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A review on tailored blanks—Production, applications and evaluation

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ABSTRACT

Tailored Blanks is the collective for semi-finished sheet products which are characterised by a local variation of the sheet thickness, sheet material, coating or material properties. With these adaptions the tailored blanks are optimised for a subsequent forming process or the final application. In principle four different approaches can be distinguished to realise tailored blanks: joining materials with different grade, thickness or coating by a welding process (tailor welded blanks), locally reinforcing the blank by adding a second blank (Patchwork blanks), creating a continuous variation of the sheet thickness via a rolling process (tailor rolled blanks) and adapting the material properties by a local heat treatment (tailor heat treated blanks). The major advantage of products made from tailored blanks in comparison to conventional products is a weight reduction. This paper covers the state of the art in scientific research concerning tailored blanks. The review presents the potentials of the technology and chances for further scientific investigations.

1. Motivation

The weight of cars has constantly risen over the years since the overall dimensions were enlarged and a multitude of electric and electronic components was included to satisfy increasing demands concerning safety and comfort (Allwood and Cullen, 2012). As a higher weight leads to increased fuel consumption the body in white must be lighter to compensate the weight of additional components. Therefore tailored blanks are used which reinforce the body in white only at areas where a higher strength or stiffness is necessary. In the beginning the term "tailored blanks" referred to blanks that were manufactured from sheets with similar or different thickness by a welding process. As the technology developed further, also smaller patches were welded or adhesively bonded on top of a main sheet to achieve a local reinforcement. In addition, an approach was published to manufacture sheets with a continuous thickness transition via a rolling process. Parallel to these three principles the idea of adjusting the material properties by a local heat treatment was pursued. Nowadays, the concept of tailored blanks is therefore divided in four sub-groups – tailor welded blanks, patchwork blanks, tailor rolled blanks and tailor heat treated blanks, see Fig. 1. Tailor welded blanks and tailor rolled blanks contribute to lightweight design because no reinforcing blanks and less joining elements are necessary. Patchwork blanks in comparison lead to a process integration since blank and reinforcing patch are formed simultaneously in one tool. The use of materials with low density or high strength leads to a weight reduction, too. But the application of aluminium or high strength steels for the body in white is limited through the low formability (Kleiner et al., 2003). Using a local heat treatment, the forming behaviour of these materials can be improved so that they can be utilised for the construction of the body in white (tailor heat treated blanks). In addition to the weight reduction, the use of tailored blanks also leads to an improved crash behaviour. However, the application of tailored blanks is not only limited to the automotive sector but can also be found in other technical fields. This paper gives an overview about the four different kinds of tailored blanks concerning advantages and disadvantages, industrial application as well as challenges and research activities.

2. Tailor welded blanks

Tailor welded blanks are semi-finished parts that consist of at least two single sheets that are welded together prior to the forming process, see Fig. 2 (Zadpoor et al., 2007).

The weld seam can be linear or non-linear. Blanks with a non-linear weld seam are also called Engineered Blanks (ThyssenKrupp AG, 2013). The sheets can exhibit different mechanical properties, thicknesses or coatings. In series production the joining of the blanks is usually done by laser welding or mash seam welding though theoretically high-frequency, friction stir, electron beam or induction welding is possible, too (Zadpoor et al., 2007).

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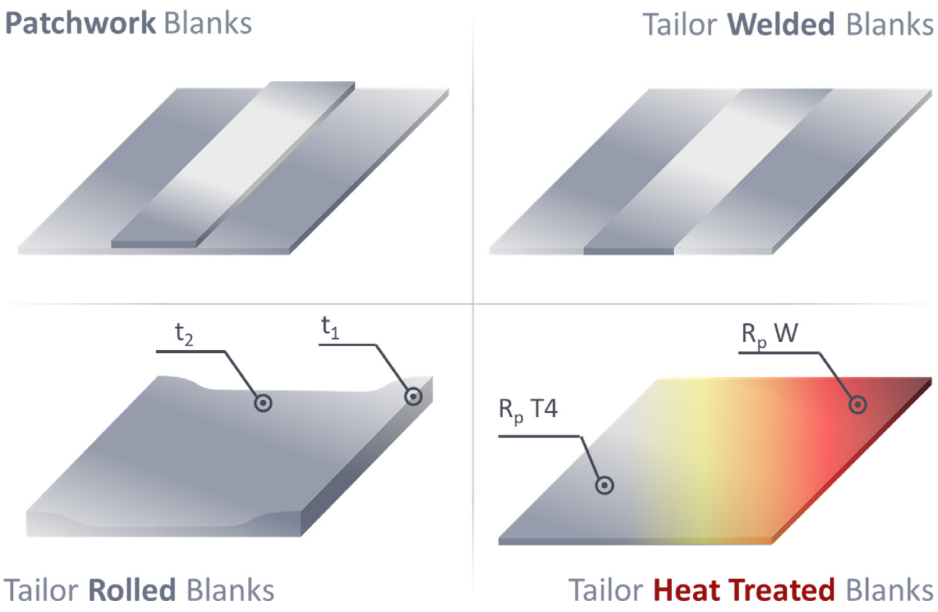

