A TRANSFER LEARNING BASED STRATEGY TO STUDY BIAXIAL COMPRESSION FAILURE OF CERAMIC FOAM

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Motivation

Developing neural network based constitutive models that predict nonlinear fracture behaviour of heterogeneous materials require large amount of training data. Generating it through FE simulations is computationally highly expensive which limits the use of such models.This expense depends on the size of the representative volume element. The larger the size, the much costlier it is to generate data. The idea in this work is to utilize the knowledge from less expensive training data generated from smaller sized volume element to better equip the neural network trained on larger sized (representative) volume element in predicting the material response.

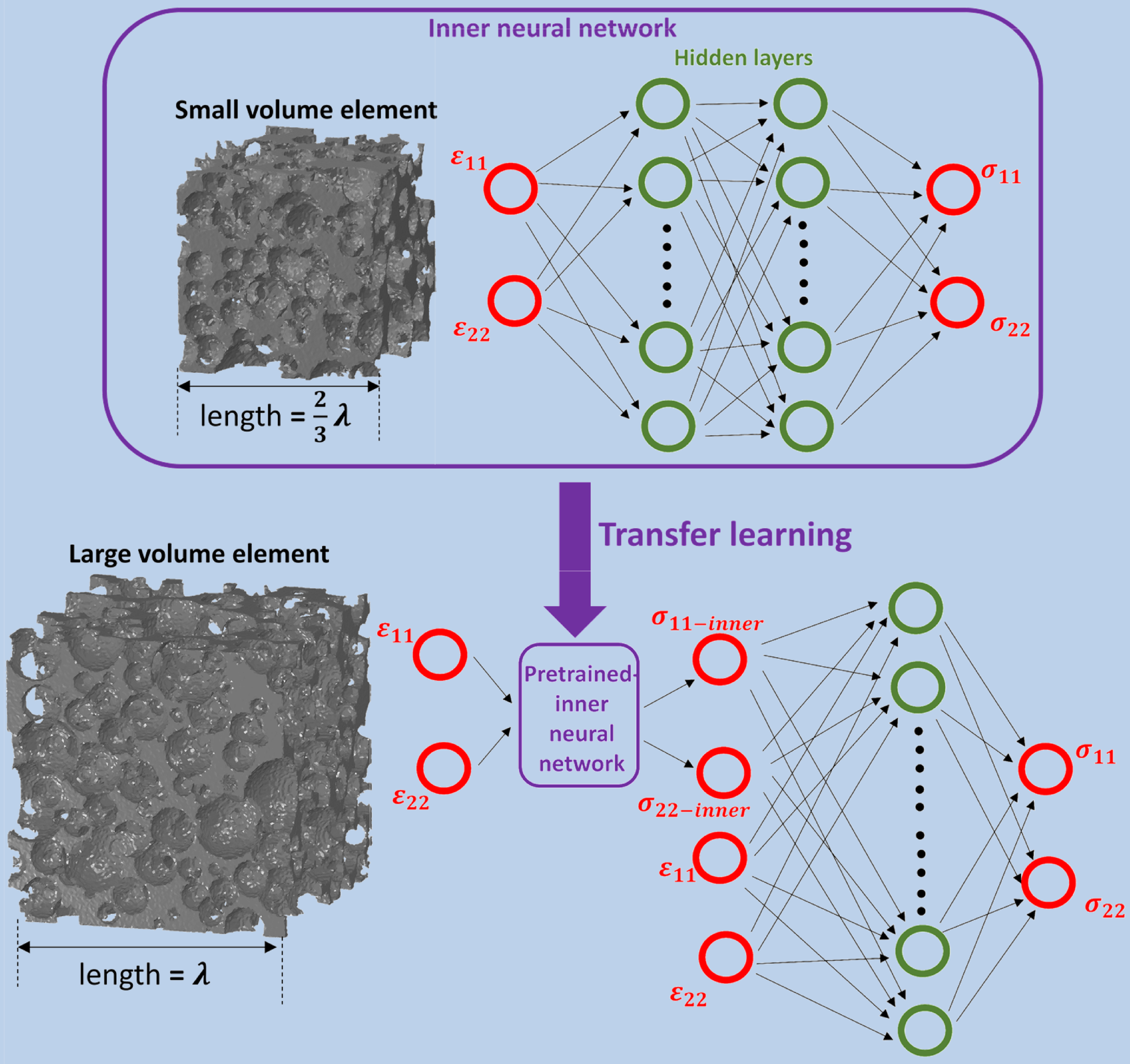

Fig. 1: Hybrid neural network – A feed forward neural network that has another pre-trained neural network embedded in it.

