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The Effect of Pineapple Leaf Fiber as a Filler in Polymer Matrix Composite for Interior Part in Automotive

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ABSTRACT

Recently, many natural fibers such as sisal, banana, kenaf, oil palm and jute have been used as reinforcement in the thermoplastic composite. Furthermore, the process of compounding materials between natural fiber and thermoplastic are applied it in the manufacturing of automotive, construction, furniture and goods industry. Pineapple leaf fiber (PALF) is one of natural fibers, which has a good potential to be reinforced with thermoplastic materials and create a new superior composite material. Therefore, this phenomenon is related to this research which is purposely to investigate the mechanical properties of PALF reinforced with polypropylene (PP) as a matrix by varying fiber weight fraction, to identify the physical properties of PALF reinforced with PP and to analyze the microstructure of PALF/PP composite. The process started with the preparation of raw pineapple leaf and then treated with alkaline treatment. PALF and PP were compounded using hot compression process by using hot press and cooling machine to produce the samples. The composite samples were prepared according to the standard requirement to perform the tensile test (ASTM D3039), density test (ASTM D792) and hardness test (ASTM D2240. Based on the result of tensile test, it was found that the maximum load of PALF/PP composite decreasing linearly with the increment of fiber loading. However, the trend for hardness and density was increasing linearly as the fiber loading increased. This study identifies that 10 wt% of fiber loading is the best selection for the composition structure of PALF/PP composite.

Keywords: Pineapple leaf fiber, polypropylene, fiber reinforced polymer.

1. INTRODUCTION

Automotive industry is among the first industries to introduce the use of natural fibers as filler in polymeric matrix (BFRP) In 1940s, Henry Ford began experimenting and producing natural composite by using hemp fiber reinforced soy resin in the manufacturing of exterior body panels [1]. During that time, soy based plastic was not economical important due to the availability of the petroleum based plastics which were cheap [2]. Decades after, new environmental regulation and the depletion of petroleum sources had revived the interest of researchers to develop a unique and superior material that was biodegradable and contributed to saving the world from pollution. Many researches had been performed by applying the BFRPs composite in automotive application. For example, car manufactures in Europe have done various researches to increase the applications of BFRP composites in automotive industry, especially in car interior parts such as door-trim panels, boot linens, truck linens, seat backs, parcel shelves, rear and front door linens [3].

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There are various types of natural fibers that have been used by researchers in the development of natural fiber (BFRPs) composites, which include coir [4], jute, sisal, kapok [5], lantana-camara [6], rice husk [7], pineapple leaf [8-11], bamboo [12-15], coconut [16], kenaf [17] and oil palm [18]. In this study, the PLAF was selected to reinforce PP composite.

Pineapple leaf fibers are a waste product of agriculture and can be obtained without significant additional cost input for industrial purposes. Therefore, many researchers discover and carry out research to investigate the effect and benefits of pineapple leaf fiber reinforced polymer composite [19-22]. Asim et al., in 2015, presented about mechanical properties of pineapple leaf fibers reinforced composites on a review of pineapple leaves fiber and its composites. The study revealed that pineapple leaf fiber had the highest cellulosic content and tensile properties as compared to jute and sisal. Feng et al., have studied chemical (23), weaving effect (26) and mechanical properties (24, 25, 27) using pineapple fiber. Their studies showed high potential for pineapple fiber as composite reinforcement. Mittal & Chaudhary studied fiber length and content on mechanical properties of pineapple leaf fiber reinforced epoxy composite (28). Their studied showed the 25 mm fiber length with 43% fiber volume exhibits the maximum impact strength.

From this review it is clear that the properties of PLAF reinforced polymer have grown tremendously in the applications as interior part in automotive industries. Therefore, this research explores the properties of pineapple leaf fiber reinforced PP composites to be applied as interior part of automotive components by verifying the properties through physical and mechanical tests.

