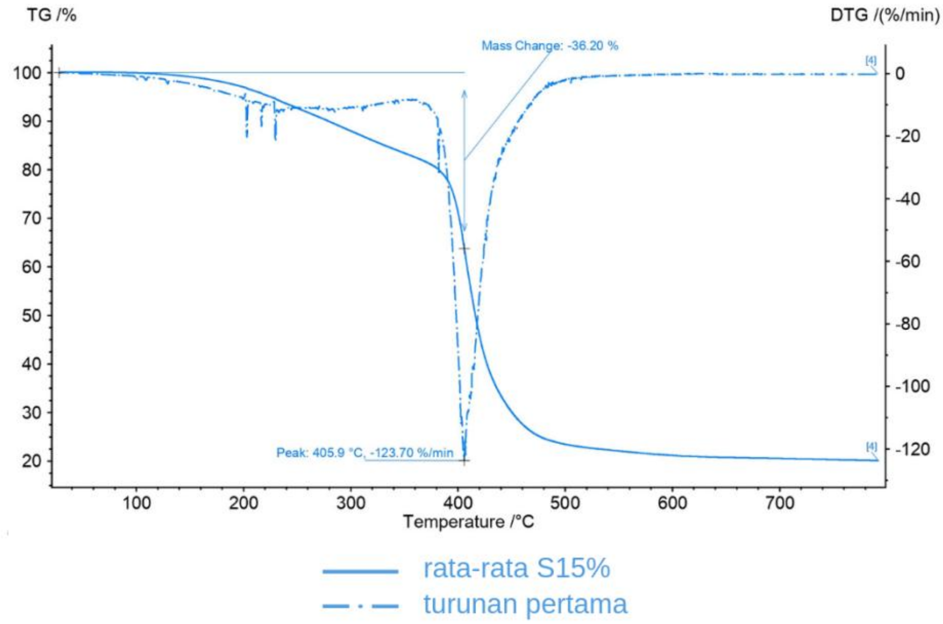


Figure 14. DTG curve of S20%

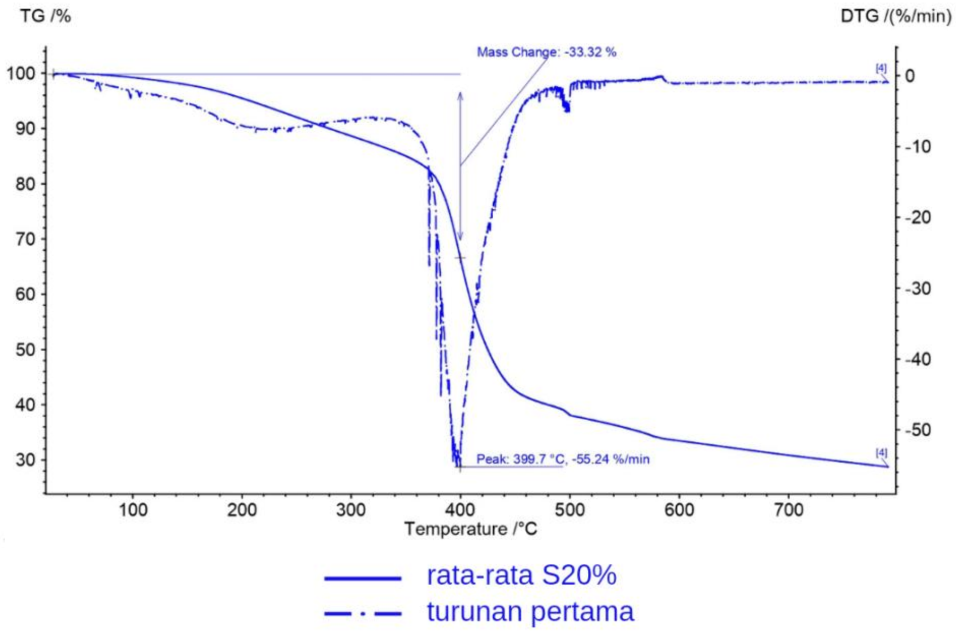


Figure 15. DTG curve of S25%

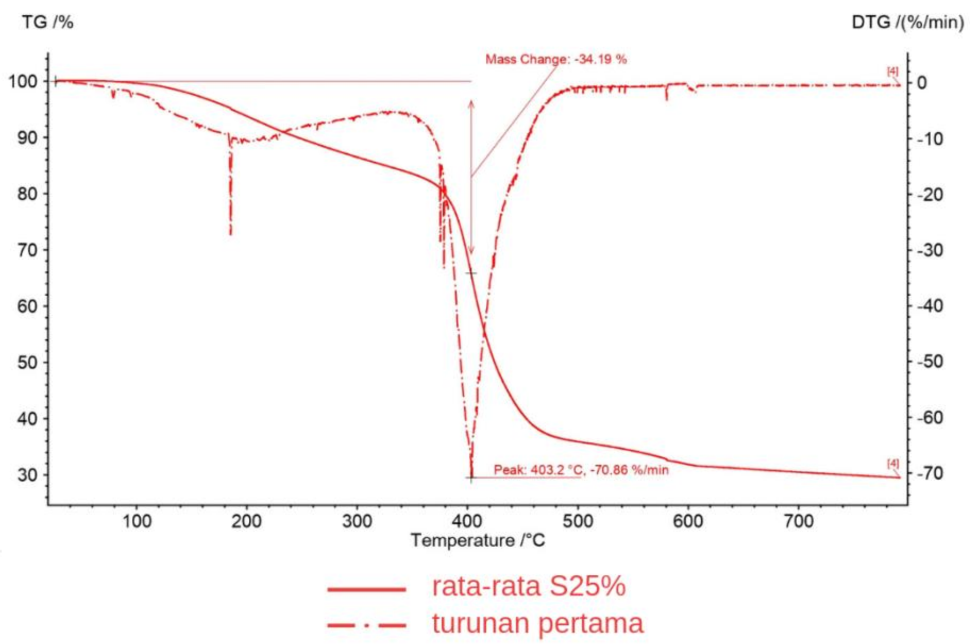
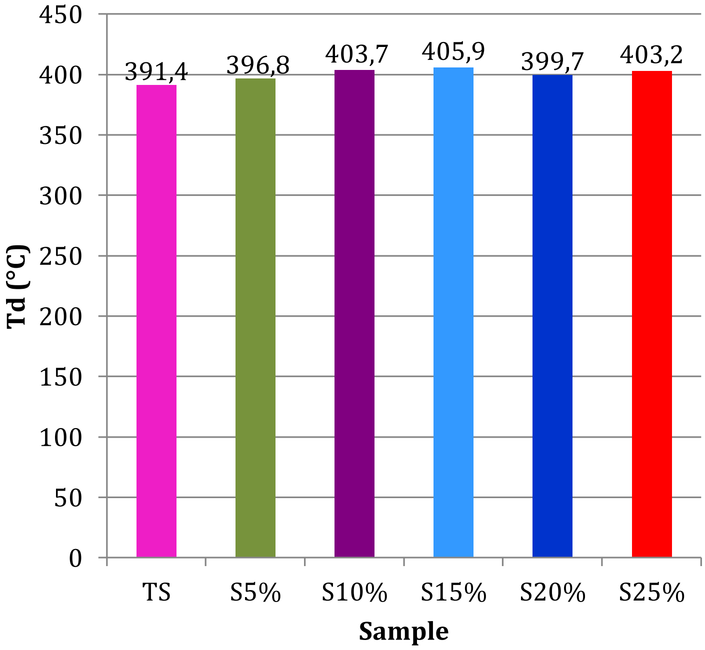


Figure 16. Td of 6 samples



Based on these data, the highest decomposition temperature value was produced by the S15% sample, namely 405.9 °C. Meanwhile, the lowest value was produced by the TS sample, namely 391.4 °C. From the variation of the first sample to the fourth sample (TS – S15%), it shows that the higher the silica concentration given to the sample, the higher the decomposition temperature value. However, in the fifth sample (S20%), the resulting decomposition temperature was lower than the previous two samples (S10% and S15%), namely with a value of 399.7 °C. Even so, this value is still higher than the TS sample which is CFRP without silica content. Then in the last sample (S25%), the temperature again rose to 403.2 °C, which is automatically also higher than the TS sample.

The highest decomposition temperature produced by the sample, namely 405.9 °C, shows that the CFRP composite with added silica can be used as a fairing component on motorbikes, where the material must be able to withstand high temperatures because the fairing is located close to the exhaust pipe, when the temperature is up to 400 °C can be achieved.

CONCLUSION

The addition of silica from rice husk ash to CFRP composites can generally improve their thermal properties, which in this case is thermal stability based on onset temperature, mass change, and decomposition temperature. The thermal stability of CFRP composites which have been improved by the addition of silica from rice husk ash is generally able to withstand ambient temperatures up to 405.9 °C.

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