Study on Wear Behaviour of Bagasse Filler Reinforced Vinyl Ester Composites

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Abstract:- **Combining two or more different materials resulting in a new material with improved properties exists from ages. Composites bestowed with advantages like light weight, high stiffness to weight and high strength to weight ratio, drew attention from the developed world towards novel application.**

Natural filler reinforced polymer composites have emerged as a potential environmentally friendly and cost-effective option to synthetic filler reinforced composites. The availability of natural filler and ease of manufacturing have tempted researchers to try locally available inexpensive fillers and to study their feasibility of reinforcement purposes and to what extent they satisfy the required specifications of reinforced polymer composite for tribological applications.

The objective of this study is to fabricate bagasse filler reinforced vinyl ester composite material with varying bagasse filler content. Specimens will be cut from the fabricated composites and the Two Body Wear in accordance with ASTM G 99. Also Three Body Abrasive Wear behavior of the fabricated composites will be studied in accordance with ASTM G 65. .

Key Words: Bagasse Filler, Vinyl Ester Composite, Three Body Abrasive Wear.

1. INTRODUCTION

Natural fibers are lignocellulose in nature. These composites are gaining importance due to their non-carcinogenic and bio-degradable nature. The natural fiber composites can be very cost effective material especially for building and construction industry (panels, false ceilings, partition boards etc.) packaging, automobile and railway coach interiors and storage devices. This also can be a potential candidate in making of composites, especially for partial replacement of high cost glass fibers for low load bearing applications. However in many instances residues from traditional crops such as rice husk or sugarcane bagasse or from the usual processing operations of timber industries do not meet the requisites of being long fibers. This biomass left over are abundant, and their use as a particulate reinforcement in resin matrix composite is strongly considered as a future possibility. Cane is crushed in a series of mills, each consisting of at least three heavy rollers. Due to the crushing, the cane stalk will break in small pieces, and subsequent milling will squeeze the juice out. The juice is collected and processed for production of sugar. The resulting crushed and squeezed cane stalk, named bagasse, is considered to be a by-product of the milling process. Bagasse is essentially a waste product that causes mills to incur additional disposal costs. Bagasse is a fibrous residue that remains after crushing the stalks, and contains short fibers. It consists of water, fibers, and small amounts of soluble solids. Percent contribution of each of these components varies according to the variety, maturity, method of harvesting, and the efficiency of the crushing plant.

Bagasse is mainly used as a burning raw material in the sugar cane mill furnaces. With increasing emphasis on fuel efficiency, natural fibers such as bagasse based composites enjoying wider applications in automobiles and railway coaches & buses for public transport system. There exist an excellent opportunity in fabricating bagasse based composites towards a wide array of applications in building and construction such boards and blocks as reconstituted wood, flooring tiles etc. Value added novel applications of natural fibers and bagasse based composites would not go in a long way in improving the quality of life of people engaged in bagasse cultivation, but would also ensure international market for cheaper substitution. Natural fibers have the advantages of low density, low cost, and biodegradability. However, the main disadvantages of natural fibers and matrix and the relative high moisture sorption. Therefore, chemical treatments are considered in modifying the fiber surface properties. A better understanding of the chemical composition and surface adhesive bonding of natural fiber is necessary for developing natural fiber is necessary for developing natural

fiber-reinforced composites. Visualizing the increased rate of utilization of natural fibers the present work has been undertaken to develop a polymer matrix composite (epoxy resin) using bagasse filler as reinforcement and to study its mechanical properties and environmental performance.
These benefits can be classified into the following categories:

- Environmental Aspects: Plant fibers are renewable resources. They need low energy requirements during production. Furthermore, natural fibers show carbon dioxide neutrality and their disposal can be done by composting.
- Biological Aspects: They are natural organic products. There is no dermal issue for their handling compared to glass fibers and do not pose a bio-hazard upon disposal.
- Production Aspects: Natural fibers are non-abrasive and exhibit great formability.
- Component Weight Issues: Natural fibers are light weight (less than half the density of glass fibers).
- Financial Aspects: Natural fibers are very cheap in comparison to glass fibers.
- General Aspects: Natural fibers show a safer crash behavior in tests (i.e., no splintering). They are also available on a worldwide basis. In addition, they exhibit good thermal insulating and acoustic properties due to their hollow tubular structures.