Nowadays, the demand for the use of fiber reinforced polymer (FRP) composites material has gained popularity in the engineering field. Most of the current FRP composites that are used in industry are made from synthetic fiber material such as aramid, carbon, boron, basalt and fiber glass. However, these kinds of fibers are harmful to the environment and human health because they are enhanced with chemicals. Therefore, for those who are continuously exposed to hazardous work environment involving synthetic fiber material, they may experience upper respiratory tract, acute irritation of the skin and eyes, as well as have a high risk to get lung related diseases. Additionally, the production of synthetic fiber causes air pollution that contributes to global warming and the depletion of petroleum resources. Besides that, when released, the product from synthetic fiber does not degrade and these results in the increase of environmental pollution and threaten human, wild life and destroys nature significantly.

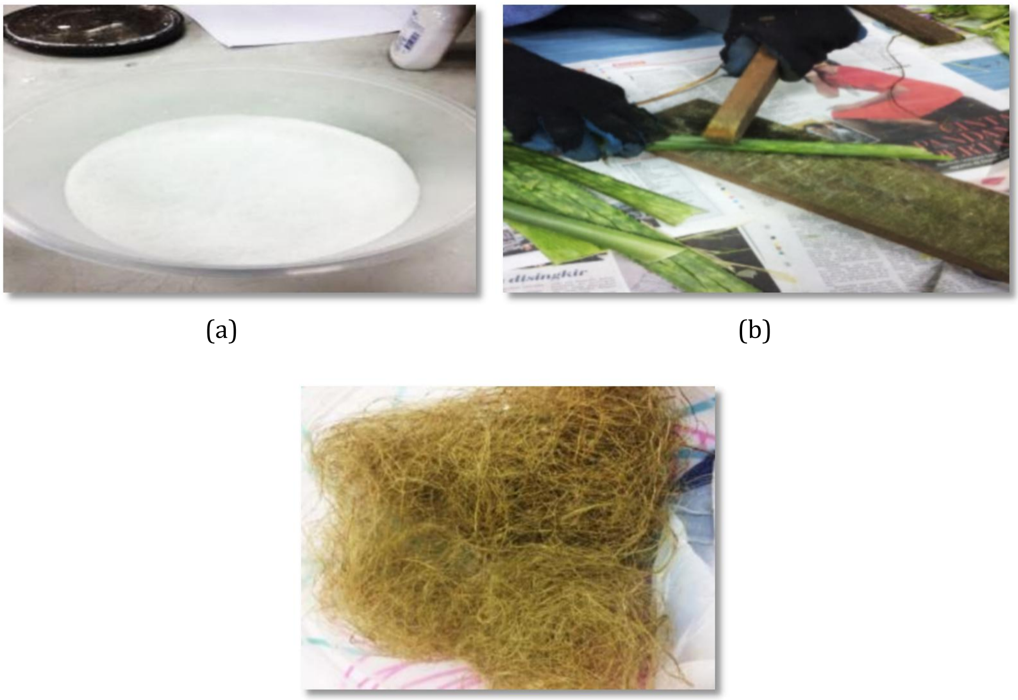
To overcome this problem, researchers contribute to protect green earth by replacing synthetic fiber with natural fiber in the manufacturing of FRP composite. Development of natural fiber composite will help to reduce ecological concerns on the consumption of petroleum based resources, environmental pollution and waste disposal problems.

2. METHODOLOGY

2.1 Materials

Polypropylene in powder form with the types of impact polypropylene was used as the polymer matrix, as shown in Figure 1(a). Pineapple leaves was collected from Muar, Johor Malaysia. In this study, PALF was extracted by manual method, which a piece of wood was used to rupture the structure of leaves as shown in Figure 1(b). After that, the leaves then were soaked in the tab water for a few minutes. The next process was using hairbrush to remove the skin leaves which still attached to the fiber surface. Then, fiber was washed by using tab water and dried under the sun until the fiber is fully dried. Lastly, by using extraction process, the fiber underwent alkaline treatment process with the aim to modify the fiber surface and its properties [20,21]. The fibers were then treated by immersing it in 5% aqueous alkali (NaOH) for 30 minutes.

After that, the fibers were washed several times with distilled water and dried it in oven at $60^{o}C$ for 24 hours. The PALF after treatment is shown in Figure 1(c). Kasim *et al*.,2016 stated that by undergoing the alkaline treatment can remove all the impurities and moisture content, increase the tensile strength of the fibers, stabilize the molecular orientation, treat the fiber surface, and improve the adhesion between the hydrophilic PLF and hydrophobic PP. After the fiber was fully dried, then chopped less than 1 cm for the next process.



