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Research paper

A study on the sandwich-style notched tensile specimens for different materials through a simulation analysis

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Abstract

Background/Objectives: This study designed a model that used the sandwich-style notched tensile specimens of the same specifications by applying to the properties of CFRP, stainless steel, and aluminum, and performed a test simulation.
Methods/Statistical analysis: The study used CATIA design software to perform the 3D modeling of the sandwich-style notched tensile specimens with the properties of CFRP, a composite material, and stainless steel and aluminum, both ordinary metals, and then, performed a tensile test simulation.
Findings: By designing the sandwich-style notched tensile specimens of the same specifications and performing a test simulation, we were able to verify the tensile strength and durability of the specimens for the different materials. This study result showed that unlike the specimens for the ordinary metals, those specimens with the properties of the composite material of CFRP first showed maximum load instead of breaking immediately due to the fibers in CFRP, before they resisted displacement in response to the alternately increasing and decreasing load until it fractured. To be specific, we saw that the CFRP specimens had the more excellent tensile strength and durability.
Improvements/Applications: The data obtained from the studies will serve as the basic data for studies on the composite materials like CFRP and other various materials.

Keywords: *Notched Tensile Specimen; Material; Mechanical Characteristic; Maximum Load; Durability.*

1. Introduction

Today, materials meet a gradually widening variety of uses such as machines, mechanical structures, automobiles, and ships. At the same time, types of materials are diversifying, which include single-metal materials, light-weight composite materials which focus on lightness, and heterogeneous materials that are made of materials with varied properties. Lately, composite materials, which are both durable and light, are actively researched and developed. Among all of them, CFRP (Carbon fiber reinforced plastic), a composite material that draws attention for its durability and lightness, is lighter and shows the tensile strength greater than ordinary metals[1-5]. In this study, for which we took notice of the composite material of CFRP, we compared and analyzed tensile strength and durability, performed a simulation analysis by designing sandwich-style notched tensile specimens that applied to the properties of CFRP, stainless steel, and aluminum, and verified the tensile strength and durability of the specimens for the different materials. Thus, the study is concerned with tensile strength with the properties of CFRP, a composite material that draws attention for its excellent durability and lightness, and stainless steel and aluminum, the widely used metals, and is designed to acquire the data for future researches on the fracture characteristics and durability of heterogeneous materials and various composite materials. We believe that the data obtained from the specific researches will serve as the basic data for researches on composite materials like CFRP and other different materials[6-10].

2. Research method and models

In this study, we used CATIA design program to perform the 3D modeling of sandwich-style notched tensile specimens applied to the properties of CFRP, a composite material, and stainless steel and aluminum, both ordinary metals, and then, performed a tensile test analysis. Figure 1 shows the specifications of tensile specimens, which are identical as seen in the figure. The specimens are 15mm wide and 80mm long. The width of the plate is 0.5mm and that of the core is 1mm. The notches are 2mm wide and 1mm long. In this study, we wanted to study the tensile strength of such sandwich-style notched tensile specimens. Additionally, Table 1 and 2 shows the properties that are applied to the different sandwich-style notched tensile specimens to perform a simulation analysis [11-12].

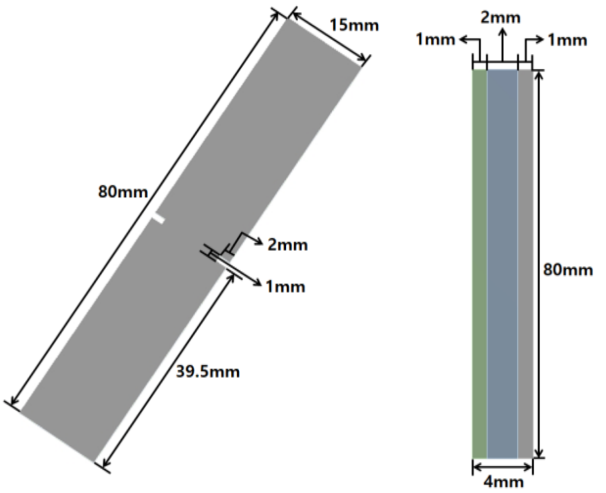

Fig. 1: Dimensions of Notched Tensile Specimen.