Fig. 1. Classification of tailored blanks.

Min et al. (2000) even suggest a combination of upset welding with flash welding to produce tailor welded blanks. Miyazaki et al. (2007) report that in the mash seam welding process less cutting accuracy of the blanks is required and high weld velocities are achievable. In contrast, laser welding produces a narrow weld seam and a small heat affected zone and leads to a weight reduction because no material overlap is necessary. Furthermore, even curved weld seams are producible. Either a CO_2- or a Nd:YAG-laser can be used for the welding process (Zadpoor et al., 2007). According to Staud et al. (2007) friction stir welding is mostly used to join “unweldable” materials like aluminium because the materials do not melt and solidify during the welding process.

Kinsey et al. (2000) state that by using tailor welded blanks an adaption to locally different loading conditions or other requirements in the part is possible. The use of a continuous weld line instead of weld spots leads to higher structural stiffness and better crash performance. Other advantages of the joining prior to the forming is the reduction of the number of the required forming tools, the higher accuracy in the forming process and the enhanced use of material which leads to less production costs. The most important advantage of parts made from tailor welded blanks is the weight reduction compared to conventional products. In the ULSAB project (ULSAB Programme Report, 2013) a car body was manufactured using tailor welded blanks and high strength steels. It could be shown that a 25% weight reduction could be achieved at no cost penalty. Disadvantages of tailor welded blanks are the high investment costs for welding processes (Mohrbacher, 2001) and the need for newly designed forming tools (Lamprecht, 2007). In this context Baron (1997) studied the production costs of tailor welded blanks in dependence of the welding method. He concluded that the welding method should be chosen regarding the product design to find the method that produces the lowest welding costs.

2.1. *Mechanical and microstructural properties, formability and failure of tailor welded blanks*

To characterise the mechanical properties of tailor welded blanks the properties of the weld seam must be evaluated. Therefore, Zadpoor et al. (2007) used tensile specimens which are reduced to the width of the weld seam in the gauge region, while other researchers like Lechler et al. (2010) also included the heat affected zone in the tensile specimen, see Fig. 3.

The mechanical properties like strength and ductility as well as the width of the heat affected zone and the formability depend on many parameters, namely material, welding method, weld line orientation, thickness ratio of the blanks and percentage of weld material in the cross-section of the specimen. In general, aluminium alloys show a lower strength after welding because their microstructure is changed. Due to the welding process the wrought structure is substituted by a cast structure with large equiaxed grains in the centre of the weld line and columnar grains in the adjacent areas caused by the temperature gradient, see Fig. 4. This leads to a decrease in ductility compared to the original sheet.

The chemical composition is preserved, but the alloying elements may be distributed more inhomogeneously than in the monolithic sheet. Furthermore the shape and the size of second particles are altered by the welding process and pores can be created in the material. For all these reasons, the mechanical values of tailor welded blanks scatter more than the values for a monolithic sheet. In non-heat-treatable aluminium alloys there is only a small decrease of the yield strength due to recovery effects while heat-treatable alloys show a more distinct drop of yield strength caused by overaging and resolutionizing (Davies et al., 1999). In contrast, tailor welded blanks made from steel exhibit an increase in hardness depending on the carbon content in the material and the welding method according to Zadpoor et al. (2007). Again the

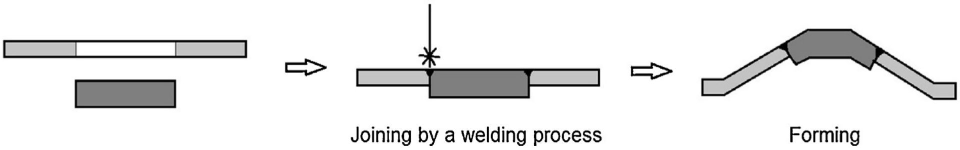

Fig. 2. Principle of tailor welded blanks (Lamprecht et al., 2005a).