(a) (b)

(c)

Figure 1. The polymer matrix, (a) polypropylene powder, (b) palf extraction method and (c) pineapple leaf fibre.

For the fabrication process, the PALF/PP composites with different compositions were prepared by using manual mixing method and were compression-moulded to form a sheet of composites. The compositions ratio of the PALF/PP composite was based on Table 1. After mixing the two materials, the mixture was transferred into the mould. The size of mold was 140 mm x 60 mm. The compounded composites were pressed by using hot press machine to fabricate the sample. The melting point temperature of PP is $170^{o}C$. The time of preheat was 5 minutes which to transfer the heat to the mould and the time for compression was also is 5 minutes under 2.5 MPa of pressure. The cooling time was 15 minutes. The dimension of the PALF/PP composite sample from the fabrication process was 140 mm x 60 mm x 2 mm. Then, the samples were cut into the dimension 140 mm x 25 mm x 2 mm based on the specified ASTM standard testing.

Table 1 Samples of PALF/PP for each composition

PALF/PP (wt.%)	Composite
10/90	
20/80	
30/70	
40/60	

2.2 Testing Method

A tensile test was performed according to ASTM D3039 which is Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials. A thin flat strip of material composite specimen (Figure 2) having a dimension of 140 mm length, 25 mm width, and 2 mm thickness was mounted in the grips of Universal Testing Machine (Instron Model 5585H) controlled by Bluehill 2 software with a 1 kN load cell and activated at constant head-speed tests of 2 min/mm. Specimens were then placed and fixed in the grips of Instron Universal Test Machine at a specified grip separation and pulled until rupture occurred. Then, the values of tensile stress, tensile strain and the percentage of elongation were obtained from the stress-strain curve diagram.

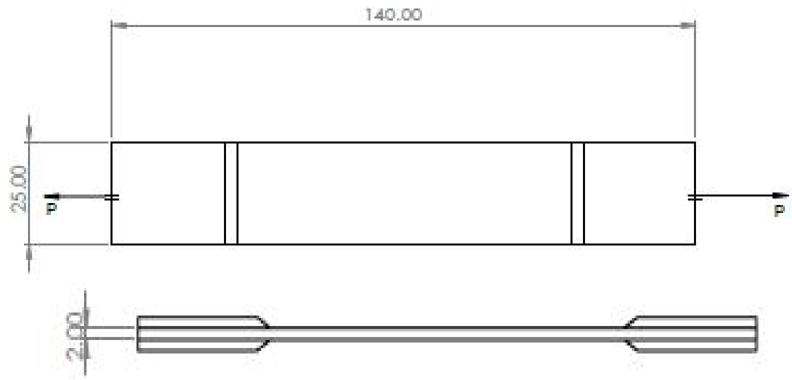


Figure 2. Schematic of tensile specimen.

For the physical characterisation, the density of the PALF/PP composite was measured by using a digital electronic densimeter (MD-300S) according to the ASTM D792. The specimens apparent masses were measured and then, the specimens were immersed in a liquid. The value of specific gravity and volume were obtained. The hardness of PALF/PP composite was measured by using an analogue Specimen hardness was tested using Shore scale D type Durometer based on ASTM D2240. The surface of the specimen was flat with the thickness at 2.0 mm. The measurement was taken at least 12 mm from the edge of the sample because the hardness characteristics tend to change at the edge of the sample.

3 RESULTS AND DISCUSSION

3.1 Effect of PLF loading on tensile

Table 2 shows the result obtained for the tensile test of the PALF/PP composite sample according to the percentage loading. The value of maximum load, tensile stress and tensile strain can be identified from this tensile test. All the values are different according to the ability of percentage loading when undergoing elongation or stretching process.