Table 1: Material Properties (Stainless Steel and Aluminum)

Material	Stainless steel	Aluminum
Density(kg/m3)	7750	2770
Young's Modulus(GPa)	193	71
Poisson's Ratio	0.31	0.33
Yield strength(MPa)	207	280
Ultimate strength(MPa)	586	310

Table 2: Material Properties (CFRP)

Material	CFRP
Density	1.57kg/m3
Poisson's Ratio(v12)	0.3
Poisson's Ratio(v23)	0.74
Tensile Modulus(E1)	132GPa
Tensile Modulus(E2)	8.98GPa
Tensile Strength(Xt)	1447MPa
Tensile Strength(Yt)	51.72MPa
Compressive Strength(Xc)	1447MPa
Compressive Strength(Yc)	206.2MPa

3. Boundary conditions

Figure2 shows the boundary conditions that were applied to the different sandwich-style notched tensile specimen models to perform a tensile test simulation. Here, the boundary conditions applied to the specimens are identical and are all assumed to be installed on the tensile tester. First, assuming that a specimen is fixed in the lower load cell of the tensile tester, we applied a fixed support to the bottom end of the specimen. Also assuming that the specimens were being applied by the upper load cell, we performed the experiment by applying force-displacement of 5mm/min to the top end of the specimen [13-14].

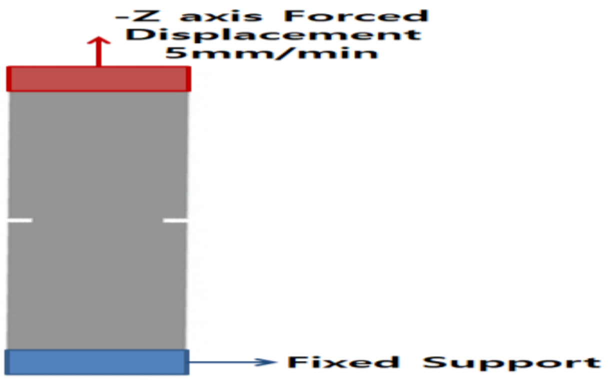

Fig. 2: Boundary Conditions of Tensile Specimen Models.

4. Simulation analysis results

Figure 3 shows in a graph the resulting load values as affected by displacement, which occurred when we performed the simulation analysis on the CFRP-stainless steel core sandwich-style notched tensile specimen model. The analysis showed that with the load-displacement in progress, the load that occurred in the specimen model tended to increase gradually, with the load sharply increasing until the load-displacement reached about 4mm and slowly increasing until the load-displacement reached about 7mm. It further showed that when the load-displacement reached about 7mm, the specimen incurred a maximum load of about 65,000N, and that after the maximum load occurred, the specimen began to fracture, with the load that applied to the specimen model decreasing gradually. However, we saw that owing to the fibers in CFRP, the load alternately increased and decreased. Figure 4 and Figure5 showed that the maximum deformation and the maximum stress occurring in the CFRP-stainless steel core sandwich-style notched tensile specimen model were 0.0136mm and 77.31MPa, respectively.

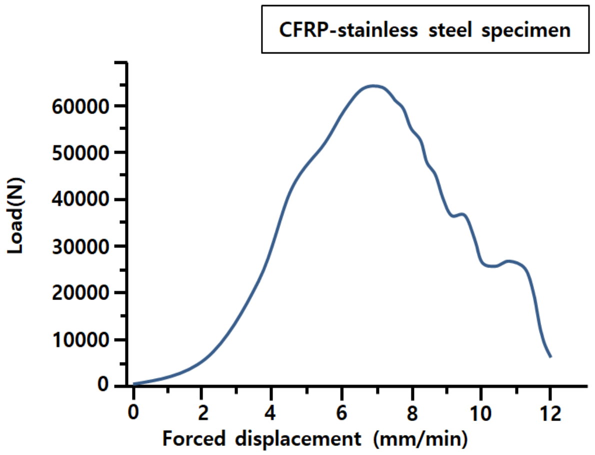

Fig. 3: Graph of Load Due to Forced Displacement at Tensile Analysis (CFRP-Stainless Steel Core Notched Tensile Specimen Model).