Problem statement

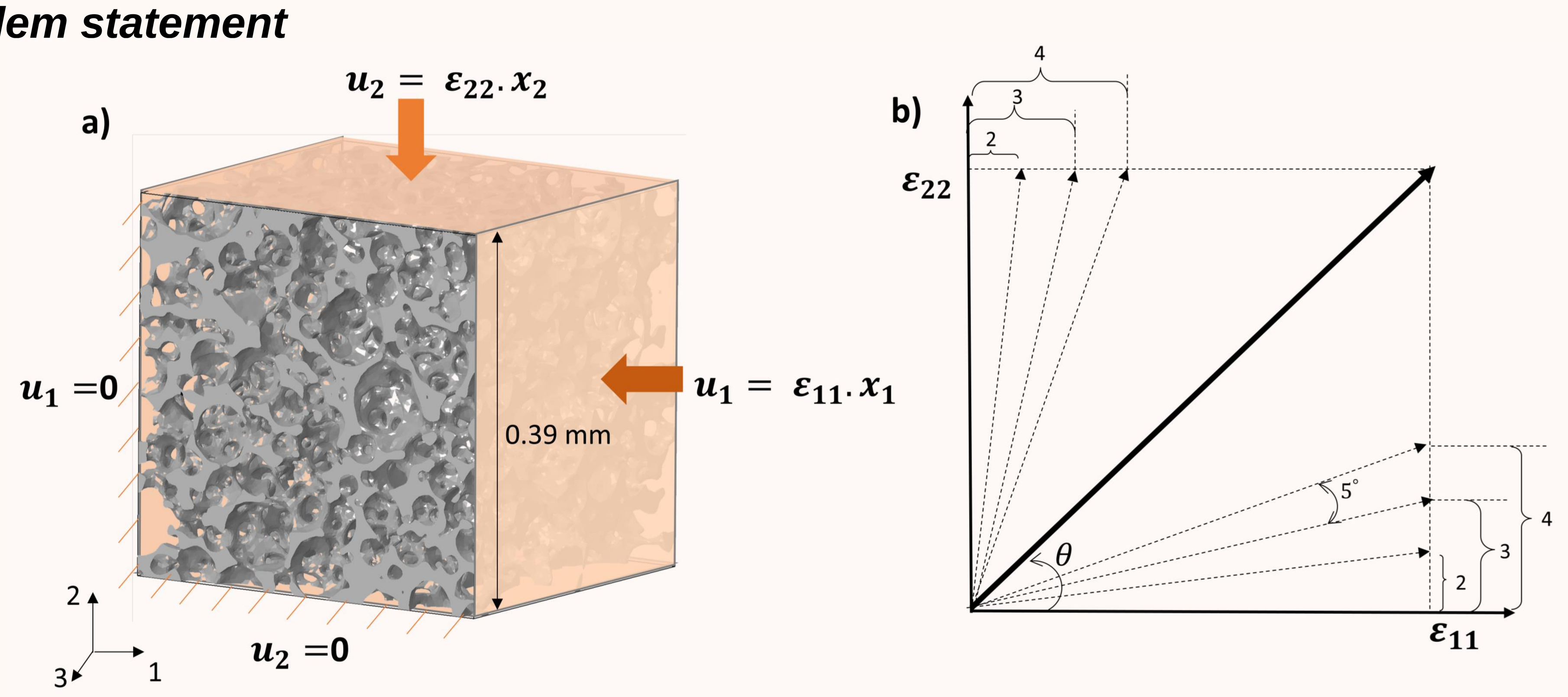

Fig. 2: a) A ceramic foam volume element (large) subjected to biaxial compression; b) training datasets for neural network.

FE simulation is conducted by applying macroscopic monotonic compressive strains in two orthogonal directions and calculating macroscopic stress (refer Fig. 2a).