Table 2 Tensile properties of the samples

PALF Loading (wt%)	Maximum Load (N)	Tensile stress, σ (MPa)	Tensile strain, Ɛ (mm/mm)
10	1262.69	25.26	0.03655
20	1194.74	23.90	0.02457
30	1176.59	23.54	0.02038
40	1072.68	21.46	0.01623

Figure 3 shows the result between the tensile stress at maximum load (MPa) against the percentage loading of PALF (wt.%). According to the results obtained, tensile stress at maximum load of 10 wt.% loading of PALF is the highest value with 25.26 MPa. However, for 40 wt.% loading of PALF fiber shows the lowest value of tensile stress at maximum load of 21.46 MPa. For the 20 wt.% and 30 wt.% loading percentage of PALF, the values are 23.90 MPa and 23.54 MPa. The pattern of the graph shows that the increase of fiber loading reduces the tensile strength. This is because the PALF/PP composite that have less fiber are more elastic than PALF/PP composite that have more fiber. Also, the addition of fibers disrupted the PP segment mobility and causing the plastic turn to be more brittle.

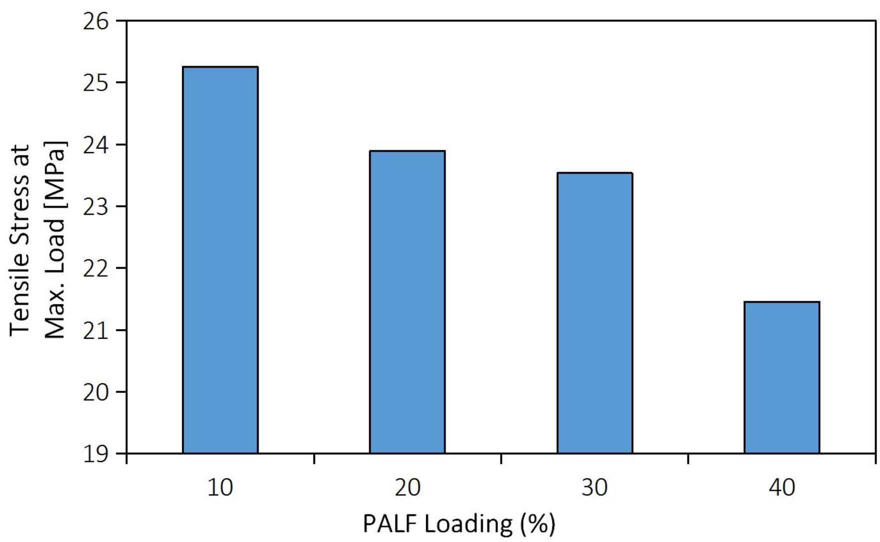


Figure 3. Tensile stress at maximum load (MPa) against PALF loading (wt%).

Figure 4 shows the result between Load (N) against Extension (mm) during tensile test for the PALF/PP composite sample with different percentage of loading (wt.%). According to Figure-3, the result shows the extension increases with decrement of fiber loading. The addition of 10 wt.% fiber loading shows the highest extension followed by 20 wt.%, 30 wt.% and 40 wt% fiber loading respectively. The increment in extension of the composite is caused by ductility properties of PP. For the 10 wt% has the lowest value of fiber loading in the PALF/PP composite sample. Thus, the ductility level is the highest, so it can be extended to the highest maximum level than other percentage of fiber loadings before it ruptured. The samples that have more fiber loading tend to rupture easily because of their low ductility behaviour. The finding is consistent with the finding of Okubo et al [14], which stated that bamboo fiber filler with more fiber loading was easily ruptured because of low density and decreased of tensile properties.

Figure 5 shows the result of tensile stress (MPa) against strain stress (mm/mm) which to define the mechanical properties of PALF/PP composite. According to the pattern of the graph, Stage I shows the strain range between fibres and matrix facing elastic deformations and in the tensile plot is observed as straight line. For the Stage II, is a region which fibres deform elastically while the matrix deforms plastically. After a few seconds, the fibres show a brittle failure because of low ductility. This agreement is consistent with the finding by Mohammed et al. [10], where the mechanical properties of PALF with vinyl ester composites decreased with the increasing of PALF filler.