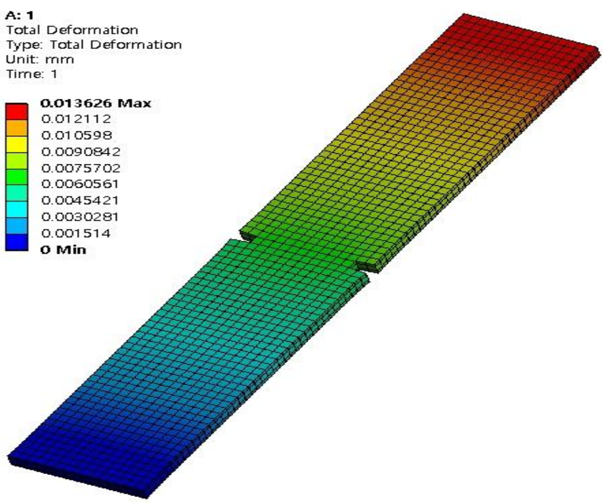

Fig. 4: Total Deformation of CFRP-Stainless Steel Core Notched Tensile Specimen Model.

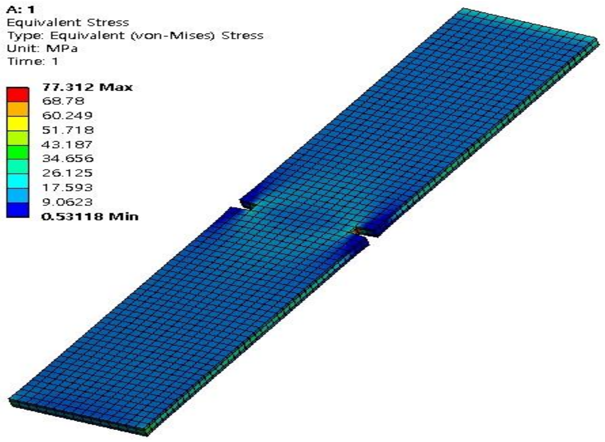

Fig. 5: Equivalent Stress of CFRP-Stainless Steel Core Notched Tensile Specimen Model.

Figure 6 shows in a graph the resulting load values as affected by displacement applied on the CFRP-stainless steel core sandwich-style notched tensile specimen model. The simulation analysis showed again that with the load-displacement in progress, the load that occurred in the specimen model tended to increase gradually, with the load sharply increasing until the load-displacement reached about 5mm and slowly increasing until the load-displacement reached about 6mm. It further showed that when the load-displacement reached about 6mm, the specimen incurred a maximum load of about 80,000N, and that from the point of the maximum load, the specimen began to fracture, with the load that applied to the specimen model decreasing gradually. However, we saw that owing to the fibers in CFRP, the load also alternately increased and decreased. Figure 7 and Figure 8 showed that the maximum deformation and the maximum stress occurring in the CFRP-aluminum core sandwich-style notched tensile specimen model were 0.0168mm and 95.15MPa, respectively.

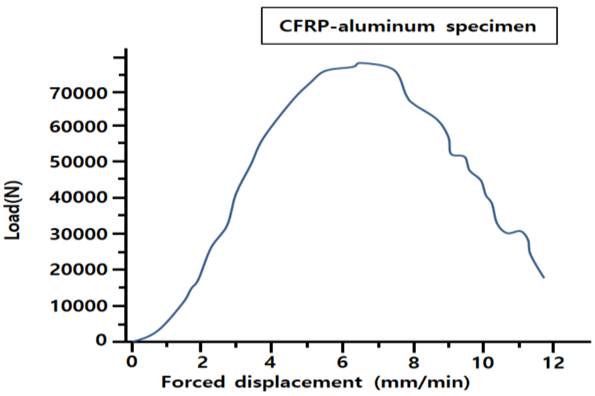

Fig. 6: Graph of Load Due to Forced Displacement at Tensile Analysis (CFRP-Aluminum Core Notched Tensile Specimen Model).

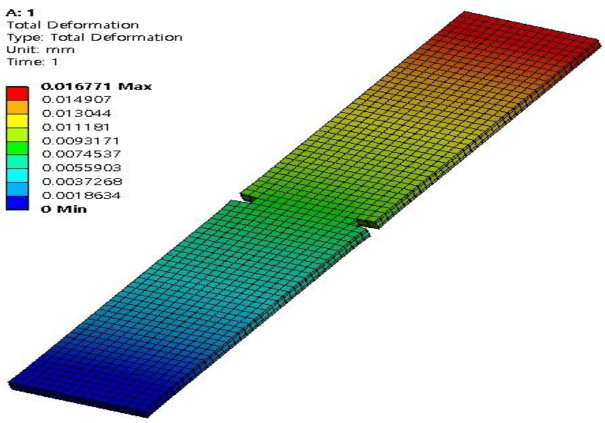

Fig. 7: Total Deformation of CFRP-Aluminum Core Notched Tensile Specimen Model.

