Investigating the Mechanical Properties of Case Carburised Steels

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Abstract

The objective of this study is to measure the material properties of the case section in case carburised steels. This data is to be used for the validation of a material model that can be applied at the design stage for heat treated components. Material properties are acquired through tensile testing of heat treated steel specimens. Tensile test specimens were uniformly heat treated prior to testing. A standard tensile test was conducted on these samples. Following this a grinding operation was used to remove equal amounts of the case from each side, and the same tensile test repeated. Specimens were tested with varying amounts of the case removed, including a specimen where the entire hardened layer was ground away. Data was acquired through the Zwick Z100 test machine, extensometer and an Imetrum Video Strain Gauge (VSG) system to monitor displacements and strain within the specimens. The data was then compared with a theoretical material model and used to validate a Finite Element (FE) model that incorporates a user defined Functionally Graded Material (FGM) parameter to apply the material properties as a function of depth within the case.

Introduction

Within literature and industry, the modelling of heat treated components is largely an ignored practise. Generally, components are designed using the raw material properties and the heat treatment is considered as an additional safety factor. By including material properties representative of the gradient in material properties found in case carburised materials at the design stage, performance gains such as mass reduction can be achieved. If applied to bearings and gears the overall efficiency of the system can be increased.

Typically, when a heat treatment is included in an FE analysis, it's limited to the proportional elastic limit and any case properties are included as a single layer. A more elegant solution would be to apply a varying material property over the hardened layer, thus better representing the heat treatment. Within most FE packages, numerous subroutines exist where complex loading or material characteristics can be applied. Within Abaqus (the software used for this project), a Used Defined Material (UMAT) can be applied to generate the user's desired characteristics however this is limited to two-dimensional control.

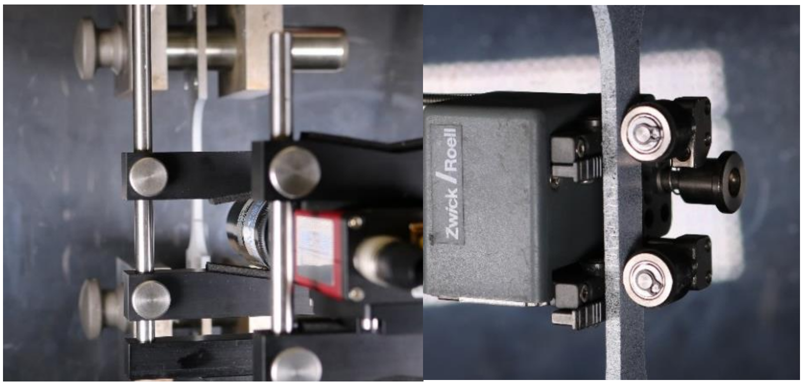

Figure 1: Tensile specimens being tested.

Within industry, it is commonplace that numerous software packages are used at the analysis stage and are usually determined by the preference of the Engineer. It is common for meshing software to create input files for an FEA solver to read. To tailor this research to industrial applications, a means of adapting the input file is the desired method to apply material properties. Naturally, the limit to the gradient of a material property is the element size, thus a balance with computational efficiency is also required.

Experimental Procedure

A tensile test in accordance with BS EN ISO 6892-1:2016 [1] was conducted with dog-bone specimens of case hardened S156 steel. Penetration of the heat treatment was such that only the flat faces were hardened. The exact heat treatment specification is not included at the request of the Industrial Sponsor. Specimens then have specific amounts of the case layer ground away and are quasi-statically tested until failure, thus generating stress/strain curves for each state, including varying amounts of the case-hardened layer. Included in the testing were specimens without heat treatment such that the core material properties can be quantified separately to the manufacturers' data sheet. A material model was then constructed from a Ramberg Osgood approximation that has been modified to be more representative of high strength steels [2].

