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Fatigue strength evaluation of linear flow split profile sections based on hardness distribution

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ABSTRACT

A concept to evaluate the fatigue strength of linear flow split profile's sections using a local strain approach based on the hardness distribution is presented. For this purpose established correlations between hardness and cyclic material properties are adapted to fit experimental results derived by fatigue tests on smooth, non-homogeneous specimens extracted from such profiles. For validation a numerical fatigue strength evaluation of a four-point-bending fatigue test of linear flow split profiles is presented using an elastic–plastic FE model with the material property distribution derived. The developed approach allows an improved estimation of the fatigue strength of the component analysed.

1. Introduction

Linear flow splitting is an innovative sheet metal forming process, which allows manufacturing bifurcated profile sections in an integral style [1]. The cold forming process leads to very high strains and steep strain gradients within the formed component. Thus, the material is work hardened non-homogeneously and its local material properties vary significantly. The material's fatigue strength is improved by the work hardening effect – but this advantage can only be utilised for optimised lightweight design if the improvement is considered in a corresponding fatigue strength assessment. Therefore, the knowledge of local fatigue strength parameters is required. But due to the large strain gradients it is impossible to extract specimens with approximately homogeneous material behaviour for fatigue tests. Hence, for numerical fatigue strength evaluation using local approaches it is necessary to derive a distribution of local cyclic material parameters within the linear flow split profile section, which is not only based on fatigue tests on specimens. Besides metallographic analysis results, hardness is the only material property, which can be derived with a satisfactory resolution in the profile's cross-section. In literature some correlations between hardness and fatigue strength properties have been published, e.g. [2]. These correlations contain experience about typical behaviour of fatigue strength parameters with respect to hardness. As a matter of fact, these correlations only give coarse approximations of the real material behaviour because they usually are not qualified to consider all influences on the cyclic material parameters. An improved accuracy can be achieved by adapting the correlations to specific fatigue test results of the treated material. This approach combines the experience contained in the estimation methods with material specific experimental fatigue information. The objective of the work described in this article is to derive a satisfactory estimation of local material parameters for a fatigue assessment of linear flow split profiles made from ZStE 500 using a local strain approach. The parameterization process presented here may be applied accordingly to other materials and other cold forming processes producing steep strain gradients.

2. Linear flow splitting

Profile sections are suitable components to realise cost-efficient light weight design. Typical examples known in the field of civil engineering are bridges and power poles. Furthermore, space-frame concepts are known in automotive engineering. A typical example is the aluminium car body of Audi A8, which is partially based on extruded aluminium sections [3]. Branched profile sections are used in product design as well. These types of profile sections are commonly applied in almost all areas of the engineering industry – well known examples are T- and H-profiles. Further on, there are many

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more applications, e.g. guide rails and multi-chambered tubes, where profiles with bifurcated cross-sections are used.

Depending on the product specifications, the manufacturing of branched profile sections is often realised by forming processes. In the field of cold forming, especially roll forming and bending of sheet metals are state-of-the-art. These processes often require the integration of additional joint patches, which are usually combined with a local sheet lamination [3]. Additionally, the potential for material strengthening due to the forming process is only utilised in a minor manner.

Linear flow splitting is an innovative cold rolling process, which tries to avoid the named disadvantages. It enables the forming of bifurcated sheet metal sections in integral design without needed joining operations, lamination of material or heat treatment of the semi-finished part. The manufacturing process is characterised by the application of a special tool system, which consists of an obtuse angled splitting roll and two supporting rolls. The generation of the bifurcation is based on a surface enlargement of the band edge, which is realised in a number of sequential forming steps (Fig. 1, [1]).

Linear flow split sections are characterised by an extensive local strain hardening. The local deformation of the microstructure is depicted in Fig. 2 for some locations within the profiles cross-section. The texture deformation in the splitting rolls contact area ("splitting centre") points out large plastic strains. With increasing distance to the splitting centre, the plastic strains at the upper side of the flange decrease, while at the flange tip no significant texture deformation occurs. At the lower side of the flange only relatively small plastic strains result from the forming process. To utilise the full potential for structural light weight design, development of suitable methods for fatigue analysis of the hardened section areas is a major challenge.

