COMPUTATIONAL MECHANICS 2019
35th conference with international participation
Srní
November 4 - 6, 2019

Loading condition monitoring on trusses applying a machine learning approach with training data of a finite element model: A study case

H. A. Tinoco[a,b,c], C. I. Cardona[a]

[a] Experimental and Computational Mechanics Laboratory, Universidad Autónoma de Manizales. C.P. 170001. Manizales-Caldas. Colombia.
[b]Institute of Physics of Materials, Czech Academy of Sciences. Brno, Czech Republic
[c]Central European Institute of Technology - Brno University of Technology, Technická 3058/10, 61600 Brno, Czech

Structural health monitoring (SHM) techniques deal with the changes in the dynamic or static characteristics of the structures that affect its performance during the service [2]. Mainly, these techniques are based on vibrations, and their implementation includes complex integrated systems not addressed from the structural design. Despite the numerous applications of SHM, loading condition monitoring (application place, direction, and magnitude) is not a very implemented strategy in this engineering field. This paper presents a methodology to monitor the application of external forces on structures using a learning machine process and finite element analysis (FEA). In Fig. 1a is described the proposed monitoring methodology, which is applied to a truss structure to validate this study. The truss contains nine structural elements, and each one presents a piezoelectric transducer to measure the forces in their links, as illustrated in Fig. 1b. The real truss was modeled by means of a FEA (implemented in Matlab with truss elements) considering their mechanical properties and loading conditions, as observed in Fig. 1c. To simulate different loading conditions, a force F_S is applied in node 3 varying two parameters, angle β, and magnitude. This is carried out to establish a database using the internal forces (in each bar) obtained by FEA.

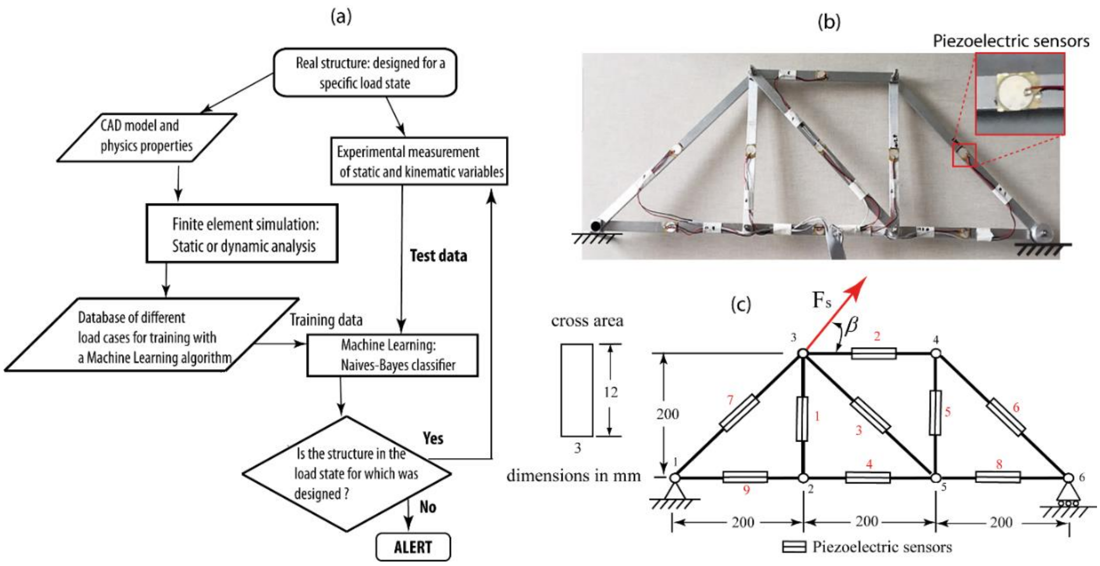

Fig. 1. (a) Methodology for SHM based on FEA and machine learning; (b) Experimental truss with piezoelectric sensors; (c) Real truss scheme for the finite element model

The applied force magnitude (F_s) was constrained to the limit state of the truss; it means that its maximum load produces an elastic behaviour in the simulation. In the experimental implementation, and before monitoring tasks, compensation values of forces were computed to normalize the electrical measurements with the finite element solutions; the results are evidenced in Fig. 2a. Naive Bayes classifier [1] was implemented for the machine learning process to monitor the force direction (known state) using the FEA solutions as a training database in the classifier. Several monitoring tests were performed with the experimental setup illustrated in Fig. 2b, but two only are reported in this study ($\beta = 150°$ and $\beta = 90°$). Fig. 2c shows the results obtained during the monitoring process (in real-time) when a force of 2.45 N was applied at the test directions. The training data means the number of simulations calculated corresponding with the divisions of β angle. For example; for $\beta = 150°$, the algorithm determined the correct β direction after 1600 training data, and for $\beta = 90°$ were necessary more than 3600 training data. This shows the importance of the database creation by FEA; however, β direction was monitored correctly in all done experiments. In a real context, the structures are designed for a known loading condition; it implies that not undesirable states could be monitored to emit early alerts. This is possible with the presented methodology since any loading state could be simulated and monitored during the service of the structure.

