DEVELOPMENT OF EMPIRICAL RELATIONSHIPS FOR METALLURGICAL DESIGN OF HOT-ROLLED STEEL PRODUCTS

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New Zealand Steel Ltd asked the Study Group to develop empirical relationships for their hot-rolled coil and plate products. These empirical formulae are intended to describe the relationship between various mechanical properties of the coil and plate products and input parameters such as processing temperatures at various stages of the operation and steel chemistry.

Once rolled these coils and plates are subjected to various tests of mechanical properties, which must have a certain minimum value for the product to pass. Only 0.2% of all coils fail but this is costly as the coils are worth about twelve thousand U.S. dollars each.

Such empirical relationships will allow the company to predict the mechanical properties of products when changes are made to the chemistry or process parameters and thus it could prove to be a useful tool to minimise the coil and plate failure rate or for the development of new products.

NZ Steel Ltd provided the Study Group with a large collection of data relating mechanical properties to the various input parameters of the hot-rolling process, which was analysed using multiple linear regression. A key measure of the analysis is the value of R^2, which should be as close to unity as possible. This is a measure of how well a variation of the input variables explains a variation in the mechanical properties.

Analyses were performed which showed that the mechanical properties do indeed depend linearly on the hot-rolling variables. Separate models were developed for each of the metallurgical properties. The model for Ultimate Tensile Strength (UTS) had the largest R^2 value of 0.94, Yield Strength (YS) was next with a value of 0.78, and Elongation had a value of 0.57.

A particular hot-rolled coil product (HA250, with a 2mm gauge) was analysed in detail. The experimental data, collected for 150 different coils, showed that the mean YS was only one standard deviation away from the YS minimum test requirement whilst the other mechanical properties were many standard deviations above their test requirement minimum values. Hence any failures of this coil product is likely to be the result of a YS test failure.

The multiple linear regression model was used to determine how much the YS could be increased by varying the steel chemistry and processing temperatures within the allowed ranges. It was found that the mean YS could be increased to about two standard deviations above the test minimum, an outcome which would dramatically reduce test failures for this product.

Of course, in reality, the optimisation problem is more complicated than this as more than one steel product uses the same chemical grade of steel. Hence optimisation of the relevant mechanical properties over a whole class of steel products needs to be done.