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Establish a Methodology for Predicting the Mechanical Properties of Composite Materials

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Abstract— ***It is difficult to predict the various properties like stress-strain behavior, tensile strength and impact strength of composites. These properties are tabulated after proper mechanical testing of the test piece. For a new composite with a new matrix material; or a new fiber material or changed fiber size / orientation and form; or different binders; predicting the properties would be difficult. The process would constitute physical manufacture of a component, followed by mechanical testing. By carrying out analysis of a new material under development using a tool such as ANSYS it would become possible to predict the properties without fabrication and testing. In cases where part of the fiber currently utilized in the composite is proposed to be replaced partly by a low cost fiber, the effect of the fiber substitution can also be predicted.***

***Keywords*— ANSYS.**

I. INTRODUCTION

Composite materials are defined as, "A mixture of two or more distinct constituent or phases."A material is said to be composite material only when it satisfies the criterion Both the constituents have to be present in reasonable proportions normally greater than 5%.It is only when the constituent phases have different properties and hence the composite properties are noticeably differing from the properties of the constituents. It should be a man made composites usually produced by intimately mixing and combining the constituents by various means. The constituent that is continuous and is often present in the greater quantity in the composite, that constituent is called as 'matrix' and the constituent which enhances or reinforces the mechanical properties of the matrix, that constituent is called as 'reinforcement or reinforcing phase'[1]. The fabrication and properties of composites are strongly influenced by the proportions and properties of matrix and reinforcement. The proportions can be expressed either via the weight fraction (w), which is relevant to fabrication or via the volume fraction (v), which is commonly used in property calculations. The definition of w and v are related simply to the ratios of weight (w) and volume (v) as follows-

Volume fractions:

$$vf = \frac{Vf}{Vc} \text{ and } vm = \frac{Vm}{Vc}, \qquad \text{--- [i]}$$

Weight fractions:

$$wf = \frac{Wf}{Wc} \text{ and } wm = \frac{Wm}{Wc}, \qquad \text{--- [ii]}$$

Where m, f, and c refers to matrix, fiber and composite respectively.

$$Wc = Wf + Wm$$

$$\text{As } W = \rho V$$

Hence,

$$\rho cVc = \rho fvf + \rho mVm$$

II. FABRICATION OF COMPOSITE MATERIALS

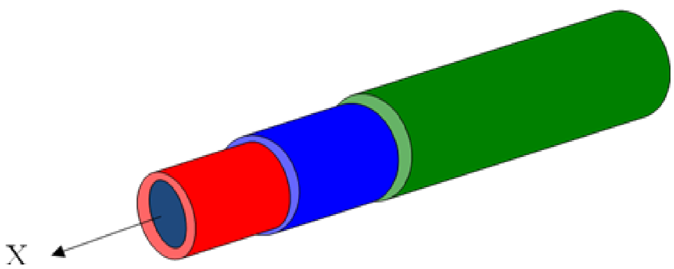

Fig 1: Layers of Composite Tube

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Each color represents a different fiber orientation and change in material properties relative to the Global Axis. The durability of a composite material can be analyzed by adapting following procedures-

1. Initially loads are applied on the composite materials.
2. Finite element modeling is done on ansys on the basis of loads.
3. Then is load is applied.

