Final Technical Report

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Abstract of Work:

Neural network systems were evaluated for use in predicting wear of mechanical systems. Three different neural network software simulation packages were utilized in order to create models of tribological wear tests. Representative simple, medium, and high complexity simulation packages were selected. Pin-on-disk, rub shoe, and four-ball tribological test data was used for training, testing, and verification of the neural network models. Results showed mixed success. The neural networks were able to predict results with some accuracy if the number of input variables was low or the amount of training data was high. Increased neural network complexity resulted in more accurate results, however there was a point of diminishing return. Medium complexity models were the best trade off between accuracy and computing time requirements. A NASA Technical Memorandum and a Society of Tribologists and Lubrication Engineers paper are being published which detail the work.

Neural network systems were evaluated for use in predicting wear of mechanical systems. The goal of the project was to show that a neural network model could predict the long term mechanical performance of a system based on a short term test. The need for this technology stems from the increasing life requirements of satellites. In the past mission life was limited by electronic components, however their reliability has increased dramatically. In current and future satellites, mechanical components are increasingly responsible for life limiting failures. The focus of this project was on components with tribological interactions including bearings, latches, hinges, and gimbals. Due to the limited availability of data on these components, three typical tribological tests methods were modeled. These tests were the pin on disk, line contact rub shoe, and 4-ball method.

Neural network models are based on an architecture similar to the human neuron. Inputs are processed by a group of neurons which then produce one or many outputs. The inputs into each neuron are scaled by individual weight factors, summed, and processed by a transfer function resulting in the output value. The arrangement of connections of the neurons is referred to as the architecture. The simplest form of network consists of three layers, input, processing, and output. The connections in this type of network exist only in the forward direction, from the input to the processing to the output layer. More complex networks exists where additional processing layers are added, connections exist in both forward and backward directions, and multiple transfer functions are used. All networks utilized in this study were trained using the back propagation method. This method consists of dividing the existing data into training, testing, and verification sets. In the training process, the neural network is presented with

the input / output data of the training set which is used to adjust the weight factors of the inputs in each neuron. As each set of training data is presented, the network weight factors are adjusted and the output nears the correct output. As training proceeds data from the testing set is used to measure progress. This data is not used to adjust the weights, it is used to measure how much error exists between the network output and the correct answer. Training typically ends when the test set error is minimized. The network weights are fixed and the network is saved. The final step is to test the network using the validation data, which it has not seen. If the network is correctly trained the error in the validation data results will be similar to that of the test data results. A large discrepancy indicts that the network has not found a general solution which usually is a result of lack of sufficient data.

Three different neural network simulator programs were used to generate the networks. The first was used to model 3 layer feed forward networks. The second was able to model feed forward, and recursive networks up to 7 layers. The third can model advanced non layered networks. Initial tests using pin on disk data indicated that the second simulator would be the best choice for testing on the remaining tribological data. The first simulator did not offer the necessary options, and the third simulator was not needed with the limited data available. Thirteen different network architectures were evaluated for each type of tribological test. The best architecture for each was the Input Layer Dampened Recurrent Network which consisted of three feed forward layers and hidden feedback layer.

Fifty seven training sets and twenty five test sets of data were used in the rub shoe model. Inputs consisted of load, viscosity, sliding distance, friction coefficient, and temperature. The output was wear volume. Two types of lubricants, PFPE type K and PFPE type F, were used. The best correlation coefficient achieved with the test data was 0.84.

The pin on disk data consisted of 59 sets of training data and 11 sets of test data. The input variables were load, speed, sliding distance, temperature, friction coefficient, kinematic viscosity. The output was wear rate. Six lubricants were used including, superrefined mineral oil, easter-based fluids, n-hexadecane, synthetic paraffinic oil, glycol derivative, and modified polyphenyl ether. The correlation coefficient using the test data was 0.93.

Twenty eight training sets and three test sets of data were used for the four ball model. Pressure-viscosity coefficient, transient friction, initial length ratio, kinematic viscosity, molecular weight, vapor pressure, surface tension, viscosity index, load, and sliding distance were used as input variables. Wear rate was the output variable. Three lubricants were used, PFPE (type K), PFPE (type F), and PFPE (type D). The best correlation coefficient was 0.92.

This preliminary research indicates that neural networks can be used to model mechanical systems. The most pressing problem with modeling is obtaining the required amount of test data. As the number of inputs increase, the amount of training data required increases quickly. It can still be a useful tool if many short term tests can be used

as input data into a network which predicts long term performance of the mechanical

component.