Use of BP Artificial Neural Network for Quantification of Defect in Multilayer Riveted Structure

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Abstract: Inspection of multi-layered riveted structures of aircraft and detection of subsurface cracks under fastener head is a major challenge in aviation industry. Magnetic field image (MFI) obtained with high sensitivity sensor array is widely used for detection of this kind of defects [1]. In MFI evaluation, one of the principal challenges is to determine the dimensions of defects from the measured data. It is a typical inverse problem which is generally considered to be nonlinear and ill-posed. Besides that, some of the difficulties of solving this problem include: i) defects embedded deep in the structure, ii) detection of small amplitude defect indications in the presence of dominant response signals from fasteners, iii) arbitrary and unknown orientation of defects, iv) effect of earth's magnetic field on weak magnetic field measurements with high sensitivity sensors.

In the paper, a method based on error back propagation (BP) training neural networks is proposed to estimate the defect dimensions [2]. Here backpropagation is used to train a multi-layered neural network such that it can learn the appropriate internal representations to allow it to learn mapping of MFI to dimensions of sublayer defects. For each sample of network training, we use experimental result of MFI obtained on top of fastener with machined defect as input vector. The dimensions of the machined defect are the expect output. The output error of the network is decreased along the gradient direction by adjusting the connection strength between the input node and the hidden layer node, and the connection strength and the threshold between the hidden layer node and the output node. In this work, a model based random interpolation is applied to generate enough number of samples for network training. Genetic algorithm is utilized to optimize the number of hidden nodes in the neural network. To demonstrate the feasibility of this algorithm, a 2 layered riveted aluminum sample with machined notches mimicking defects was fabricated and tested. Initial experiment results show that the genetic algorithm based BP neural networks have a high accuracy for quantifying of the dimensions of defects in multilayer rivet structure.

[1] C. Ye, Y. Huang, L. Udpa, and S. S. Udpa, "Differential Sensor Measurement with Rotating Current Excitation for Evaluating Multilayer Structures" *Ieee Sens. J.*, vol. 16, no. 3, pp. 782–789, Feb. 2016.

[2] Shifei Ding, Chunyang Su, "Application of optimizing BP neural networks algorithm based on Genetic Algorithm" *CCC*, pp. 2425-2428, July 2010