Predict effective failure strength constants of fiber-reinforced unidirectional composites

Problem Description

The effective initial failure strength constants of fiber-reinforced unidirectional composites are predicted using the MSG solid model. A square packed mechanical model is used as shown in Fig. 1. The MSG solid is used to first perform homogenization analysis to get the effective properties of this composite. Then, the MSG-based initial failure analysis is carried out for computing the effective strength constants, which can be used in the upper scale models (e.g., yarn or lamina).

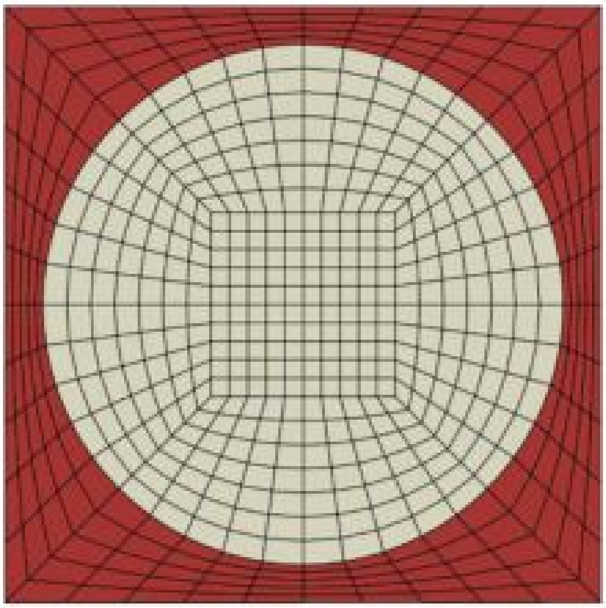

Fig. 1

The maximum stress criterion is used for both matrix and fiber. There are different built-in failure criteria in SwiftComp which can be found in the SwiftComp user manual. In addition, advanced users can also code user-defined failure criterion with the SwiftComp executable file. In this example, the fiber is usually assumed to fail only in the fiber direction and the transverse strength constants of the fiber is usually not available. Moreover, the failure in the transverse direction of the composite is dominated by the matrix. Therefore, fictitious fiber strength constants in the transverse directions are used to ensure the failure only occurs in the fiber direction.

The elastic and strength constants of fiber and matrix is given in Fig. 2. The detailed information can be found in the Ref 1.

Material	E_1 (MPa)	E_2 (MPa)	G_{12} (MPa)	G_{23} (MPa)	ν_{12}	X (MPa)	X' (MPa)
Fiber	230,000	15,000	15,000	7000	0.20	2500	2000
Matrix	4200	4200	1567	1567	0.34	69	250

Fig. 2

Software Used

Gmsh4SC 2.0

Solution Procedure

Below describes the step-by-step procedure you followed to solve the problem.

1. step 1

- Open Gmsh4SC and create a new model (Change the default name). Click Material->Thermoelastic and input the matrix and fiber properties as shown in Fig. 3 and Fig. 4.