Tayeb [20] studied the potential use of bagasse filler for tribological applications. His results shows that bagasse fiber composite can be a promising composite in friction and wear environment which can be competitive to glass fiber reinforced polyester composite. After reviewing the existing literature available on natural fiber composites, particularly bagasse filler composites efforts are put to understand the basic needs of the growing composite industry. The conclusions drawn from this is that, the success of combining vegetable natural fibers with polymer matrices results in the improvement of mechanical properties of the composites compared with the matrix materials. These fillers are cheap and nontoxic, can be obtained from renewable sources, and are easily recyclable. Moreover, despite their low strength, they can lead to composites with high specific strengths because of their low density. Thus the priority of this work is to prepare Polymer Matrix Composites (PMCs) using bagasse filler (waste from sugarcane industry) as reinforcement material. To improve the interfacial strength between the fiber and the matrix, the surface modification of the bagasse filler has to be done by chemical treatment. The composite will

then be subjected to different weathering treatments like steam, saline and subzero conditions. The flexural strength of the composite will be evaluated using three point bend test.
From the literature above it has been observed that natural fibers and filler reinforced composites has great potential in composite industry, hence we decided to try bagasse filler as reinforced with vinyl ester resin and evaluate the wear behavior of the newly developed composite.

2. MATERIALS AND METHOD

2.1 *Materials*

In this investigation, composites were fabricated using vinyl ester resin as matrix and bagasse filler is used as reinforcement in the present work. Polyflex (vinyl ester) resin with 200-60 grade (of naphtha resins and chemicals, Bangalore), and the particulate fillers used are bagasse fillers. The natural fiber , the vinyl ester properties and bagasse filler properties are given in Table 2.1.1,2.3 and2.1.2.

Table 2.1.1: Average properties of Bagasse

Item	**% Composition**
Moisture	49.0
Soluble Solids	2.3
Fiber	48.7
Cellulose	41.8
Hemicelluloses	28
Lignin	21.8

Table 2.1.2: Bagasse filler properties

Length (mm)	103–126
Weight (mg)	2–6
Tex (mg/mm)	(1.94–4.76)E-02
Diameter (mm)	1.2–2.7
Tensile strength (GPa)	0.17–0.29
Modulus of elasticity (GPa)	15–19

2.2 Reinforcement

Bagasse Filler - The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system. All of the different fibers used in composites have different properties and so affect the properties of the composite in different ways.

Bagasse is a fibrous residue that remains after crushing the stalks, and contains short fibers. It consists of water, fibers, and small amounts of soluble solids. Percent contribution of each of these components varies according to the variety, maturity, method of harvesting, and the efficiency of the crushing plant.

2.3 Matrix

Vinyl ester is a resin produced by the esterification of an epoxy resin with an unsaturated monocarboxylic acid. The reaction product is then dissolved in a reactive solvent, such as styrene, to 35 - 45 percent content by weight. It can be used as an alternative to polyester and epoxy materials in matrix or composite materials, where its characteristics, strengths, and bulk cost intermediate between polyester and epoxy. Vinyl ester has lower resin viscosity (approx. 200 cps) than polyester (approx. 500cps) and epoxy (approx. 900cps).

In homebuilt airplanes, the Glasair and Glastar kit planes made extensive use of vinyl ester-reinforced fiberglass structures. It is a common resin in the marine industry due to its increased corrosion resistance and ability to withstand water absorption. Vinyl ester resin is extensively used to manufacture FRP tanks and vessels as per BS4994.

Table 2.3: Vinyl ester resin properties

Property	Units	Results
Appearance	-	Clear Liquid
Brookfield Viscosity @ 25°C (Spindle No: 2 Speed 10 Rpm)	cps	440
Acid Value	mg KOH/g	9.65
Volatile Content (2g/150°C/1h)	%	42.35

2.4 Open Molding Method:

Table 2.4:Volume calculations

Particulars	Dimensions
Dimension of mould box	150*75*3mm
Volume of mould box	31500mm^3
Density of vinyl ester resin	0.0023g/mm^3
Mass of vinyl ester resin	0.0023*31500= 72.45g

