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Influence of joint configuration on the strength of laser welded presshardened steel

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Abstract

Presshardened steel is used in nowadays automotive production. Due to its high strength, sheet thicknesses can be reduced which results in decreasing weight of car body components. However, because of microstructure softening and coating agglomerations in the seam, welding is still a challenge. In this paper laser beam welding of 22MnB5 with varying energy input per irradiated area is presented. It is found that increasing energy input per seam length reduces tensile strength. Using a small spot size of 200 µm, tensile strength of 1434 N/mm² can be reached in bead on plate welds. In lap welds tensile strength is limited because of coating particles agglomerating at the melt pool border line. However, the resulting strength is higher when using several small weld seams than using one seam with the same total seam width. With three weld seams, each 0.5 mm in width, tensile strength of 911 N/mm² is reached in lap welding.

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1. Introduction

Nowadays, presshardened steel sheets are used in automotive production as Larsson et al. (2009) state. Naderi et al. (2011) investigated different boron contents in steel and found that boron alloyed steels obtain higher strength and ductility than steels which did not contain boron. Presshardened steels obtain a fully martensitic structure and therefore tensile strength of more than 1500 N/mm². This high strength enables a wall thickness reduction with simultaneously high crash resistance capability. However, machining this steel is a challenge. Nothhaft et al. (2012)

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carried out investigations regarding shear cutting of 22MnB5 with a sheet thickness of 1.5 mm and identified a 7° chamfer angle as suitable for a sufficient cut quality with simultaneously minimum stresses. Furthermore, investigations were carried out regarding joining. Especially plastic joining is challenging due to the high hardness of presshardened steels. Hahn et al. (2014) presented self-pierce riveting as a possibility of joining this steel to aluminum.

The weldability of 22MnB5 to itself and with DP980 was investigated by Jia et al. (2014). Tensile tests of butt joints showed failure in the HAZ in this investigation. Welding presshardened 22MnB5 results in a softening due to the martensitic grain structure. The hardness drops to about 300 HV according to investigations of Siltanen et al. (2015). When welding the quenched steel S960MC with a fiber laser was carried out by Salminen et al. (2015) using a 200 µm and 600 µm fiber core diameter respectively, hardness minima were significantly influenced by the laser spot size on the sheet surface. The base material hardness of about 380 HV0.5 was reduced to about 320 HV0.5 due to the heat input using a 0.71 mm laser beam spot. Doubling the spot size results in a hardness reduction to about 275 HV0.5.

Welding coated steels can be affected by the coating. Therefore, Geiger et al. (2009) started to develop a simulation to predict porosity and get a deeper understanding of a laser welding process with zinc coated steel. Kim et al. (2011) detected agglomerations of coating particles at the weld seam border line when carrying out lap laser beam welding of aluminum-silicon coated 22MnB5 sheets. The weld seam border line was determined as fracture location in tensile shear tests rather than the heat affected zone (HAZ). This was attributed to intermetallic compounds which were formed out of iron and aluminum.

According to Fahlström (2015) boron alloyed steel sheets are suitable for laser beam welding but distortion has to be taken into account. Welding U-shaped structures with a length of 700 mm resulted in distortions up to 8 mm.

Because of the high stiffness of these presshardened steels, precise positioning and welding preparation is a challenge. Misalignments and distortion can result in gaps during welding. For that reason Kügler et al. (2014) investigated a hybrid oscillating single-mode laser GMA welding process and its gap bridging ability. With this approach increasing gaps up to 1.0 mm can be bridged using a welding speed of 6 m/min without any adaptation of parameters during welding.

In investigations on spot welding, Schmidová and Hanus (2013) identified aluminum-silicon coating components and the resulting intermetallic phases after tensile testing on the fracture surfaces. Windmann et al. (2015) quote that removing the coating is beneficial for wetting the steel surface when joining 22MnB5 to aluminum. Furthermore, coating ablation by laser processing results in enhanced mechanical properties of welded crash structures out of 22MnB5 as Ehling et al. (2009) state.

2. Experimental

2.1. Material

For the investigations presshardened steel sheets out of 22MnB5 were used with a thickness of 1.5 mm. The coating, which prevents the steel from oxidation during presshardening, is an aluminum-silicon coating applied with 80 g/m². This coating interacts with the base material. As a consequence different layers with different aluminum contents are formed. This was intensely investigated by Windmann et al. (2013). In Fig. 1 these coating layers are exemplarily shown.