FE simulation results of the large volume element

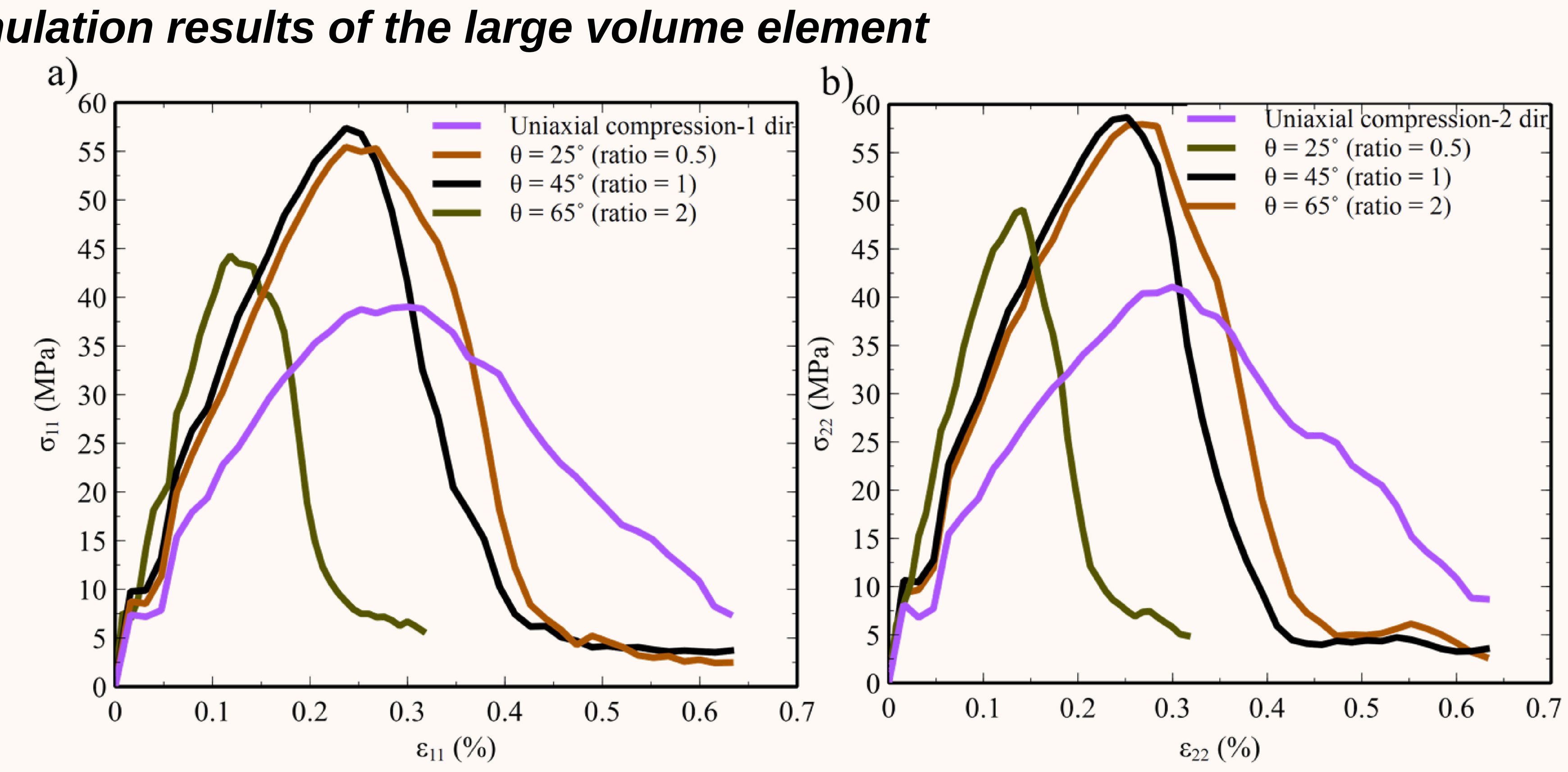

Fig. 3: Stress-strain curves from FE simulations of large volume element for load cases of uniaxial compression along 1 and 2 directions and for biaxial cases of $\theta = 25°, 45°, 65°$.

Training data for Neural networks

The two macroscopic strains are related by a ratio defined by the tangent of the angle as shown in Fig. 2b. The data points in the simulation strain-stress curves form the training data for neural networks.

