

Fatigue Life and Non-Linear Strength Predictions for Heavy Stamping Steel Parts

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ABSTRACT

Strength and fatigue life prediction is very difficult for stamped structural steel parts because the manufacturing process alters the localized material properties. Traditional tensile tests cannot be used to obtain material properties due to size limitations. Because of this, FEA predictions are most often “directional” at best. In this paper an improved prediction methodology is suggested. With a material library developed from standard homogenous test specimens, or even textbook material property tables, localized strength and plastic strain numbers can be inferred from localized hardness tests(1). The new method, using standard ABAQUS static analysis (not commercial fatigue analysis software with many unknowns), is shown to be very accurate. This paper compares the new process FEA strength and fatigue life predictions to laboratory test results using statistical confidence intervals. It is suggested that the improved prediction method can lead to better time-to-market, lower development costs, and improved design optimization.

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INTRODUCTION

Computer aided engineering (CAE) plays a very important role in product development and design validation. Analysis can replace physical testing to reduce time-to-market, decrease development costs, and improve design optimization. Confidence in the CAE analysis though, can be hindered by the simulation method, uncertainty in material properties, or even the repeatability of confirmation testing. Therefore, the word “directional” is commonly used in our engineering communications when discussing CAE results. CAE engineers are constantly trying to improve the accuracy of their results.

Stamped structural parts made from high strength low alloy (HSLA) steel are widely used in the automotive industry to optimize strength versus weight. The material properties of the stamped parts change and are localized during the stamping process, making accurate CAE simulation difficult. Traditional large tensile test specimens are difficult or impossible to obtain from local zones of interest. Without reliable material properties, it is very hard for FEA simulations to predict more accurate results.

A method for characterizing the material properties of structural steel stampings and converting those numbers into more accurate CAE analysis is presented in this paper. The examples used are structural stamped steel spring seats in MacPherson strut suspension applications. Most light vehicle strut applications use stamped spring seats that are similar in overall design, but vary considerably in

application dependent geometry and loading conditions. Once developed and validated, the FEA methodology used for similar stamped parts can be used on a wide range of specific applications.



Figure 1. Typical MacPherson strut with stamped lower spring seat

Based on material monotonic and fatigue test results, collected in cooperation with The University of Toledo, specific material models for analysis were developed. Instead of employing commercial fatigue analysis software, life prediction can be accomplished using traditional static analysis software like ABAQUS and more accurate results can be produced.

MATERIAL PROPERTY CHARACTERIZATION

1. Monotonic Material Properties

Mechanical properties for a wide range of carbon steel materials are available in published resources. Newer materials are more difficult to find. High strength low alloy steel (HSLA) is being used more often in light vehicle manufacture to optimize designs for weight versus strength. HSLA provides better mechanical properties, good resistance to corrosion, good formability and good weld-ability compared to plain carbon steel. It is easy to obtain its material properties by using traditional test methods on a suitable sized test specimen with homogenous properties(2). In some cases, though, processing methods change material properties and localize them into zones too small to provide standard tensile specimens.

Standard tensile and fatigue tests were conducted on homogeneous HSLA specimens covering a wide range of yield strengths. Typical results are shown in [figure 2](#), [figure 3](#), [figure 4](#).