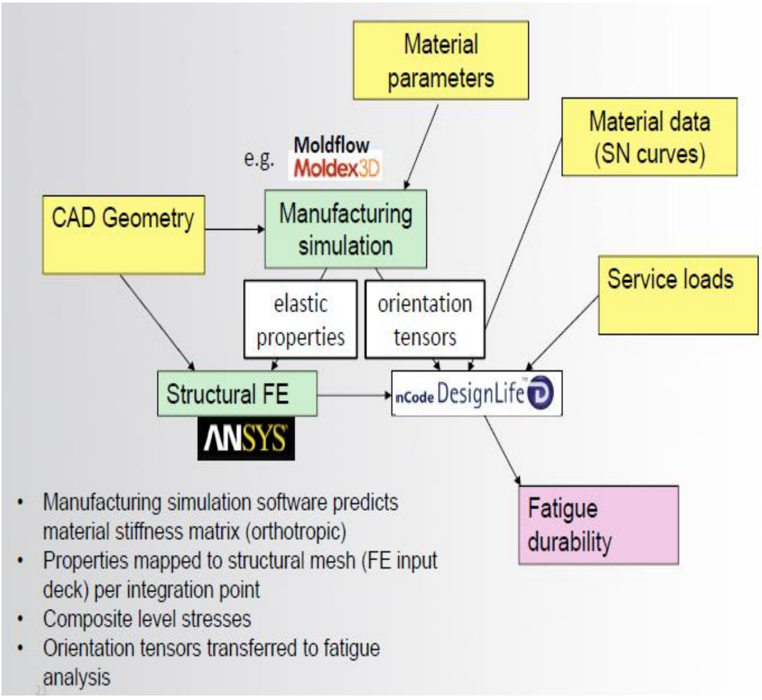

Fig 2: Work Flow

III. Methods to Predict the Properties

Various theoretical techniques can be used to predict mechanical properties such as elastic constant, mechanical strength of composite materials. Halpin-Tsai equation has been developed for predicting the elastic constants of composite fibers.[3]

A. Halpin-Tsai Equation

Halpin-Tsai and Kardos have empirically developed some generalized equations that readily give quite satisfactory results compared to complicated micromechanical equations. These equations are quite accurate at low volume fractions. They are useful in determining the properties of composite materials that contain discontinuous fibers oriented in the loading directions [5]. The equation can be written as-

$$\frac{p}{pm} = \frac{1+\mathcal{E}\acute{\eta}Vf}{1-\acute{\eta}Vf} \qquad \text{------- (A)}$$

OR

$$\acute{\eta} = \left(\left(\frac{Pf}{Pm}\right) - 1\right) / \left(\left(\frac{Pf}{Pm}\right) + \mathcal{E}\right) \qquad \text{-------- (B)}$$

Where p represents composite moduli, pm and pf are the corresponding matrix and fiber module, respectively; Vf is the fiber volume fraction $\mathcal{E}$ is a measure of the reinforcement which depends on boundary conditions (fiber geometry, fiber distribution and loading conditions.)The term $\mathcal{E}$ is an empirical factor that is used to make Eq.(A) confirm to the experimental data[2]. The function ή in Eq.(B) is constructed in such a way that when Vf=0 ,p=pm and when Vf=1 ,p=pf. Furthermore, the form of ή is such that

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$$\frac{1}{p} = \left(\frac{Vm}{pm}\right) + \left(\frac{Vf}{pf}\right) \quad for\ \mathcal{E} \rightarrow 0$$

AND

$$P=pf*Vf+pm*Vm \qquad for\ \mathcal{E} \rightarrow \infty$$

Nielson has modified the Halpin-Tsai equation to include the maximum packing factor ϕ max of the reinforcement.His equations are

$$\frac{p}{pm} = \frac{1 + \mathcal{E}\acute{\eta}Vf}{1 - \acute{\eta}\psi vf}$$

$$\acute{\eta} = \frac{\left(\frac{pf}{pm}\right) - 1}{\frac{pf}{pm} + \mathcal{E}}$$

$$\psi = 1 + \left(\frac{1 - \phi\max}{\phi 2\max}\right)\mathrm{Vf}$$

Where ϕmax is the maximum packing factor.

This analysis work aims to establish a methodology to predict properties of newly developed composites.[4] The initial part of the project would comprise of developing a correct geometric model for a particular composite, and carry out finite element analysis using the software ANSYS 14 by applying apply different boundary conditions; the values of various mechanical properties obtained from the results of this analysis will be compared with experimental data available from the manufacturers. If the model is validated after comparing the result; the second part would comprise of extending the same methodology to different types of composites with differing matrix composition and different fiber orientation. In this analysis geometric model of hybrid composite material is developed. The hybrid composite is consists of two materials- glass fiber and oil palm empty fruit bunch fiber. The size of composite sheet which will be developed will be of size 150mm×150mm×2.5mm. The model is developed on the basis of the properties of composite materials as well as resins /binders which is used between them.