Set No.	*Training datasets:*
1	uniaxial compression along 1 and 2
2	set 1 + training data : $\theta = 5°, 85°$
3	set 2 + training data : $\theta = 10°, 80°$
•	
•	
9	set 8 + training data : $\theta = 40°, 50°$

Test dataset: test data: $\theta = 45°$

Hybrid network
Transfer learning based model shown in Fig. 1

Outer network
A standard feed forward neural network trained only on data of larger volume element – similar to neural network shown in violet box in Fig. 1

Prediction of outer and hybrid neural networks

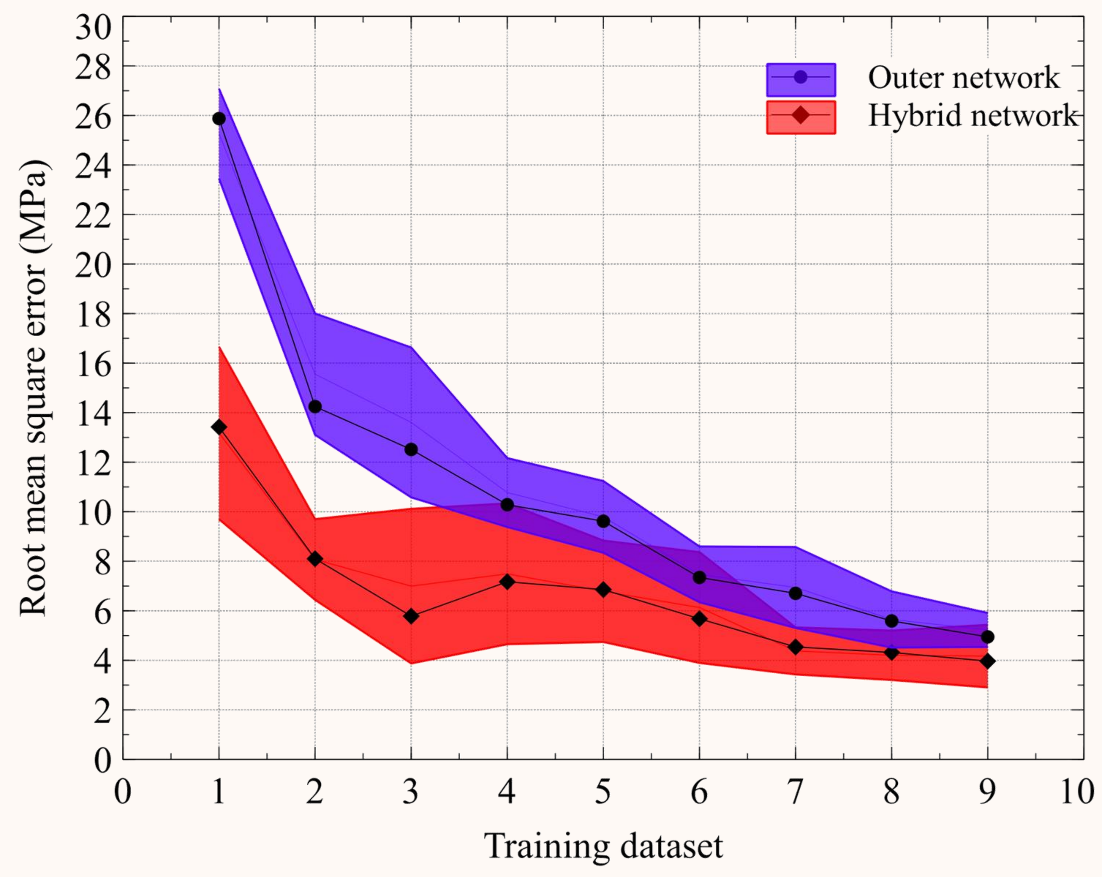

Fig. 4: Root mean square error of outer network and hybrid network for training datasets 1 to 9. The shaded regions indicate extreme values obtained by repeating the neural network training 20 times for different weight initializations.

