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ANALYSIS OF COCONUT FIBER REINFORCED COMPOSITES WITH HOT PRESS TECHNIQUES

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Abstract

Natural fibre waste is a material with high material resistance, including fibres derived from coconut fruit. Coconut fruit waste is frequently underutilised and can contribute to environmental pollution if not handled correctly. This study's objective is to convert waste from coconuts into fibres, incorporate them into composite mixtures, and produce robust materials. Using coconut fibre presents a significant advantage in that it is easily biodegradable, reducing environmental pollution. The aim of this research is to produce a composite board material using HDPE plastic and coconut fibre, which is resistant to corrosion, through the hot felting method. This method of producing composite materials results in minimal voids and high material density, effectively reducing the chances of material failure. The composite specimens were subjected to testing following the ASTM D 638-01 standard. Technical abbreviations used throughout the text will be explained upon first use. The study achieved an excellent average tensile strength, strain, and elastic modulus of 22.45 MPa, 7.15%, and 5.13 MPa, respectively. The manufacture of composite materials using coconut coir fibre combined with HDPE plastic through the hot felting method resulted in high material strength, corrosion resistance, and reprocessability.

Keywords: *HDPE Plastic, Coconut Fiber, Composite Board, Tensile Test.*

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1. INTRODUCTION

Waste is the most important problem in any hemisphere. Waste can cause various kinds of problems, through this problem arises various problems such as slums, diseases, and natural disasters [1]. According to the Ministry of Environment and Forestry of the Directorate General of Trash, Waste and B3 Management of the Directorate of Trash Management, the number of landfills that occur in Indonesia in 2021 is 63,000 – 64,000 tons / day. Waste production will increase as the population increases [2].

The increasing amount of waste, optimal processing is needed so as to prevent environmental problems in the future. According to the Ministry of Environment and Forestry, Directorate General of Trash, Waste and B3 Management, Directorate of Waste Management, waste that has been managed in 2021 is 63% or around 15 million tons / year. Waste handling that has been widely applied is the concept of 3R (reuse, reduce, and recycle) and the concept of processing at the source into a new form of energy or something that has a resale value [2]. One concept that can be used is to convert and process these plastics into

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composite boards. This data is useful for researchers and structural engineers dealing with laminates reinforced with added materials. In previous research conducted by Mufklikun et al [3], it was found that the use of CFRP - SPCC fibres can increase the strength of materials obtained from experimental testing and numerical analysis applied in the automotive and structural fields. Research carried out by Fahmi and colleagues [4] demonstrated that manipulating temperature during the manufacturing of composite boards using a mixture of rice plant husk material and HDPE waste can enhance material strength. The researchers employed the hot press method, which improved production efficiency and reduced manufacturing costs. Research by Garcia et al. [5] demonstrated that the inclusion of peanut shells, made from organic materials, can increase the mechanical strength of HDPE composite mixtures.

In this study, engineering was carried out on the use of high-density polyethylene (HDPE) plastic waste, and coconut fibers applied in the manufacture of composite boards [6]. So the title of this study is "Fibrous Composites Analysis of Coconut Fibers with Hot Press Technique", It is hoped that the research on this study can really work well and as expected. Hopefully, this final project can provide benefits for readers and all fields who need references for this research.

2. MATERIAL AND METHOD

2.1. Material

In this study, engineering was carried out on the use of High density polyethylene (HDPE) plastic waste, and coconut fibers applied in the manufacture of composite boards [7]–[9].