2.5 Treatment of bagasse:

- Baggases is taken in a container.
- Prepare 5 wt% NaOH solutions in water
- Mix the sugarcane pulp in NaOH for 5 hrs. at 40-50 °C
- After 5hr wash completely
- Dry the treated Bagasse
- Cut or grind or mill into powder
- Use that as filler

Bagasse fibers, 50 cm long, were soaked in a 5% NaOH solution at 30°C with a liquor ratio of 10:1. The fibers were kept immersed in the alkali solution for 5 hrs. The fibers were then washed several times with fresh water to remove any NaOH sticking to the fiber surface, were neutralized with dilute acetic acid, and were finally washed again with distilled water. A final pH of 7 was maintained. The fibers were then dried at room temperature for 48 h, and then it was grinded into powdered form and was used as filler.

2.6 Specimen Preparation

The steps involved in preparation of Bagasse fiber reinforced vinyl ester composites by open mould technique are as follows:

- The surface of mould and release film is cleaned with soft brush and cloth by using acetone. A layer of release film is applied on the cleaned surface.
- The mould is waxed clearly above the release film and also in the side such that there is no any gap for the flow of resin.
- The vinyl ester resin is weighed to the required extent to that weight of reinforcement material taken and is put in to a bowl.
- Catalyst ANDONOX KP-9 which is 1.5ml with that of the weight of 100g of vinyl ester resin is added to the bowl containing vinyl ester and stirred uniformly.
- Similarly PROMOTER (10% DMA) and ACCELERATOR (3% CO-etoate) with is 1.5ml with that of the weight of 100g of vinyl ester resin is added

to the bowl containing vinyl ester and stirred uniformly.
- The stirred mixture is been poured into the mould.
- Same procedure is repeated for all other combinations..
- After pouring it is kept drying for 10hrs.
- And thus the required specimen is obtained.
- By following the same procedure as said above composite material having filler composition of 5%, 10%, 15% and 20% are prepared.

Table 2.6: Details of composition of composites

Samples	Matrix Wt. %	Fillers Wt. %
Vinyl ester – filler	100	0
Vinyl ester – filler	95	5
Vinyl ester – filler	90	10
Vinyl ester - filler	85	15

3. EXPERIMENTATION

3.1 Experimental Set-up

A set of experimental tests had been carried out to evaluate the wear behavior of bagasse filler reinforced vinyl eater composites. The fabrications and experiments have been conducted at room temperature**.**

3.2 Wear

In materials science, **wear** is the erosion of material from a solid surface by the action of another solid. The study of the processes of wear is part of the discipline of tribology. There are five principal wear processes:
- Adhesive wear
- Abrasive wear
- Surface fatigue
- Fretting wear
- Erosion wear

Plastic deformation at the interface often leads to wear; i.e. deformation induced wear. Wear can also be caused by chemical process. The consequence of film failure is severe wear. Wear in these circumstances is the result of adhesion between contacting bodies and is termed adhesive wear**.** Then the intervening films are partially effective then milder forms of wear occur and these are often initiated by fatigue process due to repetitive stress under either sliding or rolling.

These milder forms of wear can therefore be termed fatigue wear**.** On the other hand if the film material consists of hard particles or merely flows against one body without providing support against another body then a form of wear, which sometimes can be very rapid, known as abrasive wear occurs. Two other associated forms of wear are erosive wear (due to impacting particles) and cavitation wear**,** which is caused by fast flowing liquids. In some particle situations, the film material is formed by chemical attack of either contacting body and while this may provide some lubrication, significant wear is virtually inevitable. This form of wear is known as corrosive wear and when atmospheric oxygen is the corroding agent, then oxidative wear is said to occur. When the amplitude of movement between contacting bodies is restricted to, for example, a few micrometers, the film material is trapped within the contact and may eventually become destructive. Under these conditions fretting wear may result. There are also many other forms or mechanisms of wear. Almost any interaction between solid bodies will cause wear. Typical examples are impact wear caused by impact between two bodies, melting wear occurring when the contact loads and speeds are sufficiently high to allow for the surface layers of the solids to melt and diffusive wear occurring at high interface temperatures. This dependence of wear on various operating conditions can be summarized.