IV. ANSYS

In recent years, the numerical simulation technology is being utilized efficiently all over the world. ANSYS is perhaps become the most popular CAE software in mechanical engineering, in civil constructions and in science of materials namely with composite materials and hybrid material structures. With this we can improve the workflow of composite materials.

Advantages of ANSYS

- Changing material properties or layer orientation is simple.
- Many different orientations can be analyzed in a short amount of time.
- ANSYS can predict results before fabricating composite sample.
- Complex geometries can be modeled and evaluated easily.

V. PROCEDURE FOR ANALYSIS OF COMPOSITE MATERIALS

Step-1- Modeling of composite slab of given dimension in solid work and importing of geometry in Ansys workspace.

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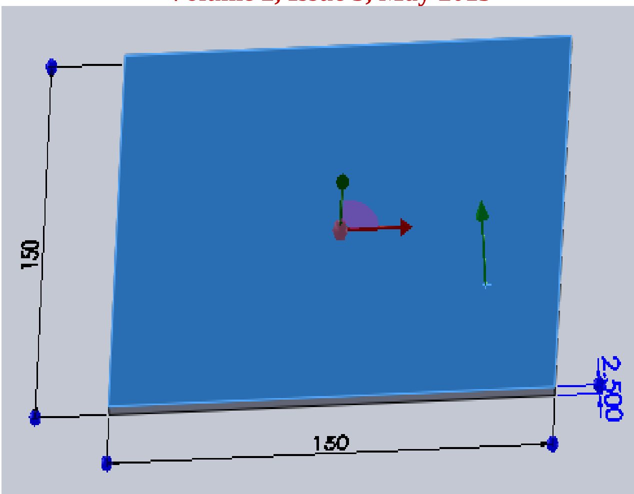

Fig 3 : Geometry of Ansys

Step-2- Defining each layer and meshing for creation of number of nodes and number of elements**.**

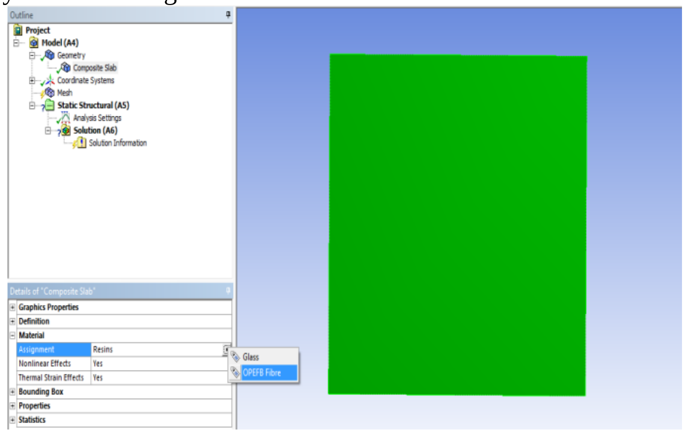

Fig 4: Creation of Nodes

Create Mesh
No. of Nodes: - 17300
No. of Elements: - 2401

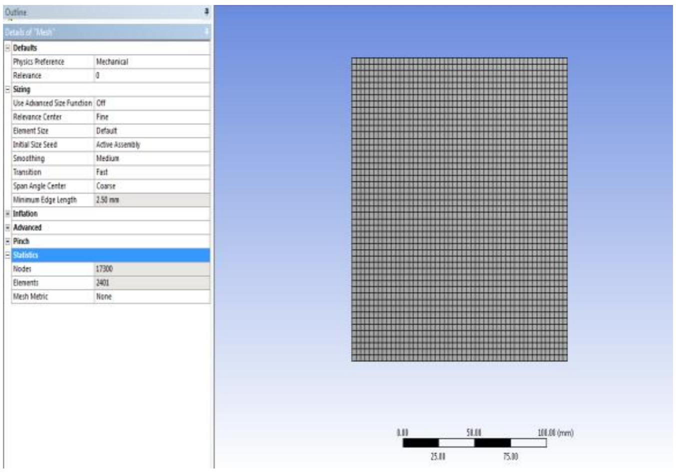

Fig 5: Nodes and Element

Step-4- Application of loads and analysis of composite in the form of stress induced on composite as the load changes. A] Diagram showing just layers for application of load