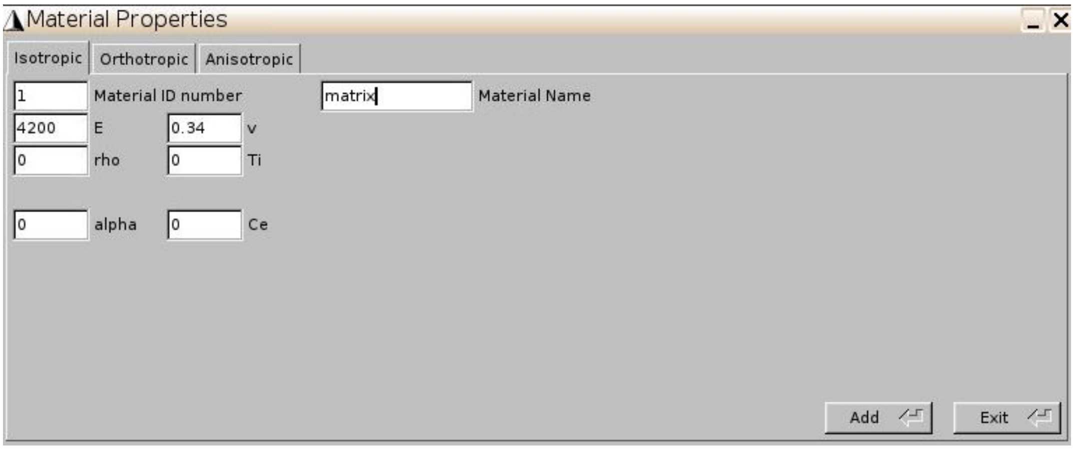

Fig. 3

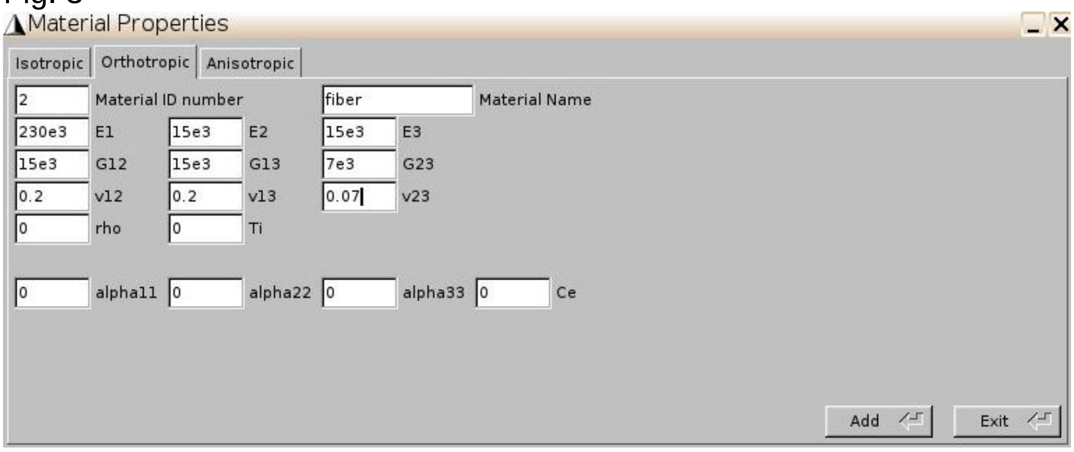

Fig. 4

- Click Geometry->Common SG-> 2D SG->Other 2D SGs. Select Square Pack Microstructure and the corresponding fiber and matrix materials as shown in Fig. 5. In this example, the fiber volume fraction is assumed to be 0.6.

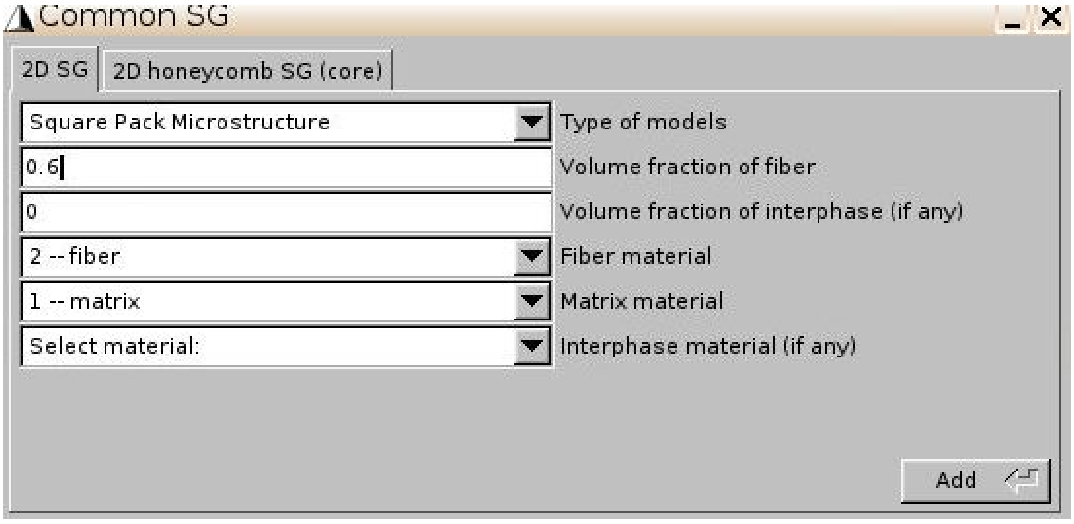

Fig. 5

* Click Mesh->Generate 2D mesh->Generate (Fig. 6.).