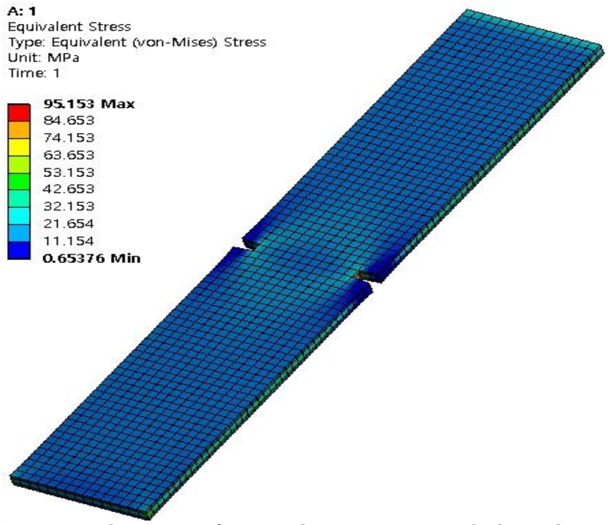

Fig. 8: Equivalent Stress of CFRP-Aluminum Core Notched Tensile Specimen Model.

Figure 9 shows in a graph the resulting load values as affected by the displacement applied on the aluminum-stainless steel core sandwich-style notched tensile specimen model. The simulation analysis showed that with the load-displacement in progress, the load that occurred in the specimen model tended to increase gradually, with the load sharply increasing until the load-displacement reached about 4mm and slowly along a gentle curve until the load-displacement reached about 5mm. It further showed that when the load-displacement reached about 5mm, the specimen model incurred a maximum load of about 100,000N, and that after the maximum load occurred, the specimen model began to fracture, with the load that applied to the specimen model decreasing gradually. Figure 10 and Figure 11 showed the deformation and the stress occurring in the aluminum-stainless steel core sandwich-style notched tensile specimen model, with the maximum deformation being 0.021mm and the maximum stress being 118.94MPa, respectively.

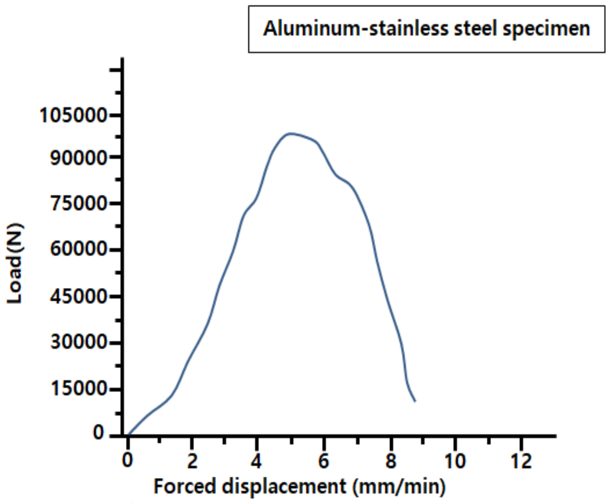

Fig. 9:.Graph of Load Due to Forced Displacement at Tensile Analysis (Aluminum-Stainless Steel Core Notched Tensile Specimen Model).

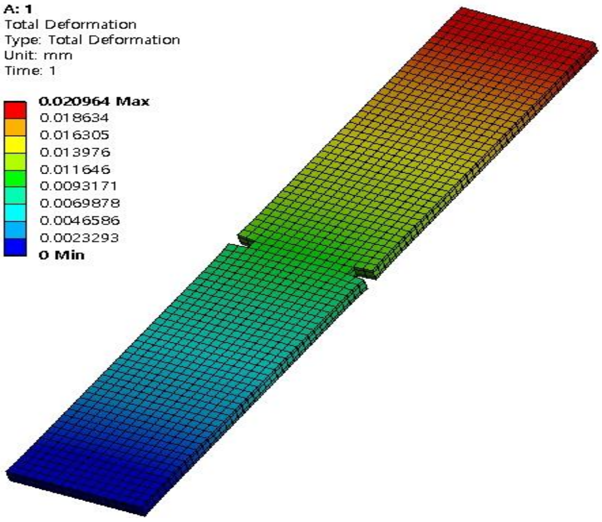

Fig. 10:. Total Deformation of Aluminum-Stainless Steel Core Notched Tensile Specimen Model.