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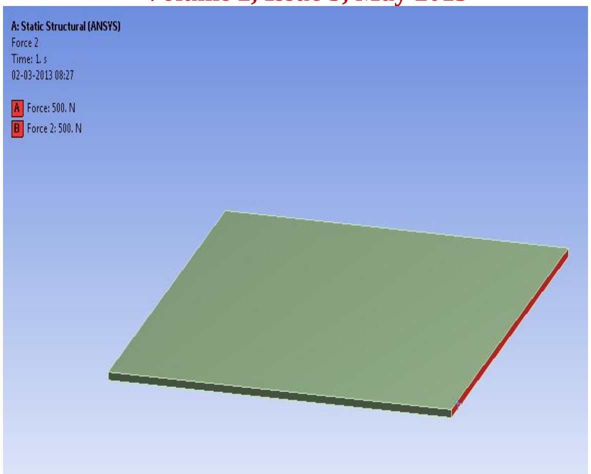

Fig 6(a) : Layers of fload[7]

B] Analysis of stress induced when 100 N forces is applied.

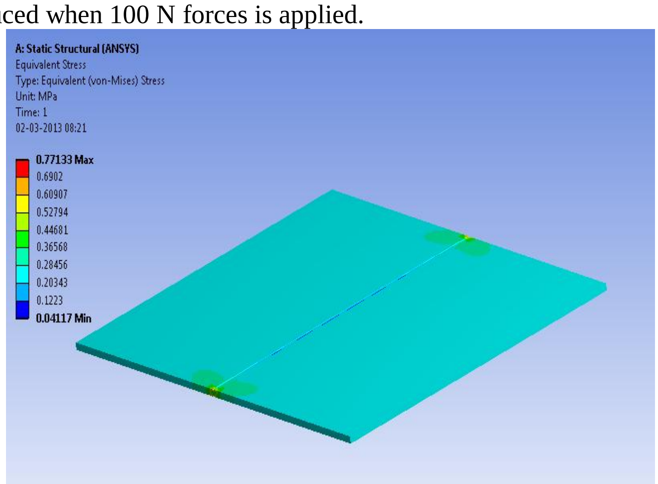

Fig 6(b) : 100N force is applied[7]

C] Analysis of stress induced when 500 N force is applied.

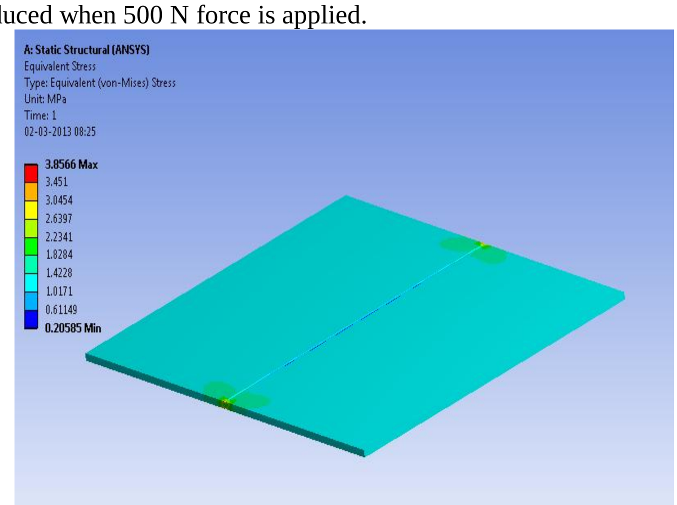

Fig 6(c) : 500N force is applied[7]

D] Analysis of stress induced when 1500 N force is applied.

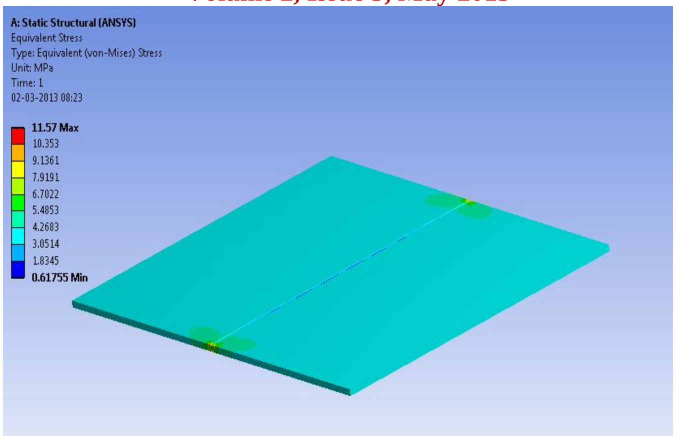

Fig 6(d) : 1500N force is applied[7]

Above analysis shows that as load goes on increasing stress produced also increases.

