9th International Conference on Hot Sheet Metal Forming of High-Performance Steel — CHS² 2024
27–29 May 2024, Nashville, Tenn., USA
10.33313/512/B1002

Improved Fatigue and Fracture Resistance of 22MnB5 Steels With Added Nb and Mo

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Abstract

The addition of Nb and Mo in 22MnB5 steels has proved to improve mechanical properties and hardenability. It is a good strategy to increase the applicability of hot-stamped products in parts with high mechanical requirements, such as those subjected to cyclic loading, i.e. the vehicle chassis parts. This paper shows the improved fatigue and fracture resistance of thick 22MnB5 plates (4.5 to 8mm thick) with added Nb and Mo. The fatigue resistance has been analyzed in the high cycle fatigue regime and is related to the fracture toughness in the frame of elastic-plastic fracture mechanics. Such an approach is presented as a tool to evaluate the effect of manufacturing processes like welding on the fatigue behaviour of high-strength steels.

1 Introduction

Heavy-duty vehicles (HDVs), including lorries, buses, and coaches, are collectively responsible for more than 25% of the greenhouse gas (GHG) emissions generated by road transport in the EU. Despite some improvements in fuel consumption efficiency in recent years, these emissions continue to rise, primarily due to the increasing volume of road freight traffic. In 2023, as part of its efforts to fight the climate crisis, the European Commission proposed a revision of Regulation 2019/1242, which established CO_2 emission standards for HDV. This revision introduces stronger CO_2 emissions standards from 2030 onwards and extends the scope to include smaller trucks, city buses, long-distance buses, and trailers. The new targets aim to reduce CO_2 emissions per km from new HDVs by 90% by 2040, with intermediate goals for 2030 (-45%) and 2035 (-65%). HDV chassis components represent almost 35% of the unladen weight of a rigid truck (12 tonnes gross vehicle weight) and have a significant potential for lightweighting. However, such parts often require sheet thicknesses above 3 mm for safety reasons [1]. While high-strength steels are perfect candidates for such applications, their high tensile strength, combined with the need for large sheet thicknesses, results in high forming loads during the stamping processes.

Press hardening, initially developed for body-in-white (BiW) components, is an exceptional process for achieving complex geometries with high tensile strength while preserving component stiffness. This technology can be extended to chassis components, where the stamping loads during forming can be significantly reduced due to the elevated temperatures involved in the hot stamping process. Nonetheless, the thicker plates required by HDV chassis components, compared to BiW components, necessitate an adjustment of the process windows to obtain fully martensitic microstructure throughout the material thickness [2]. To address this requirement and to facilitate industrial implementation, a new thick hot-rolled press hardening steel (PHS) has been developed. This alloy incorporates niobium to promote a fine and homogeneous martensitic microstructure, along with molybdenum to enhance hardenability [3].

Chassis parts must resist high cyclic loads and deal with the unavoidable defects introduced during part manufacturing. As shown in previous works [4], the tolerance to manufacturing defects can be described by the fracture toughness of the material. It means that a good material candidate for lightweight chassis design has to present high fatigue resistance and high toughness. In this work, the fatigue resistance, and the fracture toughness of the standard boron steel 22MnB5 and the new alloy 22MnB5 NbMo have been analyzed and compared. Fatigue resistance was evaluated by using the rapid fatigue test known as the stiffness method [5] the fracture toughness was determined in the frame of elastic-plastic fracture mechanics through the essential work of fracture methodology. The aim is to investigate the impact of Nb and Mo additions on the fatigue and fracture resistance of the press-hardening steels to assess their applicability as lightweight materials for HDV chassis parts.