3.2.1 Abrasive Wear Test

The schematic representation of rubber wheel test set up was shown in Figure 6.12. In the present study, silica sand (density 2.6 g/cm3) was used as the abrasive. The abrasive particles of AFS 60 grade silica sand were angular in shape with sharp edges. The abrasive is fed at the contacting face between the rotating rubber wheel and the test sample. The tests were conducted at a rotational speed of 200 rpm. The rate of feeding the abrasive was 255±5 g/min. The sample was cleaned with acetone and then dried. Its initial weight was determined in a high precision digital balance (0.1mg accuracy) before it was mounted in the sample holder. The abrasives were introduced between the test specimen and rotating abrasive wheel composed of chlorobutyl rubber tyre (hardness: Durometer-A 58-62). The diameter of the rubber wheel used was250 mm. The test specimen was pressed against the rotating wheel at a specified force by means of lever arm while a controlled flow of abrasives abrades the test surface. The rotation of the abrasive wheel was such that its contacting face moves in the direction of sand flow. The pivot axis of the lever arm lies within a plane, which was approximately tangent to the rubber wheel surface and normal to the horizontal diameter along which the load was applied. At the end of a set test duration, the specimen was removed, thoroughly cleaned and again weighed (final weight). The difference in weight before and after abrasion was determined. At least four tests were performed and the average values so obtained were used in this study. The size of the specimen was 70 x 30 x 3 mm. The experiments were carried out for load of 23N at a constant sliding velocity of 2.15 m/s. Further the abrading distances were varied in steps from 150 to 600 m. The specimen holder was designed to ensure that samples are removed and replaced during each test such that the wear scar was always at the same location. The wear was measured by the loss in weight, which was then converted into specific wear rate using the measured

density data. The specific wear rate (KS) was calculated using following mathematical relation:

$$K_s = \frac{\Delta V}{Ld}\left[\frac{m^3}{Nm}\right] \quad \ldots . (3.2.1)$$

Where, ΔV is the volume loss in m³, L is the load in Newton, and d is the abrading distance in meters.

3.2.3 Specimen Dimensions:

- Test specimen from all four compositions were cut into dimensions of
  70mm X 30mm X 3mm.

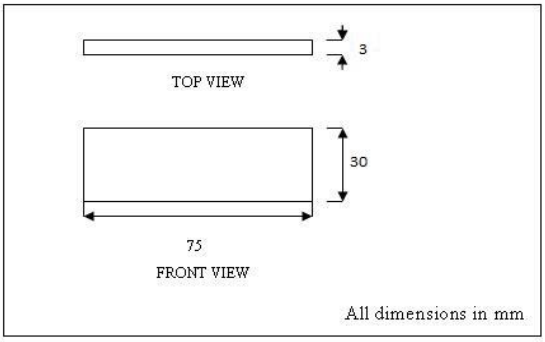


Fig 3.1: Specimen for Three body abrasive wear test

3.2.4. Three Body Abrasive
Wear Test Set Up:

Loads applied (N) = 23 N.
Sliding velocities (m/s) = 2.15

Fig 3.3: SEM Micrograph of the used erodent

3.2.2 Test Specimens:

The wear behavior of bagasse filler reinforced vinyl eater composites were studied using a Dry Sand/Rubber wheel abrasive Tester (RWAT-ASTM G65). The three body wear test was conducted on composites with 0%, 5% ,10%,15% and 20% bagasse filler content.

Abrading distance (m) = 150,300,450,600.
Wheel diameter (mm) = 250
Rotational speed (RPM) = 200
Abrasive sand = Silica sand (200-250 µm)
Abrasive feed rate = 255±5 g/min

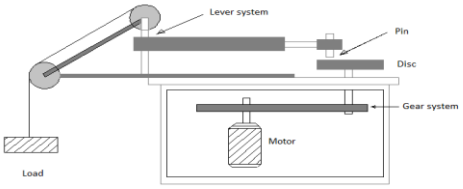


Fig 3.2: Three-dimensional schematic of sand/steel wheel Machine : (1) load lever, (2) specimen,(3) counter face, (4) hopper, and (5) load cell

Fig 3.4: Picture of dry sand/rubber wheel abrasive wear test experimental setup

3.2.5 Wear Loss Calculation:

Initial Weight – Final Weight= Wear Loss (g) . . . (3.2.5)

3.3 Two Body Wear Test

Pin- on- disc testing is a commonly used technique for investigating sliding wear. As the implies, such apparatus consists essentially of a 'pin' to which test specimen is glued is in contact with a rotating disc. Usually a pin is a cylinder. In a typical pin-on-disc experiment, the coefficient of friction is continuously monitored as wear occurs, and the material removed is determined by weighting and/or measuring the profile of the resulting wear track. Changes in coefficient of friction are frequently

indicative of a change in wear mechanism, although mark changes are often seen during the early stages of wear test as equilibrium conditions become established.