Step-5-Analysis of composite when direction of fibers kept unidirectional and bidirectional**.**
A] When fibers are kept unidirectional
1] For 100 N load.

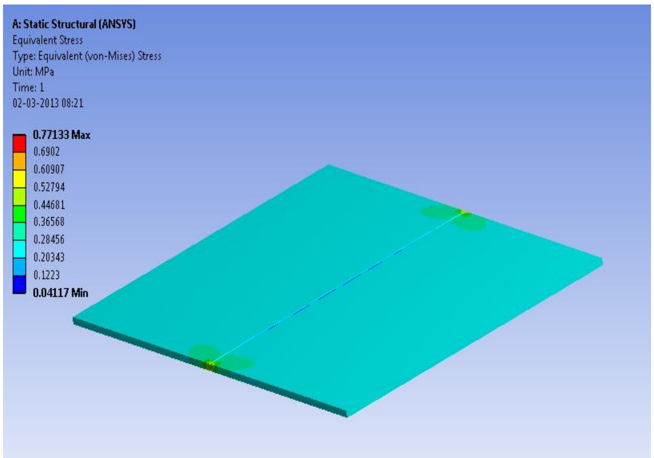

Fig 7(a) : 100N force is applied with fibers

2] For 500 N load.

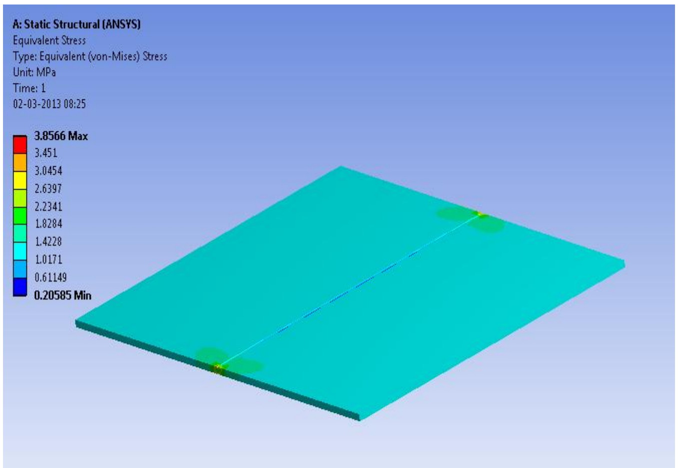

Fig 7(b) : 500N force is applied with fibers

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3] For 1500 N load.