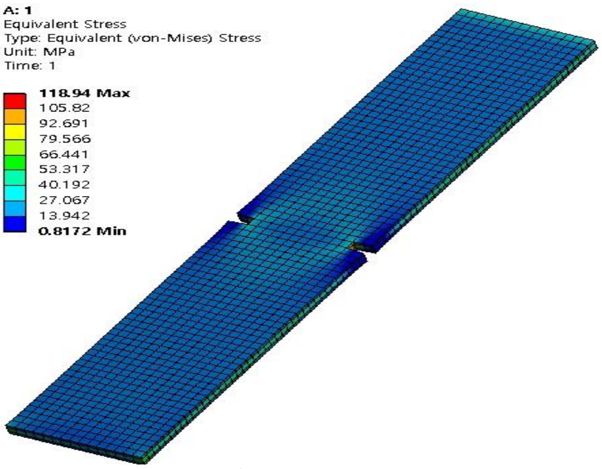

Fig. 11:. Equivalent Stress of Aluminum-Stainless Steel Core Notched Tensile Specimen Model.

Fig. 12 shows in a graph the resulting load values as affected by the displacement applied on the stainless steel-aluminum core sandwich-style notched tensile specimen model. The simulation analysis showed again that with the load-displacement in progress, the load that occurred in the specimen model tended to increase gradually, with the load sharply increasing until the load-displacement reached about 4mm and slowly increasing until the load-displacement reached about 5mm. It further showed that when the load-displacement reached about 5mm, the specimen model incurred a maximum load of about 115,000N, and that after the maximum load occurred, the specimen model began to fracture, with the load that applied to the specimen model decreasing gradually. Fig. 13 and Fig. 14 showed the deformation and the stress occurring in the stainless steel-aluminum core sandwich-style notched tensile specimen model, with the maximum deformation being 0.024mm and the maximum stress being 136.78MPa, respectively.

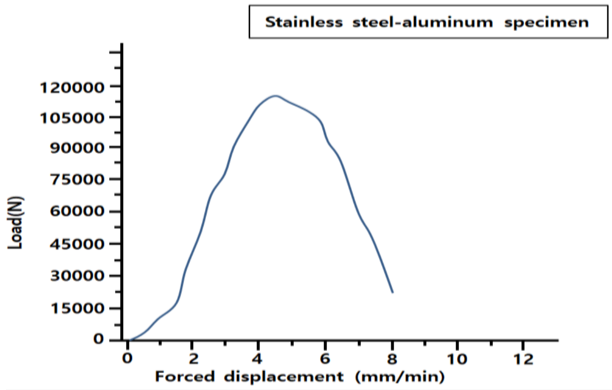

Fig. 12:. Graph of Load Due to Forced Displacement at Tensile Analysis (Stainless Steel-Aluminum Core Notched Tensile Specimen Model).

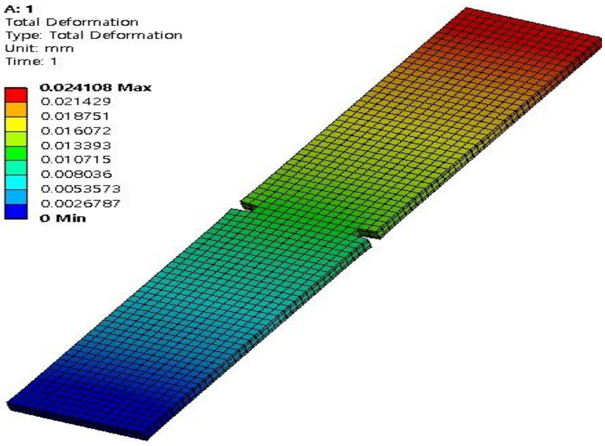

Fig. 13:. Total Deformation of Stainless Steel-Aluminum Core Notched Tensile Specimen Model.

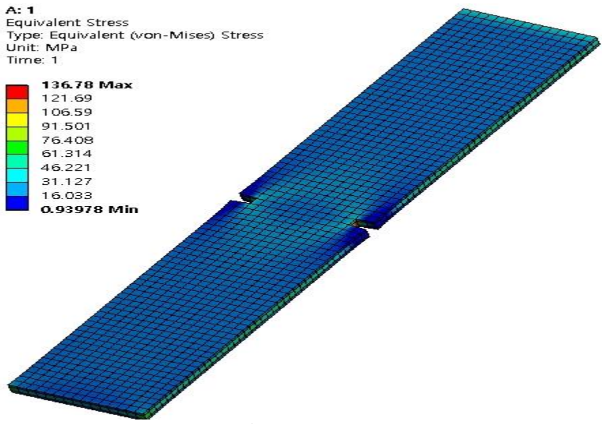

Fig. 14:. Equivalent Stress Ofstainless Steel-Aluminum Core Notched Tensile Specimen Model.

