Examples Class: Neural Networks

The Charpy toughness of a steel weld is one of the most important measures of the ability of a material to absorb energy on impact. If this toughness is low, then a material may shatter like glass and hence would be dangerous to use.

The toughness depends on temperature - things generally absorb less energy at low temperatures, and are said to be *brittle* at low temperatures. Toffee is a good example, brittle at low temperatures and ductile at high temperatures. The toughness is therefore frequently characterised by a transition temperature corresponding to a particular value of the absorbed impact energy.

In a recent paper, French [1] reported the temperature T_{27J} corresponding to a measured Charpy impact energy of 27 J as a function of the yield strength (YS), oxygen content (O) and the microstructure. The latter included the fraction of acicular ferrite (AF) in the as–deposited weld and a percentage of reheated microstructure (R) in the whole of the multipass–weld. Do not worry about the detailed meaning of the microstructure, simply note that these two kinds of microstructure greatly influence mechanical properties. Acicular ferrite grows on oxide particles in the steel and is good for toughness, whereas the reheated microstructure is bad for toughness.

The data from these experiments were analysed using linear regression as follows:

$$T_{27J} = 0.007(YS) + 550(O) + 0.034(R) - 0.31(AF) - 74, \qquad {}^{\circ}\mathrm{C} \qquad (1)$$

where YS is the yield strength in MPa, the concentration of oxygen in in wt%, and the reheated (R) and acicular ferrite (AF) are as percentages. The range of applicability of the equation can be gauged from Table 1, which contains information from 59 separate measurements.

The analysis indicated a standard error of $\pm 12\,^{\circ}\mathrm{C}$, with a correlation coefficient of 0.78. It is possible that a better interpretation of the data and associated uncertainties can be obtained using a non–linear method, which does not have an *a priori* assumption

Input element	Minimum	Maximum	Mean	Standard Deviation
Yield Strength (MPa)	360	630	516	55
Oxygen (wt%)	0.03	0.12	0.06	0.02
Reheated Material (%)	20	79	41	13
Acicular Ferrite (%)	5	86	54	15
Temperature at 27J (°C)	-88.0	-13	-54	18

Table 1: Characteristics of the measured parameters in the experiments conducted by French [1].

of the relationship between the variables, which accounts for the interactions between the variables, and which comments not only in the perceived level of noise in the output, but also on how the uncertainty of fitting depends on the particular region of input space where the prediction is being made.

The Task

1. Given the dataset, create a neural network model which has as inputs the yield strength, oxygen concentration, reheated material, and acicular ferrite. The output is the temperature T_{27J}. The smaller the value of T_{27J}, the better is the ability of the material to absorb energy on impact.
2. How does the perceived level of noise in the output correspond to that given by the linear regression?
3. Investigate the effect of the reheated microstructure on the transition temperature. How is the observed effect reflected in the σ_w value, which represents a partial correlation coefficient?
4. The linear regression equation predicts that T_{27J} can be minimised by reducing the oxygen concentration to zero and the acicular ferrite content to 100%. Does this make physical sense?
5. Given an acicular ferrite content of 80–100%, show that the neural network model correctly predicts that the best toughness does not occur when the oxygen concentration is zero.

REFERENCE

1. French, I. E. : *Australasian Welding Journal* **44** (1999) second quarter, 44–46.