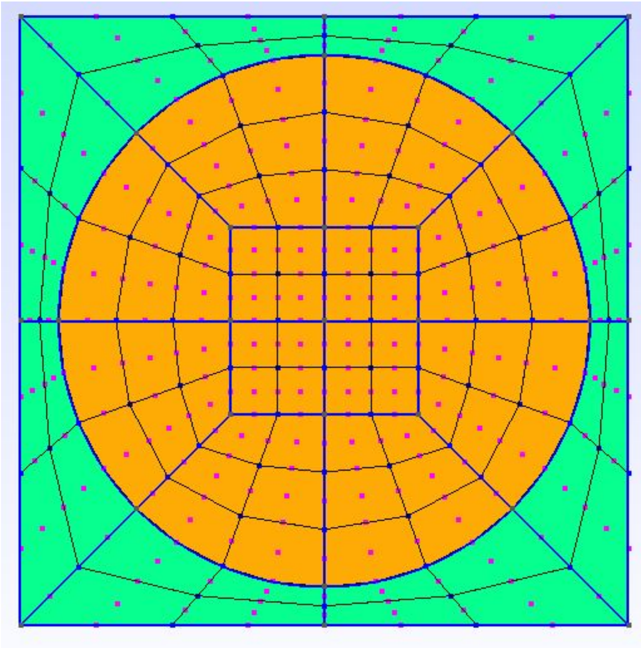

Fig. 6

* Click SwiftComp->Homogenization->Solid model. Keep the default parameters and click save and run. The homogenization results will automatically pop up (Fig. 7.).

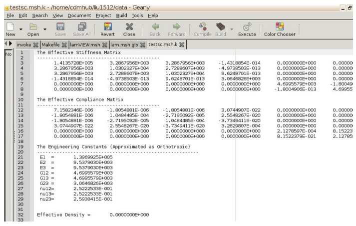

Fig. 7

2. step 2

- Click SwiftComp->Static failure->Input failure constants. Assign failure criterion to the matrix first (Fig. 8.) and input the failure constants (Fig. 9.). Repeat this step to define the fiber failure constants as shown in Fig. 10 and 11. Note that the fiber is non-isotropic material and we also assume some fictitious strength constants with big numbers.

