Chapter 11
Fabrication of Tailor-Made Metallic Structures for Lightweight Applications and Mechanical Behaviour

R. Ganesh Narayanan
Department of Mechanical Engineering, Indian Institute of Technology, Guwahati, India

Perumalla Janaki Ramulu
School of Mechanical, Chemical and Materials Engineering, Adama Science and Technology University, Adama, Ethiopia

Satheeshkumar V.
Department of Production Engineering, National Institute of Technology Tiruchirappalli, India

Arvind K. Agrawal
https://orcid.org/0000-0003-2151-6404
Madanapalle Institute of Technology and Science, India

Sumitesh Das
Research and Development, Tata Steel Limited, Jamshedpur, India

Ajay Kumar P.
Department of Mechanical Engineering, Indian Institute of Technology Tirupati, India

V. Vishnu Namboodiri
National Institute of Construction Management and Research, Hyderabad, India

ABSTRACT

Tailor-made metallic structures are fabricated by welding, adhesive bonding, and mechanical joining methods. Here the aim is not only to fabricate lightweight structures, but also to develop novel methods of joining. Lightweight structures are advantageous in several ways including reduction of fuel consumption and vehicle emissions. Developing novel methods of joining is advantageous due to the possibility of joining of dissimilar materials, improved mechanical performance, and microstructures. In the chapter, initially, tailor-welded blanks (TWB) are introduced, and after that, fabrication of TWBs by laser welding, friction stir welding, and friction stir additive manufacturing are elaborately discussed. Some critical issues in modeling the deformation during fabrication of TWBs is also discussed. A brief account of mechanical behavior of adhesive bonded sheets and mechanical joining are presented in the later part.

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INTRODUCTION TO TWB AND FABRICATION BY LASER WELDING

Introducing TWB

Tailor Welded Blank (TWB) consists of metallic sheets with similar or dissimilar thickness, materials, coatings etc. welded in a single plane before forming. TWBs are formed like un-welded blanks to manufacture automotive components. By using this technology, it is possible to produce parts with varying mechanical properties, leading to component optimization (Pallett & Lark, 2001). Among all the welding methods, laser welding is used predominantly to TWBs as the process is quick and produces smaller welds. The main catalyst behind the sudden growth of TWB is to maintain the market share of steel material in the face of competition generated by aluminium alloys towards weight reduction (Pallett & Lark, 2001).

Some of the advantages of using TWBs in the automotive sector are, (1) scrap materials from stamping industries can be reused to have new stamped products, (2) by distributing material thickness and properties, part consolidation is possible resulting in cost reduction and better quality, stiffness and tolerances, (3) provides greater flexibility for component designers, (4) weight reduction of the product can be achieved and hence fuel consumption is lowered, and (5) improved corrosion resistance and product quality. Research shows that a 1% reduction in vehicle weight can result in a reduction of fuel consumption to 0.6 – 1% (Pallett & Lark, 2001). With these advantages, the potential of TWBs was soon recognized by steel industries and a consortium called Ultra Light Steel Auto Body (ULSAB) concept was then developed (WorldAutoSteel, 2020)

Some of the applications of TWB include center pillar, bumper, front door inner, and rear door inner (Irving, 1995; Prange et al., 1994). Nevertheless, the applications are not restricted to automotive sector, as construction industries also show encouraging pathway in using TWB as part of buildings (Pallett & Lark, 2001). Some applications of laser-welded TWBs are listed in Table 2.1(WorldAutoSteel, 2020). In the case of aluminium alloys, 5xxx for automotive inner body panels, and 6xxx for outer body panels are mainly used. Specifically, these include 6111-T4, 5754-O, 6061, 5182, 5052 and 5454. Some of the applications of aluminium TWBs made by laser welding, include deck lids, hoods, floor and door inner panels, side frame rails etc. (Das, 2000). Several applications in European and USA market, variety of welded sheets in the form of three piece blanks, non-linear weld lines, details on noise separation, and introduction of multi-piece blank lines can be noted (Rooks, 2001).

In laser welding, CO_2 and ND:YAG (Neodymium:Yttrium-Aluminum-Garnet) laser welding techniques are widely used to produce TWBs. A typical experimental setup is shown in Figure 1 (a) in which two steel sheets are clamped for CO_2 laser welding. Initially, a pointer is displaced at the interface of sheets to check the alignment of sheets with laser source. Figure 1 (b) shows the laser-welded TWB made of steel sheets. Edge quality is crucial and generally, machined edges are preferred for laser based TWB fabrication (Ono et al., 2004). Some of the problems encountered while welding Aluminium sheets are (i) excessive porosity and hot cracking of the fusion zone, (ii) poor coupling during laser welding because of high reflectivity of the metal, (iii) degradation of weld zone properties, and (iv) loss of alloying elements in fusion zone (Das, 2000). Of the two techniques, CO_2 based is accepted widely, safer and less expensive. However, it is subjected to high reflectivity of laser beam on the Al solid surface for a particular wavelength. ND:YAG laser welding has the advantage of uniform energy distribution than CO_2 laser beam over a wide area. It provides the ability to span over large gaps, while maintaining weld speed and quality.