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On the characterisation of a generic hardening model beyond the onset of necking.

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Abstract

Finite element model updating is an inverse method which enables to arrive at a complete solution for the diffuse necking of a thick tensile specimen. The method relies on the characterization of a phenomenological strain hardening model. Therefore, the method's accuracy is limited due to the predefined character of the analytical function. Consequently, identifying a generic strain hardening model is proposed in this work. First, different possible generic functions to characterize the actual strain hardening behaviour of a material have been scrutinized. Next, the optimal identification procedure has been examined whereof finally, the flexibility of the model has been probed.

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Keywords: Post-necking, Strain hardening, FEMU, thick HSS

1. Introduction

Research about fracture mechanics is gaining more interest in recent years. The line pipe industry needs to estimate the amount of deformation the pipe can undergo before failure occurs [1]. Likewise, the automotive industry is interested to study the ductile fracture behaviour of clinched joints [2] and failure behaviour of advanced high strength steels [3]. Consequently, to simulate, predict and better understand these processes, the strain hardening behaviour in the post-necking region is required.

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To obtain the post-necking strain hardening behaviour, the strain hardening behaviour of the pre-necking region, obtained by the conventional method, can be extrapolated. However, no guidelines are available to extrapolate the pre-necking strain hardening behaviour. These extrapolation are also disputable because the post-necking yield curves are obtained without any deformation information from the post-necking region. and can lead to different and potentially unsafe results [4]. Another method was developed by Bridgman who proposed an analytical correction method to measure the post-necking strain hardening behaviour [5]. However, some parameters for the analytical correction method are difficult to measure and can induce substantial errors as well.

To cope with these problems, several authors have used Finite Element Model Updating (FEMU) [6, 7, 8, 9] or the Virtual Fields Method [10] to identify the strain hardening behaviour beyond the point of maximum uniform elongation. Both methods rely on the identification of a phenomenological model. However, due to the predefined character of the phenomenological model, the accuracy is limited to fit a prescribed analytical function to the actual plastic material behaviour. To create a more flexible and possible more accurate phenomenological model, a combination of analytical functions can be used [5, 9]. Although these combined functions could possibly result in a more accurate approximation of the actual plastic material behaviour, a predefined function is still characterised. Moreover, the user has the difficult choice between different phenomenological models to obtain the best fit for the actual plastic behaviour of the material under investigation.

In this work, the possibility of characterising a non a priori defined function on thick steels has been investigated. First, several non-prescribed analytical functions have been considered as possible generic function. An optimal generic function should be able to follow an existing phenomenological model, a random strain hardening model and should consist out of a minimum number of unknown parameters due to the use of FEMU in this work.

From these conditions, the optimal generic function has been selected . Different approaches for the characterisation of the optimal generic function are applicable, therefore, they have been scrutinised in a numerical concept study where FEMU has been employed to characterise a reference phenomenological strain hardening model. Finally, to probe the flexibility of the function and characterisation procedure, it has been used to identify a random strain hardening model.

2. Numerical concept study to differentiate the different possible analytical functions.

To investigate which non-predefined analytical function could possible approximate the actual strain hardening behaviour of a collection of materials, different analytical functions have been employed to fit a reference strain hardening model shown as the black solid line in Fig. 1, which has been identified recently on a 10 mm thick S690QL steel grade [11].

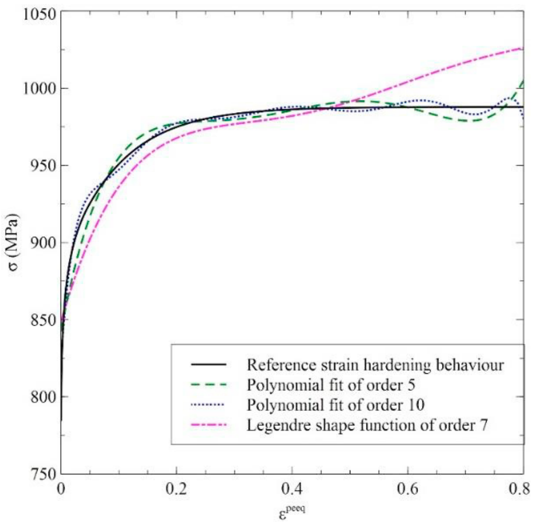

Fig. 1: Fitting of a reference strain hardening model by some generic functions

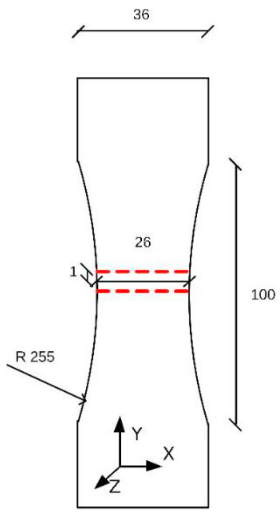

Fig. 2 Dimensions of the notched specimen