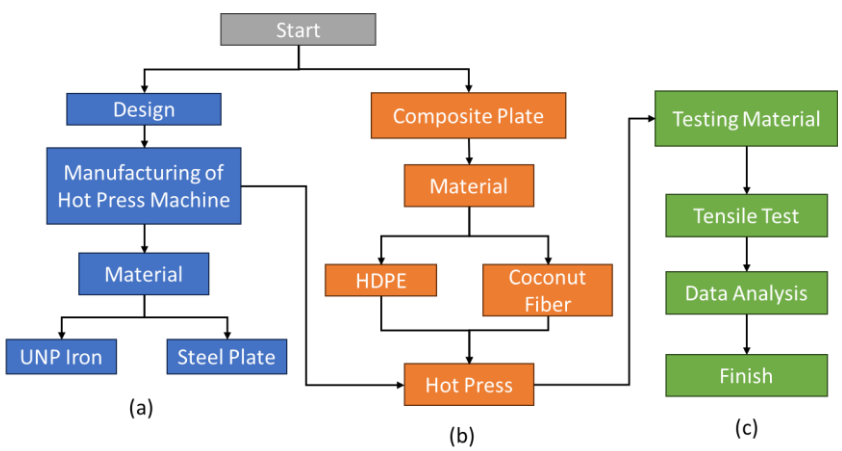

Figure 1. Research flowchart. (a) Process of making hot poress machine, (b) Process of making composite plate, (c) Testing material of plate composite.

The process of making a hot press machine begins with designing using solid works media. The materials used in the manufacture of hot press machines are: UNP iron size 8, steel plate with a thickness of 10 mm and 6 mm [7]. Hot press machine has a size (350 x 350 x 1200) mm, while, the mold has a size (330 x 230 x 40) mm. The working system of this hot press machine is used to press composite materials. The power source used is from the strength of the human hand manually by pressing the lever, the pressure center of this hot press machine is a hydraulic jack with a capacity of 5 tons.

The composition of the materials used is high-density polyethylene (HDPE) plastic weighing 75 grams and coconut fiber weighing 5 grams. Then cut the aluminum foil as large as the mold to be used, then insert it into the mold, the use of aluminum foil is intended so that the material that has been inserted into the mold can be removed easily and the resistance of aluminum foil material to high temperatures is very efficient in the hot press process. Aluminum foil that has been neatly arranged according to the mold is then placed High density polyethylene (HDPE) plastic on the top of the aluminum foil. After tidying up the high-density polyethylene (HDPE) plastic, then arrange the coconut fibers on top of the plastic in parallel to fill the mold. After finishing arranging the coconut fibers in parallel, place the high-density polyethylene (HDPE) plastic on top of the fibers that have been arranged. If all material preparation processes have been completed, the hot press can be carried out. Setting the hot press machine according to the cooling temperature, after reaching the desired temperature, input the material that has been arranged into the hot press machine. The material that enters the hot press machine is heated to unite the material, the unification process takes 45 minutes. After that, turn off the hot press machine, then wait for it to cool down, the cooling process takes 10 minutes. After cooling, the composite board is ready to be removed from the mold.

To find out the characteristics of composite boards from the combination of coconut fibers with plastic by conducting tensile testing [10]–[21]. In this tensile test, it uses ASTM D 638 - 01 with the aim of measuring how much force is required for the specimen and how far the specimen stretches or extends to the breaking point. The tensile testing method ASTM D 638 - 01 is used to determine the tensile strength of plastic materials, and can be used to test any material up to a thickness of 14 mm [22].

The shape of the test specimen is as shown in Figure 1.

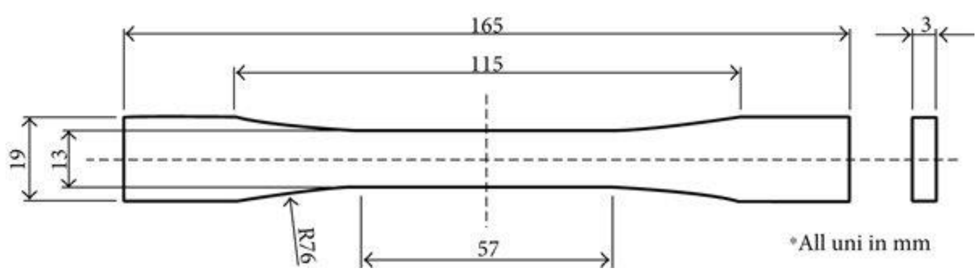

Figure 2. Dimensions of ASTM D 638 - 01 standard tensile test specimen

Composite tensile test using tensile testing machine with specifications:

Model Number	: ALX - J
Dimensions	: (230 x 150 x 490) mm
Weight	: 9 kg
Max load	: 500 N

Tensile testing was carried out four times with a composition between plastic and coconut fibers of (75 grams: 5 grams) with the dimensions of the test object according to ASTM D638-01 standards [23] .