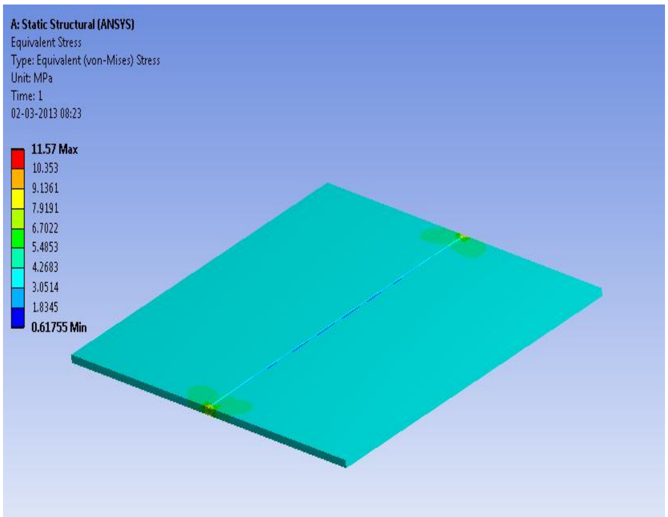

Fig 7(c) : 1500N force is applied with fibers

B] When fibers are kept bidirectional

1] For 100 N load

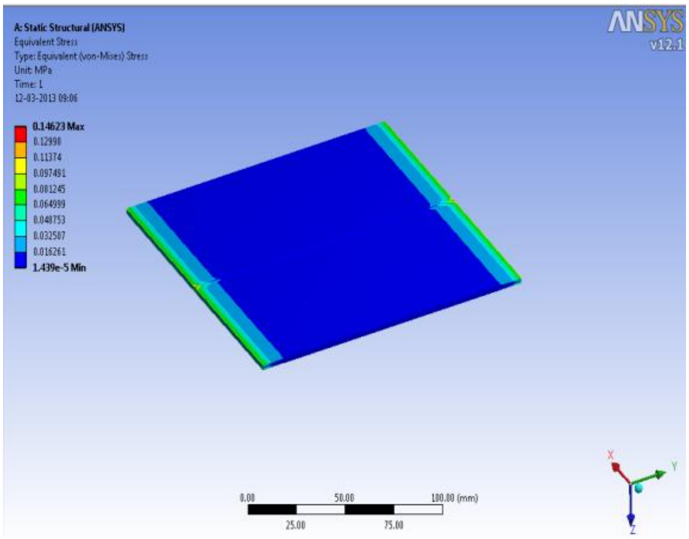

Fig 8(a) : 100N force is applied with fibers bidirectional

2] For 500 N load.

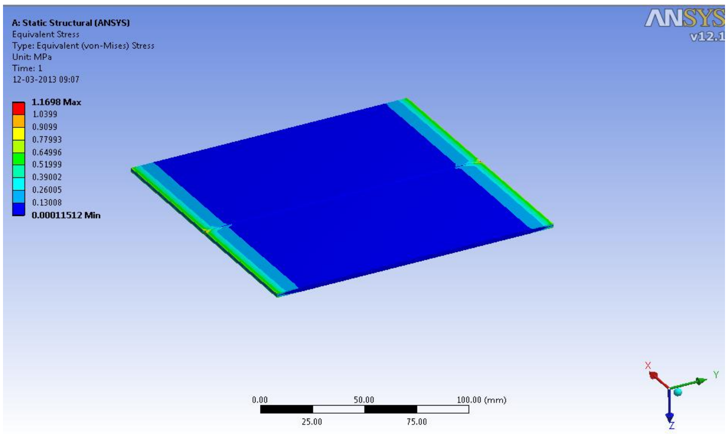

Fig 8(b) : 500N force is applied with fibers bidirectional

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3] For 1500 load.

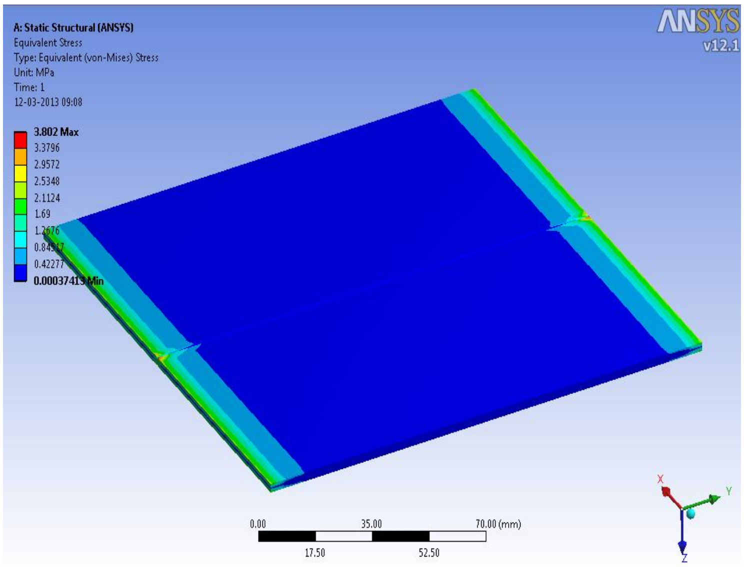

Fig 8(c) : 1500N force is applied with fibers bidirectional

From this analysis it is clear that stress is less in bidirectional fiber orientation as compared to stress induced in unidirectional fiber orientation.

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