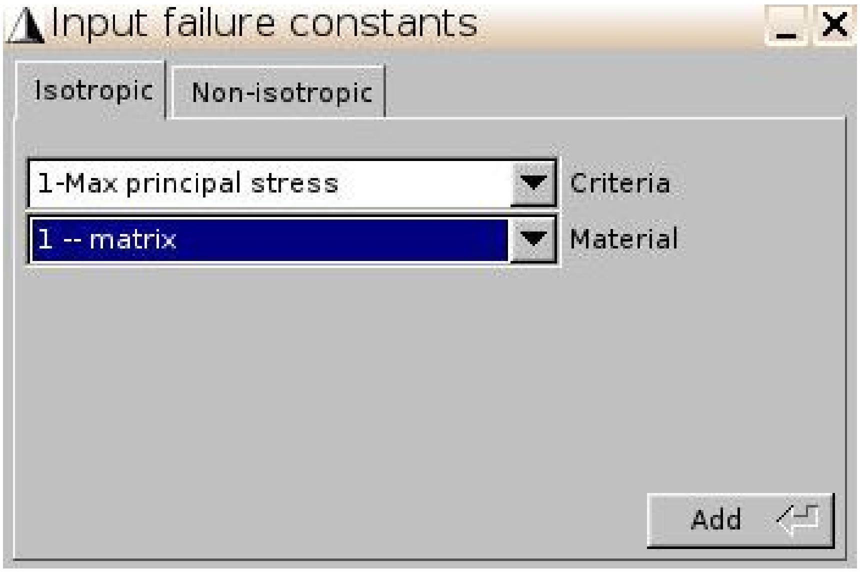

Fig. 8

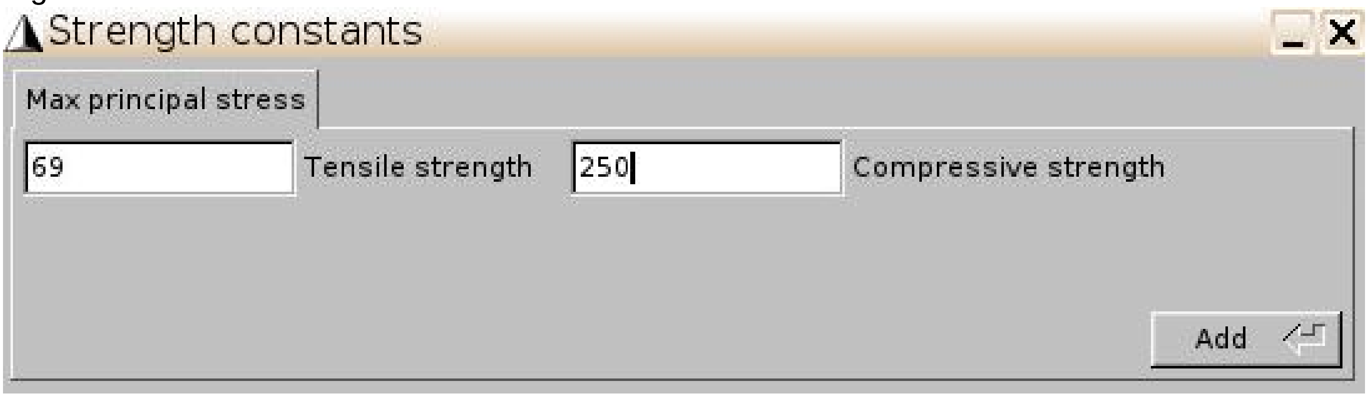

Fig. 9

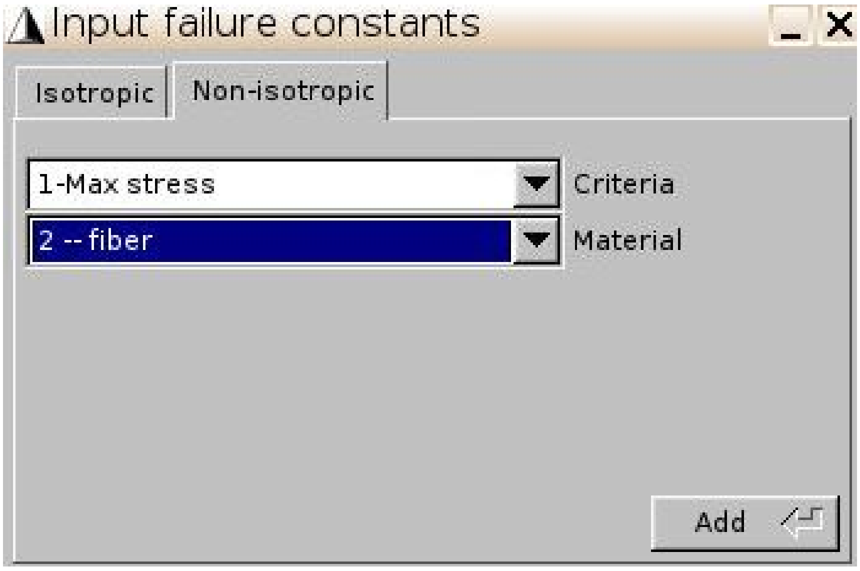

Fig. 10

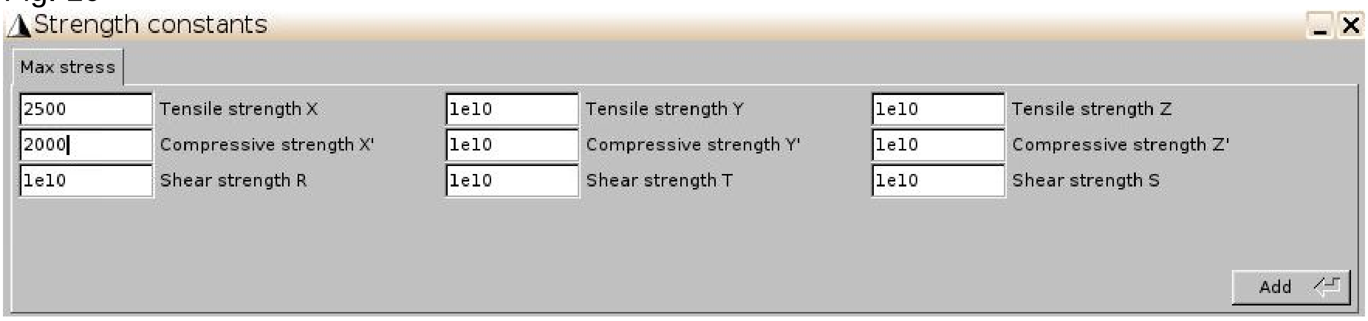

Fig. 11

- Click Effective strength constants and select stress-based failure criterion. Click run. The effective failure strength constants for this fiber-reinforced unidirectional composite is obtained as shown in Fig. 12.

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Initial Failure Strengths: Positive Negative
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       1.5188224E+003      1.2150579E+003
       5.2647021E+001      1.9075007E+002
       5.2647021E+001      1.9075007E+002
       6.1353391E+001      6.1353391E+001
       4.8869771E+001      4.8869771E+001
       4.8869771E+001      4.8869771E+001
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Fig. 12

References

1. Liu, X., Gasco, F., Goodsell, J. and Yu, W., 2019. Initial failure strength prediction of woven composites using a new yarn failure criterion constructed by deep learning. Composite Structures, 230, p.111505.