The manufacture of tensile test specimens can be done in the following ways:

Making the design adjusted to the dimensions of the ASTM D 638 - 01 tensile test standard, the use of design applications in this study is Solid Work. After the design process is complete, the printout of the design is used to mark the specimen using a marker marker, which later the shape of the printout is cut according to the size that has been designed. The specimen is given marks and points adjusted to the ASTM D 639 -01 tensile test measurement standard which will later become the focus of observation in the test.

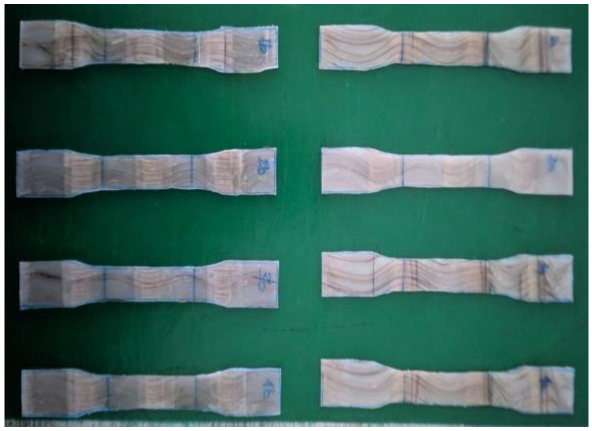

Figure 2. Tensile testing specimens

3. RESULT AND DISCUSSION

Table 1. Composite tensile test with a composition of 75 grams (HDPE) and 5 grams (Coconut fiber)

No	Specimen Code	Thick (mm)	Wide (mm)	Large (mm^2)	Tensile Strength (N)	σ (MPa)	Lo (mm)	ΔL (mm)	ε (%)	E (MPa)
1	A1	2	13	26	631,2	24,28	57	2,12	3,72	6,53
2	A2	2	13	26	268,7	10,33	57	4,2	7,37	1,40
3	A3	2	13	26	1143	43,96	57	2,13	3,74	11,76
4	A4	2	13	26	291,6	11,22	57	7,85	13,77	0,81
			Median			22,45			7,15	5,13

Referring to Table 2 obtained graph charts of tensile strength, strain, modulus of elasticity as shown in Figure 3, Figure 4 and Figure 5.

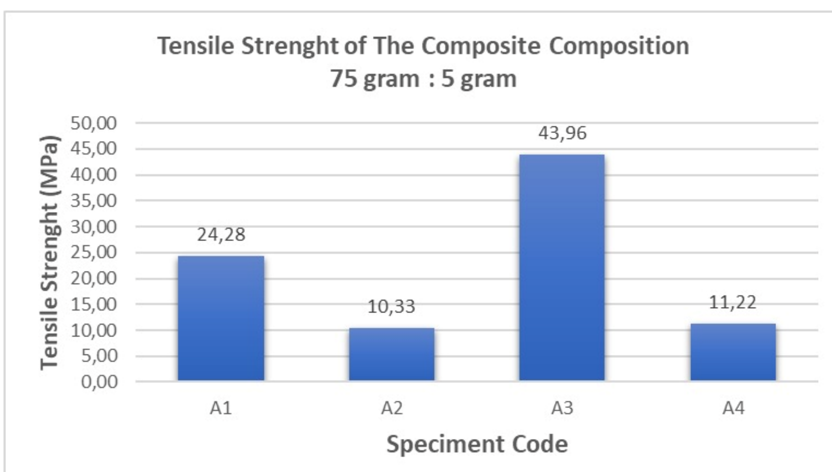

Figure 3. Tensile strength of a composite with a composition of 75 grams (HDPE) and 5 grams (coconut fiber)

The tensile strength result of tensile testing with a composite composition (75 grams: 5 grams) is the highest tensile strength in specimens with code A3 of 43.96 MPa, while the lowest is found in specimens with code A2 of 10.33 Mpa.The difference in tensile test results on the specimens shown in Figure 3 is due to the uneven distribution of fiber on the total specimen area. The stress acting on the fiber made from coconut trees is also not evenly distributed, so the results shown in this tensile test have differences. The data results show that specimen A3 has the highest value of 43.96 MPa when compared to other specimens. Specimen A3 has the highest value due to the even distribution of coconut fiber in the total area of the specimen so that the stress distribution can be delivered optimally.