The main variables in which affect friction and wear are velocity and normal load. In addition, specimen orientation can be important if retained wear debris affects the wear rate.

3.3.1 Specimen and Pin

Dimensions:

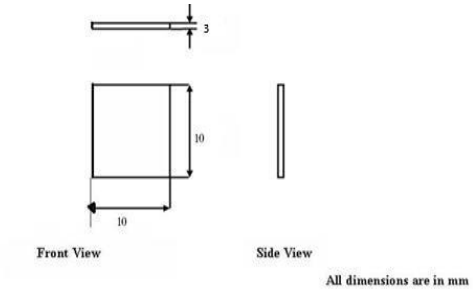


Fig 3.5 Specimen for Two body wear test

- Specimen dimensions are 10mm×10mm.
- The length of pins is 25mm and diameter is 8mm.

3.3.2 Pin-on-Disc Test Setup:

Loads applied(N) = 25,35
Sliding speed(rpm) = 200,300
Sliding distance(m) = 150,300
Track diameter (mm) = 250

3.3.3 Sliding Speed Calculation:

Sliding speed in (m/s) $v=\pi*D*N/60000$ . . . . (3.2)

Where, D is the wear track diameter in mm.
N is the disc speed in R.P.M
Distance travelled = π *D*n .Where, D is the track diameter

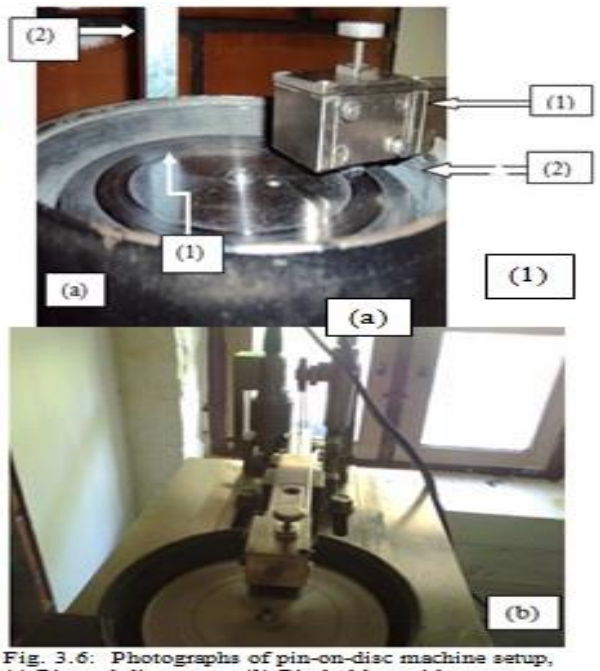


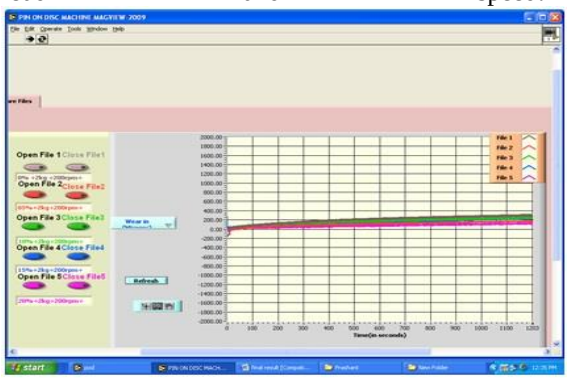
Fig. 3.6: Photographs of pin-on-disc machine setup, (a) Pin and disc set up (1) Pin holder with screw, (2) Specimen with holder,(b) Loading arrangement (1) Load cell (2) Loaded lever arm