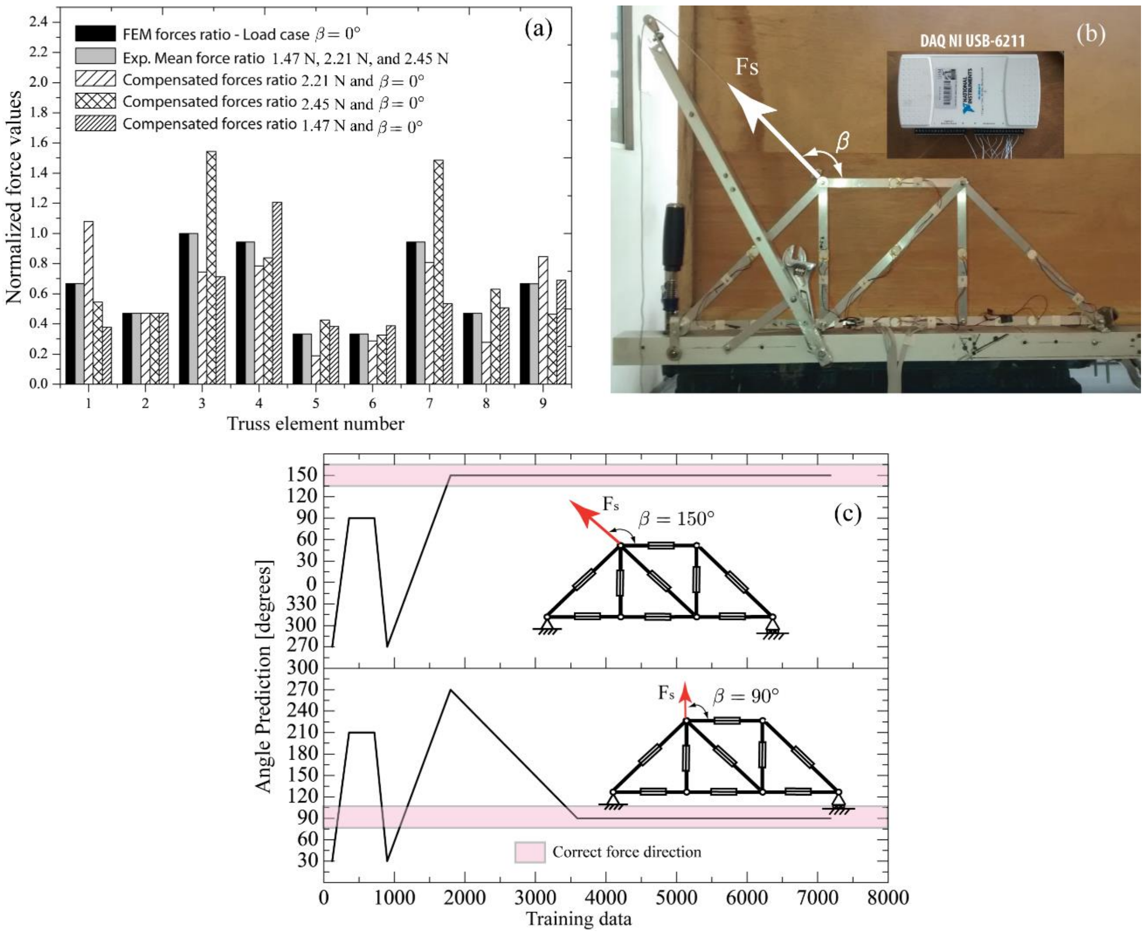

Fig. 2. (a) Electrical force normalization with FEA data; (b) Experimental application of the force in β direction; (c) Angle prediction for two experimental cases

References

[1] Friedman, N., Geiger, D., Goldszmidt, M., Bayesian network classifiers, *Machine learning* 29 (2-3) (1997) 131-163.

[2] Goyal, D., Pabla, B.S., The vibration monitoring methods and signal processing techniques for structural health monitoring: a review, *Archives of Computational Methods in Engineering* 23 (4) (2016) 585-594.