Specimens with values below the results of specimen A3 such as specimens A1, A2 and A4 show the distribution of coconut fiber fibers is not evenly distributed throughout the specimen area. When tensile testing is carried out the first applied stress is not properly distributed throughout the specimen.

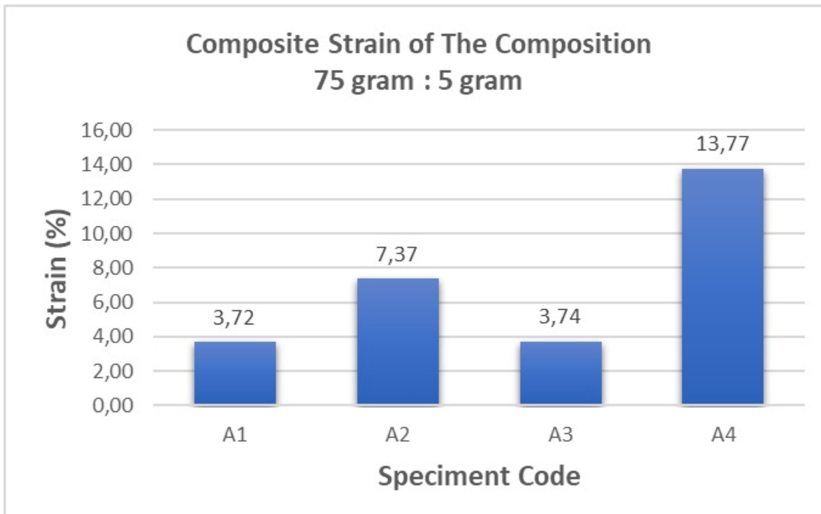

Figure 4. Composite strain with a composition of 75 grams (HDPE) and 5 grams of (coconut fiber)

The result of strain in tensile testing with a composite composition (75 grams: 5 grams) is the strain with the largest value found in specimens with code A4 of 13.77%, for the smallest value is found in specimens with code A1 of 3.72%.

The size of this strain is due to the distribution of coconut fibers made in the specimen, Figure 4 shows specimens that have low strain, namely in specimen A1 with a value of 3.72 MPa and specimen A3 with a value of 3.74, these two specimens have the lowest strain caused by applying stress to the tensile test. The ability of this material is obtained from the combination of HDPE plastic and coconut fiber combined. While the A4 specimen shows that the strain value is the highest when compared to other specimens, it is because the specimen tested for stress is only dominant in HDPE plastic material. HDPE plastic material has greater strain properties when compared to coconut fiber. Therefore, the distribution of coconut fiber evenly over the entire specimen area greatly affects the strain value.

When compared with the value in the tensile test shown in Figure3, the strain value is directly proportional, the greater the stress value, the lower the strain value produced, and vice versa, the large strain in HDPE plastic and coconut fiber composites indicates that the distribution of matrix fibers and adhesives is not evenly distributed properly.

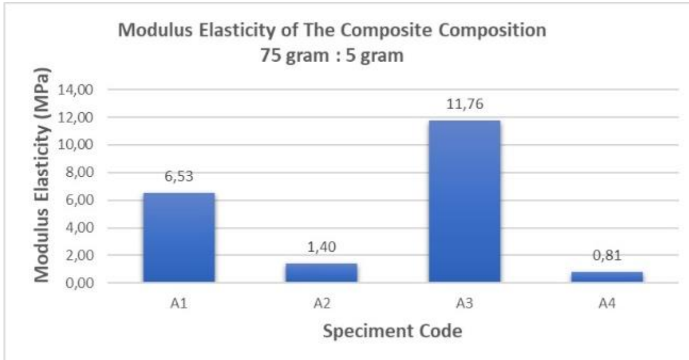

Figure 5. Modulus of elasticity of a composite with a composition of 75 grams (HDPE) and 5 grams of (coconut fiber)