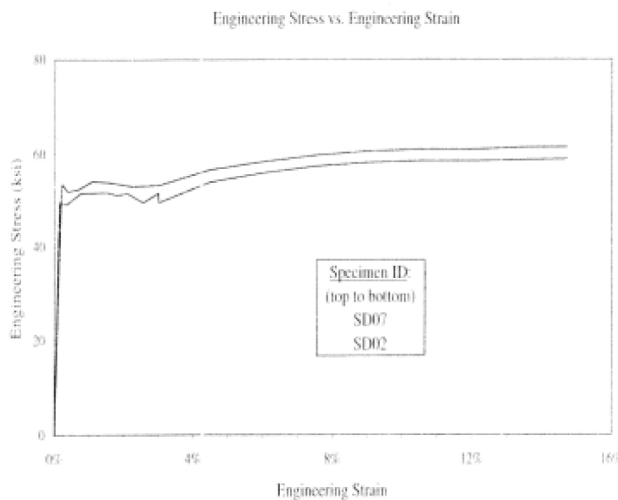


Figure 2. Stress-Strain Curve from Monotonic Test

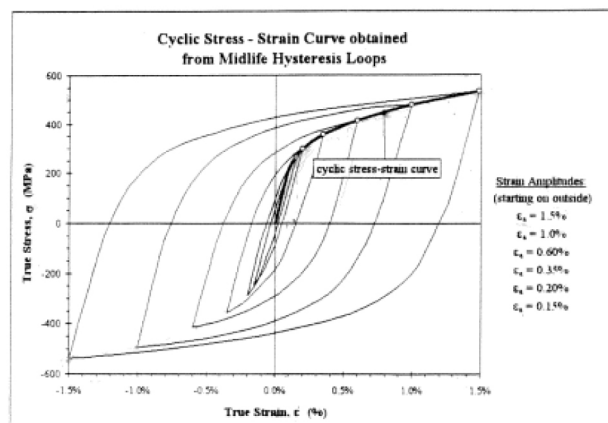


Figure 3. Fatigue Test Curves

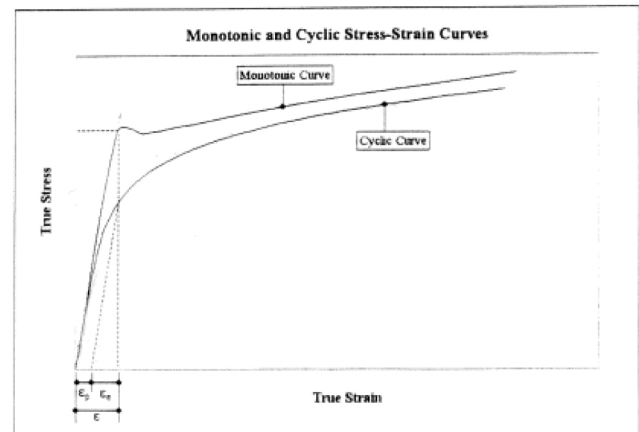


Figure 4. Monotonic and Fatigue Curves.

In [Figure 4](#), the fatigue curve is obtained by using the Ramberg-Osgood equation:

$$\frac{\Delta \epsilon}{2} = \frac{\Delta \sigma}{2E} + \left(\frac{\Delta \sigma}{2K'} \right)^{\frac{1}{n}}$$

$$\frac{\Delta \sigma}{2} = K' \left(\frac{\Delta \epsilon_p}{2} \right)^n \quad (1)$$

The test data for materials with different strengths were recorded and summarized for future use.

This data does not include corrections for localized material property changes associated with cold work in small curvature areas of a stamped part. It does not include stress concentrations.

Surface hardness can be measured in local areas of stamped structural parts without specimen size constraints. The relationship between the hardness and the material ultimate strength can be found in engineering handbooks. From testing on HSLA steels yielding in the 40ksi to 80ksi range, the difference between the ultimate strength and yield strength was found to be about 10ksi. Elongation at ultimate strength varies based on the ultimate strength or yield strength with a range of 8% to 15%. Lower strengths have the higher elongation numbers.

For stamped structural parts, surface hardness can be converted to ultimate strength. Since the estimated tensile strength is the material tensile true stress, it can be converted by using the following equation to obtain its yielding strength with the assumption of the material elongation (engineering).

$$\sigma^T = \sigma^E (1 + \epsilon^E)$$

$$\epsilon^T = \ln(1 + \epsilon^E) \quad (2)$$

Therefore, the baseline material properties (monotonic) are determined.