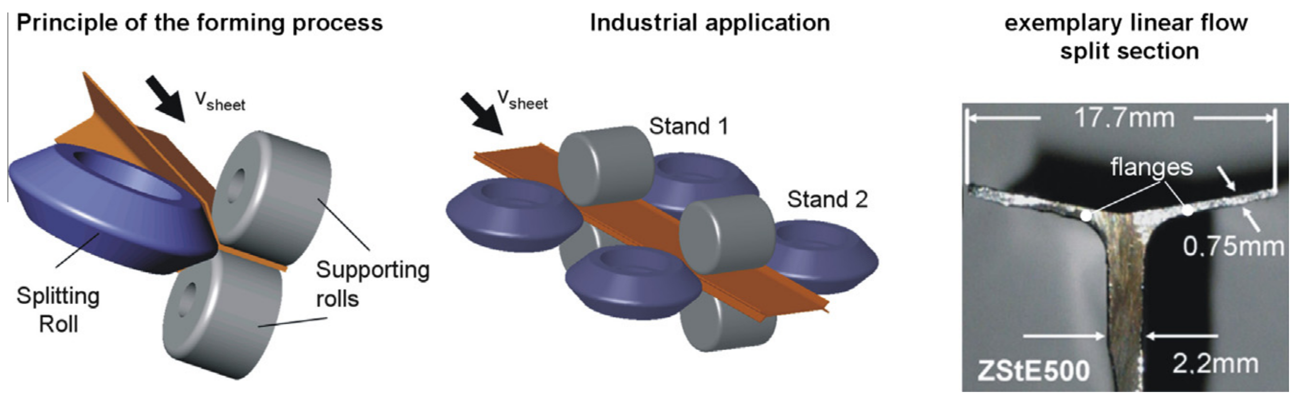

Fig. 1. Principle of the linear flow splitting process (left hand side), industrial application (centre) and an example for a linear flow split section prototype using ZStE 500 [1].

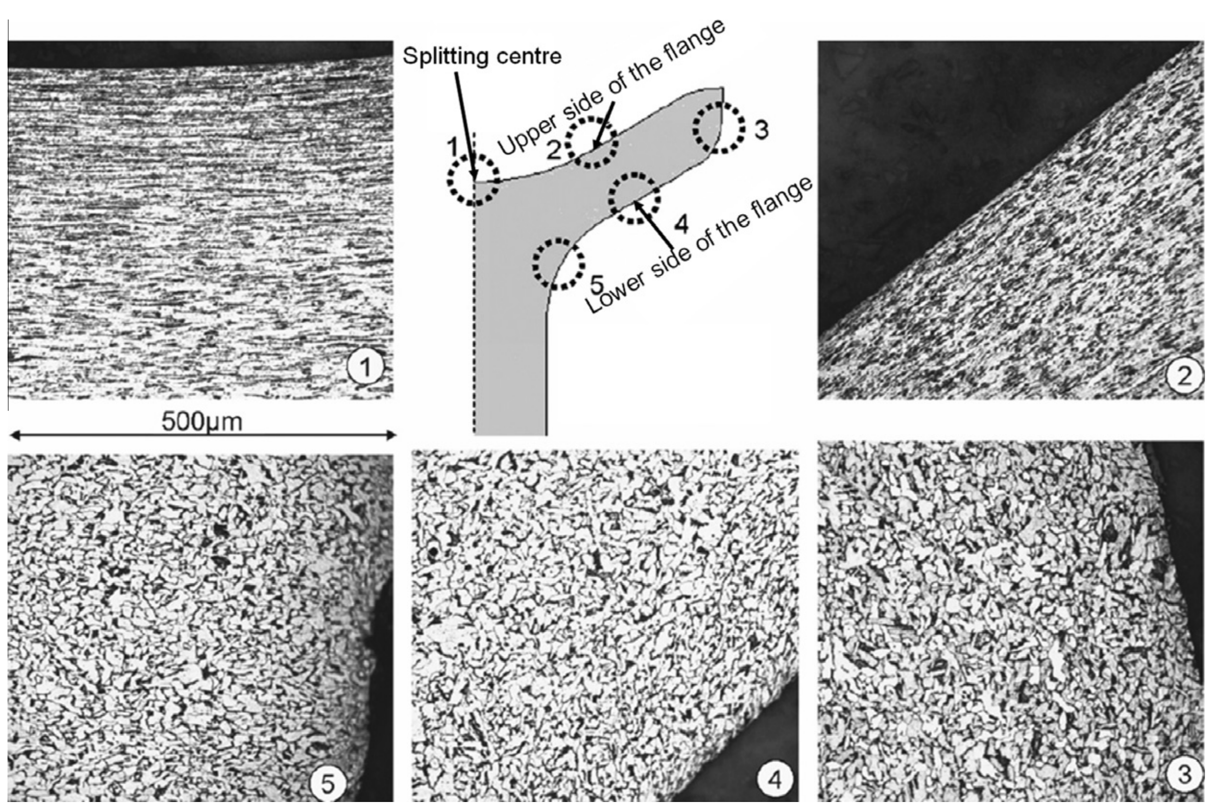

Fig. 2. Metallographic micrographs of chosen section areas (DD11) [1].