Fig 3.7: Experimental setup of pin-on-disc test apparatus

Fig 3.8: Control unit for computerized pin-on-disc test

3.3.4 Procedure:

- Pin-on-disc test was conducted according to ASTM G-99.
- Specimen and pin are cut according to ASTM G-99 standards fig (6.15)
- Test specimen is glued to the pin.
- Initial weight of the test sample is taken.
- Placing the leveling block to ensure that the specimen is clamped properly.
- Fixing the specimen in the specimen jaw.
- Cleaning the disc in acetone.
- Placing weighs on weight pan.
- Removing the leveling block.
- Setting the initial reading of wear rate and frictional force on the controller to zero
- Running the machine for a fixed sliding speed for fixed number of revolutions of the wear disc.
- At the end of test results the values of frictional force, wear rate and coefficient of friction is noted.
- Test samples are weighed after the test (Final reading).
- Difference between initial and final weight is the wear loss.
- The above procedure can be repeated by varying load and speed.



4. RESULTS AND DISCUSSIONS

In this project, Bagasse filler reinforced vinyl ester composites with varying percentage of filler are fabricated and their wear behavior is evaluated.

As mentioned in the Chapter 5, two types of test specimens according to ASTM standards with varying compositions were fabricated and tested. The wear loss have been represented as shown in Table 4.1, 4.2, 4.4, and 4.5.

4.1 Experimental Results:

Vinyl ester Composite specimens without filler and 5%, 10%, 15% and 20% bagasse filler are tested.

4.1.1 Wear Tests

Three Body Abrasive Wear Test At 23N Load

Table 4.1.1: Showing three body abrasive result for 23N

% of filler	Sliding distance in m	Time in min	Speed in rpm	Initial weight in g	Final weight in g	Wear Rate (g)
0%	150	1.13	200	9.4375	9.3920	0.0455
	300	2.17	200	7.6884	7.5568	0.1316
	450	3.21	200	8.4111	8.2603	0.1508
	600	4.24	200	8.8147	8.6038	0.2109
5%	150	1.13	200	5.2613	5.2045	0.0568
	300	2.17	200	5.5512	5.4196	0.1316
	450	3.21	200	5.9885	5.8536	0.1349
	600	4.24	200	8.1813	8.0203	0.1610
10%	150	1.13	200	7.0280	6.9593	0.0687
	300	2.17	200	7.8669	7.7293	0.1376
	450	3.21	200	8.2841	8.1133	0.1253
	600	4.24	200	9.1421	8.9845	0.1576
15%	150	1.13	200	7.5874	7.5005	0.0869
	300	2.17	200	7.7395	7.6060	0.1385
	450	3.21	200	9.8448	9.7895	0.1012
	600	4.24	200	9.7747	9.5908	0.1453
20%	150	1.13	200	4.5056	4.4342	0.0714
	300	2.17	200	5.1458	4.9879	0.1579
	450	3.21	200	5.6810	5.6525	0.0845
	600	4.24	200	7.2254	7.1460	0.0907

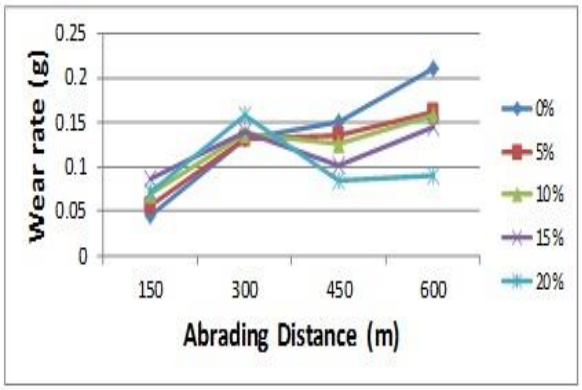


Fig 4.1: Wear Rate of composites as a function of abrading distance at 23N

Graph shows with the Wear rate with respect to Abrading distance, from the tests it is observed that,

- Wear rate decreases with increase in speed of the rubber wheel
- Wear rate decreases with increase in the filler content.

Discussion

The least wear rate of 0.0845 g occurs in 20% filler content sp[ecimens at a abrading distance of 450 m at 200 rpm for 23N and the highest wear rate of 0.2109 g occurs in specimens without filler content at a abrasive distance of 600 m at 200rpm for 23N. The wear rate decreases with the increase in filler content indicating that the bagasse filler show good resistance to wear on the Three body Abrasive wear of fabricated components.

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