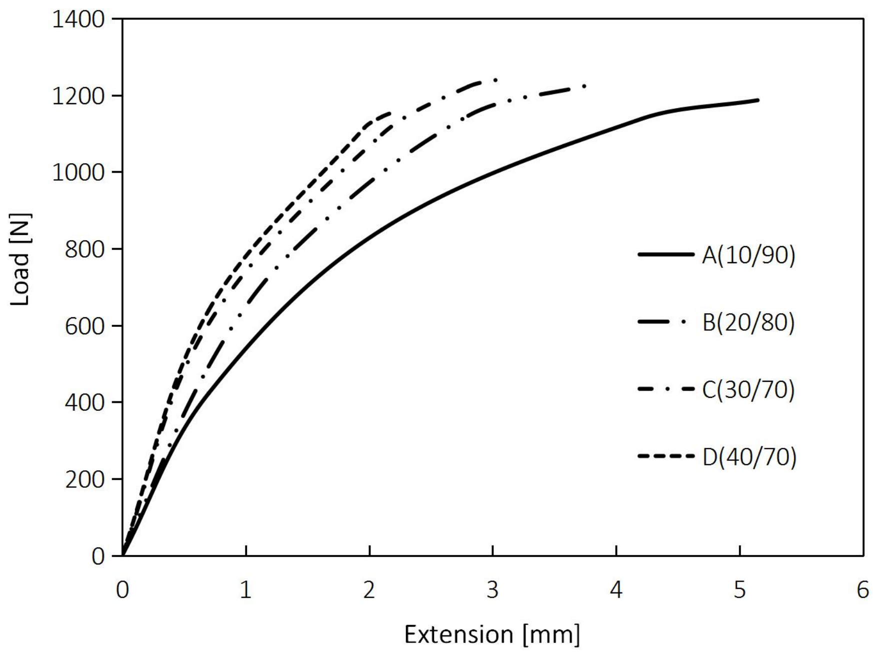


Figure 4. Load (N) against Extension (mm) with the different percentage of fiber loading (wt.%).

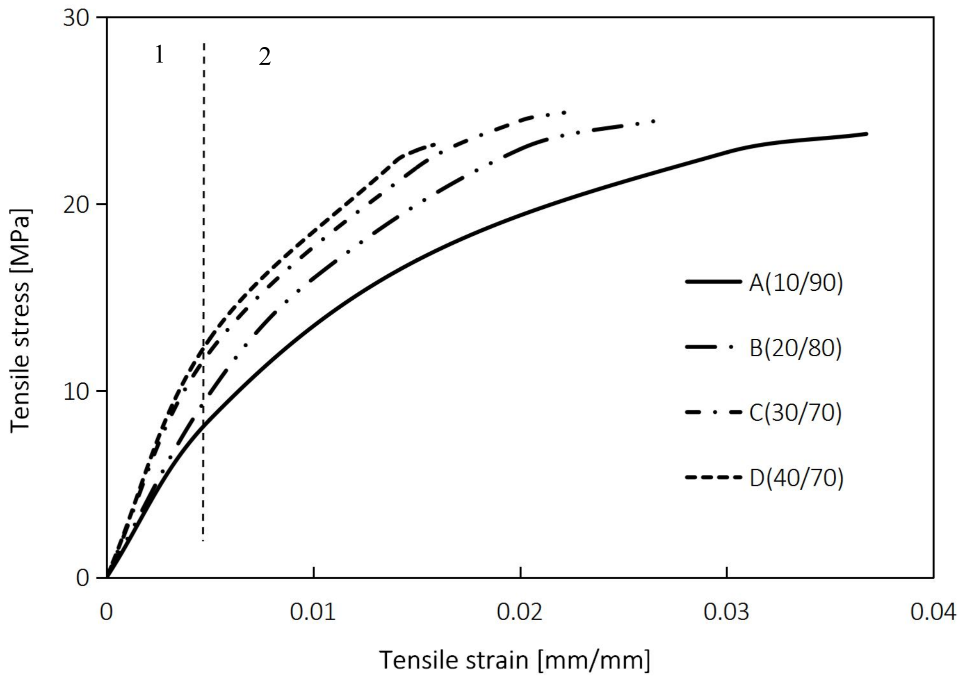


Figure 5. Tensile Stress (MPa) against tensile strain (mm/mm) with the different percentage of fiber loading (wt.%).