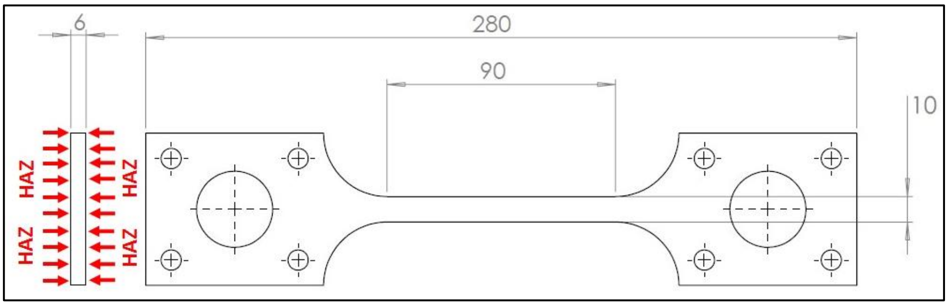

Figure 2: Tensile specimen dimensions (mm)

Experimental Results

Using the Ramberg Osgood approximation for each section of the case, a stress/strain curve was generated and deemed comparable to the physical data. In addition to this the strain characteristics post yield are to be analysed using the VSG data to validate a computational model.

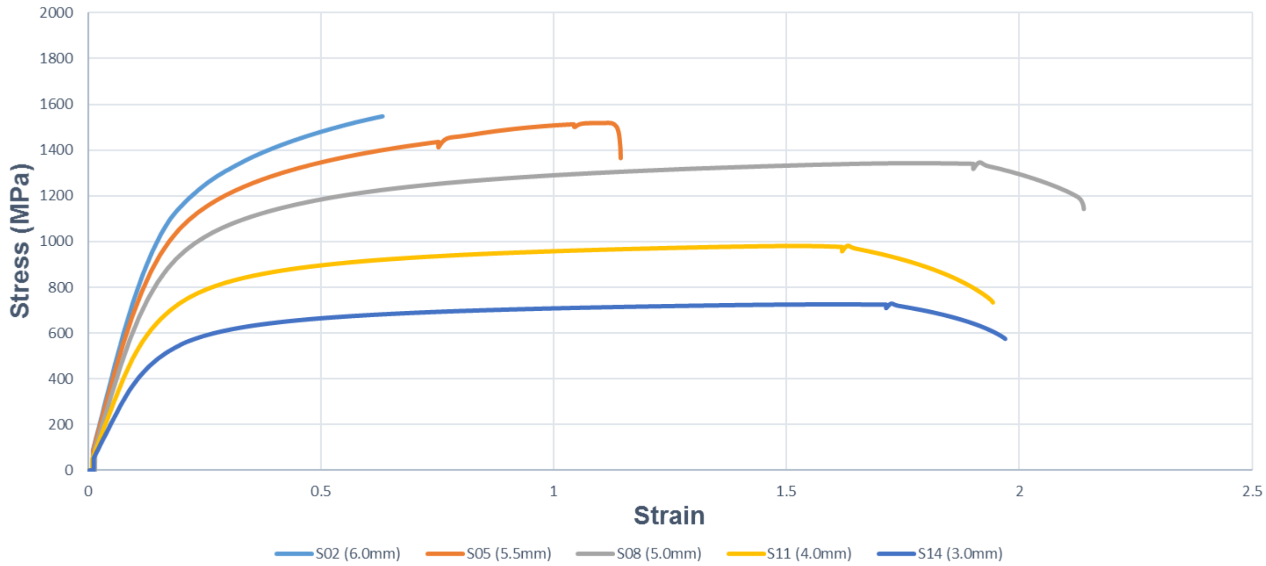

Figure 3: Stress/Strain curves from the ground tensile specimens.

Conclusions/Future Work

A Matlab script that modifies FE input files, assigns new material properties to various elements based on their geometry and depth from a surface is being developed which will be applied to tensile specimens and more complex geometries.

In future, the material data will be applied to more complex geometries such as gear involutes. The additional challenge of a depth dependent material property on a 3D geometry is significant but will significantly improve the accuracy of computational models.

References

[1]. BS EN ISO 6892-1:2106. (2016). 6892: Metallic materials, Tensile testing, Method of test at room temperature.
[2]. Rasmussen, K. 2001. Full-range Stress-strain Curves for Stainless Steel Alloys. The University of Sydney.