The result of the elasticity modulus of tensile testing with a board thickness of 2 mm is the greatest tensile strength found in specimens with code A3 of 11.76 MPa, while the lowest is found in specimens with code A4 of 0.81 MPa. In the data results seen in Figure 4 is a graph that shows the force required for a specimen to experience strain, and in specimen A3 requires the greatest force to experience strain. The lowest result is found in specimen A4 which is 0.81 Mpa, due to the softer nature of the material compared to other specimens. The graph with the highest value in specimen A3 shows that this specimen is more brittle than the other specimens, the force required is also greater. When referring to the material properties of HDPE plastic blends mixed with coconut fiber, this is related to the distribution and coconut found in the entire specimen area. Distributions and coconuts that are evenly distributed will cause smaller strain capabilities and require greater stress when compared to specimens that do not get a less than optimal distribution of coconut fibers. It can be seen in Figure 4 that specimens A1, A2 and A4 have low modulus values compared to specimen A3. The distribution of coconut fiber in specimen A3 is the most optimal.

The fault results were obtained after tensile testing was obtained. The fault itself consists of two types, namely tenacious faults and brittle faults [24]. Various fault results from the tensile examiner can be seen in Figure 5 where the fracture with ductile properties has a characteristic white fracture on HDPE plastic reinforcement, when viewed in Figure 5 the white fracture is due to the force acting on the specimen is more inclined to HDPE plastic material, the new force acts on the coconut after the specimen with HDPE plastic material fails. And the force acting on coconut fiber is not the same as the force received on HDPE plastic material.

Based on Fig.6 (a), composite materials form a type of ductile fault, ductile fault that is the uprooting of fibers from resin caused when the resin cracks due to tensile loads, the ability to withstand the load will soon decrease. Then in materials that experience brittle fracture, there tends to be no visible white strain, when compared to specimens that experience ductile fracture. The brittle fracture is due to the most optimal distribution and coconut. When referring to the specimen in Figure 6, it can be seen that the fracture is not aligned at each fiber placement. The force acting is not well optimized, the specimen experiences debonding of the coconut fiber against the HDPE plastic reinforcement.

Based on Fig.6 (c), composite materials form a type of ductile fault, ductile fault that is the uprooting of fibers from the resin caused when the resin cracks due to tensile loads, the ability to withstand the load will soon decrease [25]. Fractures like this are caused by the force acting on specimen A2 debonding against. HDPE plastic, so the stress acting on the HDPE plastic reinforcing material is greater than that of coconut fiber. Coconut fiber with good distribution throughout the specimen area does not cause heavy fracture to only one material in the composite specimen. If you look back at Figure 7, the coconut fiber fracture has a different length if drawn in a straight line. The force that works is only distributed on one side, after the fiber fails, the remaining stress only works on the coconut fiber on the other side that has not received stress distribution.

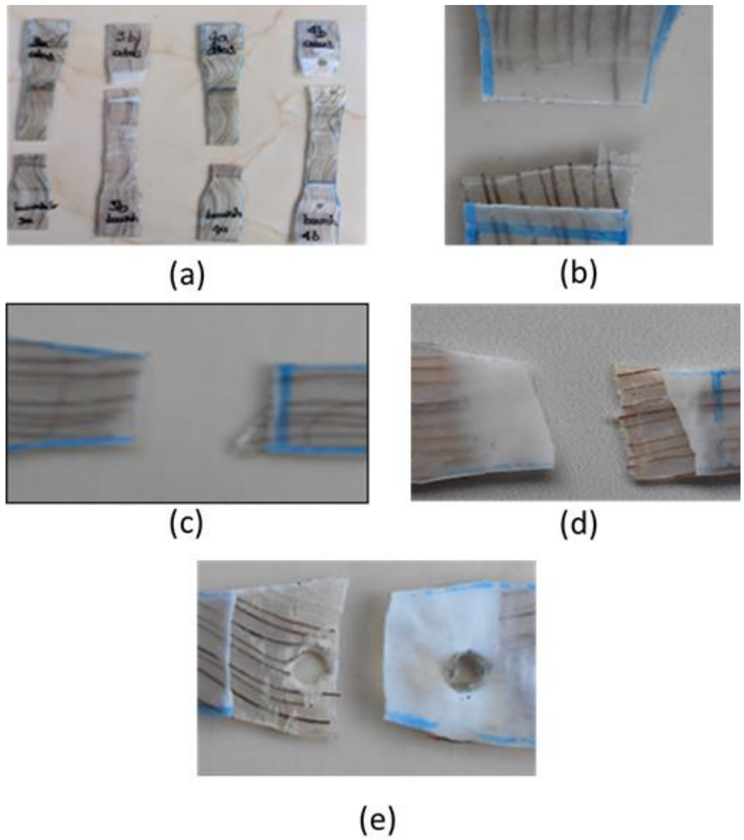

Figure 6. Specimen tensile test failure. (a) Fault photographs with code A1, (b) Specimen bonding failure, (c) Fault photographs with code A2, (d) Fault photographs with code A3, (e) Fault photographs with code A4