5. Comparison of analysis results and discussion

Table3 shows specific comparison results of simulation analyses of the different sandwich-style notched tensile specimen models. To compare the different specimen models, CFRP-stainless steel core sandwich-style notched tensile specimen model showed the maximum load of about 65,000N when the displacement reached about 7mm, and CFRP-aluminum core sandwich-style notched tensile specimen model registered the maximum load of about 80,000N when the displacement reached about 6mm. Moreover, we saw that aluminum-stainless steel core sandwich-style notched tensile specimen model showed the maximum load of about 100,000N when the displacement reached about 5mm, and stainless steel-aluminum core sandwich-style notched tensile specimen model showed the maximum load of about 115,000N when the displacement reached about 5mm. Meanwhile, the deformation and the stress for CFRP-stainless steel core sandwich-style notched tensile specimen model were about 0.0136mm and about 77.31MPa and the deformation and the stress for CFRP-aluminum core sandwich-style notched tensile specimen model were about 0.0168mm and about 95.15MPa, while the deformation and the stress for aluminum-stainless steel core sandwich-style notched tensile specimen model were about 0.021mm and about 118.94MPa. Lastly, the deformation and the stress for stainless steel-aluminum core sandwich-style notched tensile specimen model were about 0.024mm and about 136.78MPa. This study is thus concerned with tensile strength as shown in CFRP among other composite materials, which draws attention for its excellent durability and lightness, and stainless steel and aluminum, which are widely used metals, and is designed to acquire data with a view for future studies on the fracture and durability of heterogeneous and various composite materials. The data obtained from the studies can be utilized as the basic data for studies on the composite materials like CFRP and other various materials.

Table 3: Comparison Analysis Results of Specimen Models

	Maximum deformation (mm)	Maximum equivalent stress (MPa)	Maximum Load (N)
CFRP-Stainless	0.0136	77.31	65,000
CFRP-aluminum	0.0168	95.15	80,000
Aluminum-stainless steel	0.021	118.94	100,000
Stainless steel-Aluminum	0.024	136.78	115,000

6. Conclusions

In this study, we designed sandwich-style notched tensile specimen models that applied to the properties of CFRP, stainless steel, and aluminum and performed a simulation analysis, reaching the following conclusions.

1) By designing the sandwich-style notched tensile specimen models of the same specifications and performing a simulation analysis, we were able to verify the tensile strength and durability of the specimen models for the different materials.
2) CFRP-stainless steel core sandwich-style notched tensile specimen model showed the maximum load of about 65,000N when the displacement reached about 7mm, and CFRP-aluminum core sandwich-style notched tensile specimen model showed the maximum load of about 80,000N when the displacement reached about 6mm. Aluminum-stainless steel core sandwich-style notched tensile specimen model showed the maximum load of about 100,000N when the displacement reached about 5mm, and stainless steel-aluminum core sandwich-style notched tensile specimen model registered the maximum load of about 115,000N when the displacement reached about 5mm. Meanwhile, the deformation and the stress for CFRP-stainless steel core sandwich-style notched tensile specimen model were about 0.0136mm and about 77.31MPa and the deformation and the stress for CFRP-aluminum core sandwich-style notched tensile specimen model were about 0.0168mm and about 95.15MPa, the deformation and the stress for aluminum-stainless steel core sandwich-style notched tensile specimen model were about 0.021mm and about 118.94MPa, while the deformation and the stress for Stainless steel-aluminum core sandwich-style notched tensile specimen model were about 0.024mm and about 136.78MPa,
3) The analysis showed that unlike the specimen modes for the ordinary metals, those specimen models with the properties of the composite material of CFRP first showed the maximum load instead of breaking immediately due to the fibers in CFRP, before they resisted the displacement in response to the alternately increasing and decreasing load until it fractured. To be specific, we saw that the CFRP specimen models had the more excellent tensile strength and durability.
4) This study is thus concerned with tensile strength as shown in CFRP among other composite materials, which draws attention for its excellent durability and lightness, and stainless steel and aluminum, which are widely used metals, and is designed to acquire data with a view to future studies on the fracture and durability of heterogeneous and various composite materials. The data obtained from the studies can be utilized as the basic data for studies on the composite materials like CFRP and other various materials.

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