Comparison of prediction (test dataset) of hybrid neural network and outer neural network with actual FE results

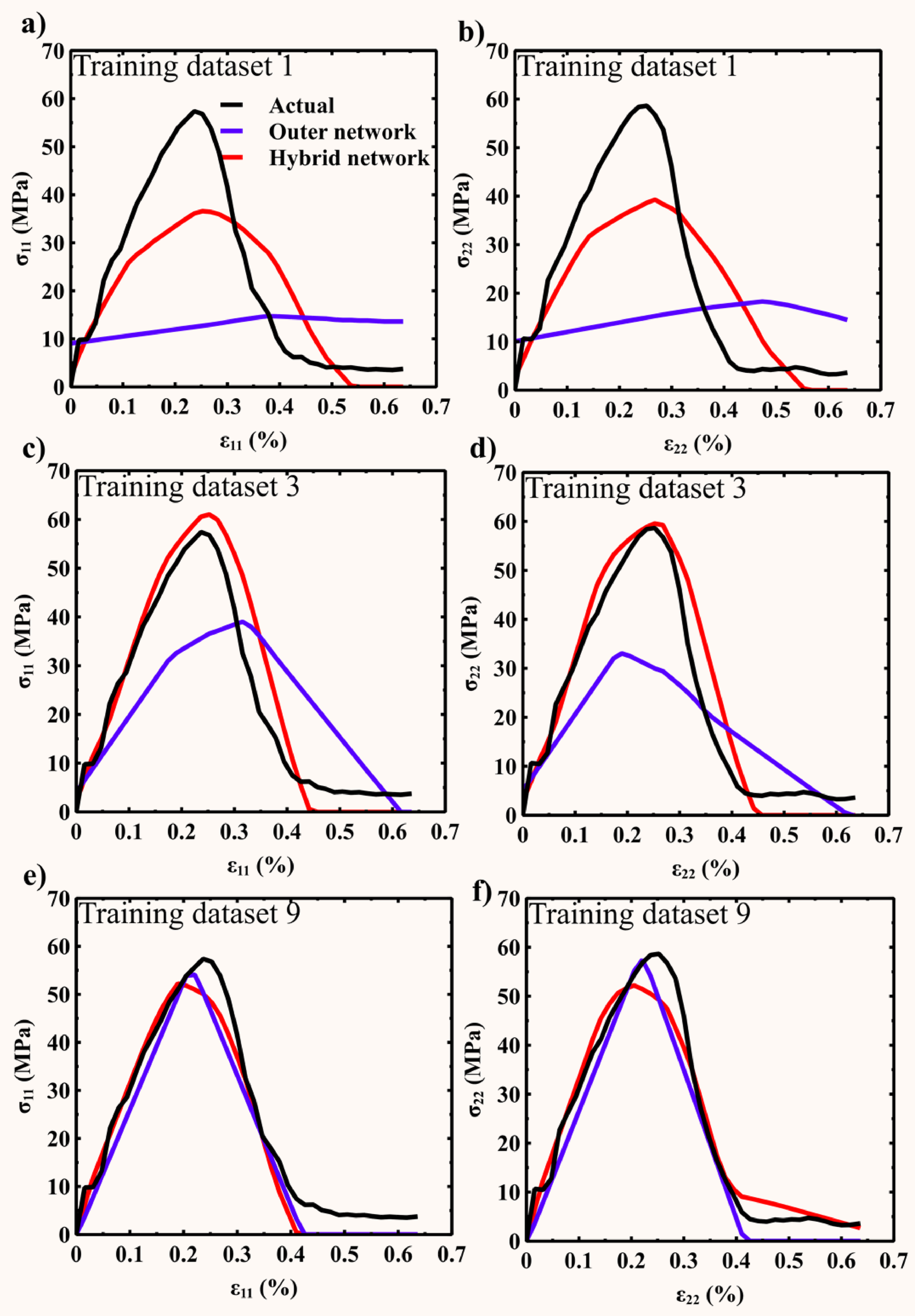

Fig. 5: Prediction of stresses at $\theta = 45°$ by hybrid and outer neural networks trained on datasets 1,3 and 9 with actual FE results.

Conclusions

1. The work demonstrates that studying volume elements of smaller size and then transferring the knowledge learned from them to neural networks of larger (more representative) volume elements increases the predictive ability of neural networks.
2. Since generating training data on smaller volume elements is computationally cheaper, this strategy can lead to better neural networks that require less amount of expensive training data.

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