Based on Fig.6 (d), composite materials form a type of ductile fault, ductile fault that is the uprooting of fibers from the resin caused when the resin cracks due to tensile loads, the ability to withstand the load will soon decrease. In the discussion of specimens in Figure 8 shows that the fracture in specimen A3 is evenly broken, the cut coconut fiber has a length that is almost the same length, and when compared to the coconut fiber fracture in other specimens which have different fracture lengths and the stress that works is distributed optimally. On the fracture with white color can be said to be debonding between coconut and HDPE plastic. This white fiber fracture is normal because the toughness of coconut fiber is greater than HDPE plastic, the drawn coconut fiber is also superior based on the orientation direction.

Based on Fig.6 (e), composite materials form a type of ductile fault, ductile fault that is the uprooting of fibers from the resin caused when the resin cracks due to tensile loads, the ability to withstand the load will soon decrease [24]. If there are imperfections in the material, such as microscopic cracks or non-uniform structures as seen in Figure 9 with specimen A4, this could be the starting point of a possible fracture. When a load is applied, the crack will begin to develop, and if it reaches a critical dimension, a fracture may occur. In addition, stress concentrated at a particular point in the material can be a trigger for fracture, be it due to a design flaw or due to uneven load distribution. Then ductile materials will usually show warning signs before a fracture occurs, such as a significant change in shape or elongation. The fracture that occurred in specimen A4 shown in Figure 6 occurred at the base of the specimen, indicating that the coconut fiber distribution occurred in only a few parts, this fracture occurred at an undesirable stress concentration point.

From the tensile test, it is known that the difference in the results obtained is influenced by the distribution of coconut fibre combined with HDPE plastic by the hot press method. The highest tensile results were obtained in specimen A3 with a value of 43.96 Mpa. The highest value is obtained due to the distribution and evenly distributed. The specimen with the lowest value is due to the uneven distribution of coir fibre, the energy distributed in the composite specimen cannot be channeled to the entire specimen properly.

In a study conducted by Samadam et al [26], it was shown that the distribution of reinforcement in a composite material has a significant effect on the strength of the material and the characteristics formed from the results of making composite materials. The current research is mixing coconut coir fibre with HDPE plastic. And see the effect of reinforcing fibre distribution on material strength.

4. CONCLUSIONS

- The research utilized the hot press technique to analyze coconut fiber composites, yielding the highest value in the specimen during mechanical testing. The most even fiber distribution occurred in specimen A3, with a value of 43.96 MPa.
- Performance Metrics: Within the scope of this investigation, a comprehensive analysis was conducted to evaluate three pivotal performance metrics. The mean tensile strength of the composite material was meticulously determined and found to be 22.45 MPa.
- Examining the strain behavior, the composite displayed an average strain of 7.15%, with specimen A4 exhibiting the highest recorded strain at 13.77%. This particular observation highlights a noteworthy aspect of the study, suggesting that the non-uniform distribution of coconut fibers within the composite contributed to elevated strain values. However, this came at the cost of compromising the material's overall strength when subjected to applied forces. Furthermore, the modulus of elasticity, a critical parameter characterizing the material's ability to deform under stress, was ascertained to be 5.13 MPa. This value provides valuable insights into the material's structural integrity and flexibility. The combined assessment of these performance metrics offers a nuanced understanding of the mechanical behavior of the coconut fiber composite, shedding light on both its strengths and limitations in practical applications.
- The use of natural fibers as reinforcing materials poses limitations on mechanical consistency due to various factors such as moisture content, plant type, orientation, and so forth. Further research is necessary to investigate the optimal performance aspects of coconut fibers as a reinforcement material from multiple perspectives

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