3.2 Effect of PLF Loading on Density

Table 3 shows the results of density (g/cm^3) and the percentage of PALF loading for PALF/PP composite. The result shows that the value of density increases with the increment of PALF loading. For the 10 wt.% of PALF loading has the lowest value of density which is 0.9940 g/cm^3 while 40 wt.% of PALF obtained the highest density of 1.0045 g/cm^3. For the 20 wt.% and 30 wt.%, both of them have constant value of density which is 0.9970 g/cm^3. This increasing trend is obtained due to the increment of fiber loading that affects the composition in the composite. When there is more fiber loading, the spaces between fiber and matrix are closer which indicates the composition is more pack. The finding is consistent with the finding of Selamat et al. [12], which stated that when bamboo fiber filler loading increased, the density of the bamboo/polypropylene (B-PP) composites also increases.

Table 3 Density properties of the samples

PALF loading (wt.%)	Density (g/cm^3)
10	0.9940
20	0.9970
30	0.9970
40	1.0045

3.3 Effect of PLF Loading on Hardness

Table 4 shows the results of hardness (Shore-D) and the percentage of PALF loading (wt.%). Based on the table, shows that the pattern of the data increases due to the increment of fiber loading. The 40 wt.% of PALF loading has the highest fiber loading and the highest value of hardness which is 71.50 (Shore-D) while 10 wt.% of PALF loading has the lowest value of hardness with 69.00 (Shore-D). This pattern is obtained due to the increment of fiber loading.

When the quantity of loading is high, the composite is stronger than less fiber loading. This agreement is consistent with the finding by Loh [17], where the shore hardness of Kenaf fiber/polypropylene (K-PP) composite increased with higher amount of kenaf filler.

Table 4 Hardness properties of the samples

PALF loading (wt.%)	Hardness (Shore-D)
10	69.00
20	69.70
30	70.00
40	71.50

3.4 Microstructure Analysis

Figure 6 shows the scanning electron microscope (SEM) micrograph of PALF/PP composite after tensile test, the incremental fiber loading causes the structure of PALF/PP composite to become fibrous and not aligned. The adhesion bonding between fiber and matrix tends to become weaker due to the higher fiber loading.

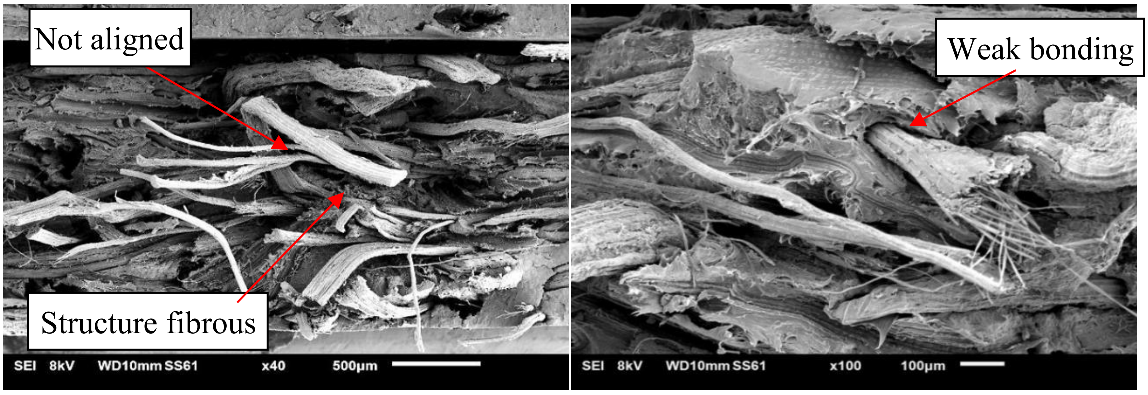


Figure 6. SEM micrographs of fracture surface of PALF/PP composite after tensile test.

4 CONCLUSION

From the obtained results in this research, tensile test shows linear decremented pattern with the increment of fiber loadings percentage. 10 wt.% of fiber loading shows the highest value of tensile strength which is 25.26 MPa. Moreover, for the hardness and density results, 40 wt% shows the highest result, correspond to 71.50 Shore-D and 1.0045 g/cm^3 respectively. According to the result, it can be identified that the percentage of fiber loading affects the mechanical and physical properties of PALF/PP composite. The decrease in PALF is beneficial if it is properly mixed with the PP during fabrication process. Thus, it can be concluded that the natural composite with 40 percentage of fiber loading has a good potential to produce superior composite materials properties and can be applied as interior part in automotive application. By adding another mechanical tests, such as impact test and water absorption test for further analysis will become our research focus in the future.

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