Recent development in sheet metal forming of titanium alloys

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Abstract. Complex thin-walled titanium alloy components play a key role in the aircraft, aerospace and marine industries, offering the advantages of reduced weight and increased thermal resistance. The geometrical complexity, dimensional accuracy and in-service properties are essential to fulfil the high-performance standards required in new transportation systems, which brings new challenges to titanium alloy forming technologies. Traditional forming processes, such as superplastic forming or hot pressing, cannot meet all demands of modern applications due to their limited properties, low productivity and high cost. This has encouraged industry and research groups to develop novel high-efficiency forming processes. Hot gas pressure forming and hot stamping-quenching technologies have been developed for the manufacture of tubular and panel components, and are believed to be the cut-edge processes guaranteeing dimensional accuracy, microstructure and mechanical properties. This work intends to provide a critical review of high-efficiency titanium alloy forming processes, concentrating on latest investigations of controlling dimensional accuracy, microstructure and properties. The advantages and limitations of individual forming process are comprehensively analysed, through which, future research trends of high-efficiency forming are identified including trends in process integration, processing window design, full cycle and multi-objective optimization. This review aims to provide a guide for researchers and process designers on the manufacture of thin-walled titanium alloy components whilst achieving high dimensional accuracy and satisfying performance properties with high efficiency and low cost.

Key words: titanium alloys, hot forming, sheet forming, microstructure.

Introduction

Demand for low density and high strength materials in the aviation sector has expanded greatly due to ambitious carbon emission and fuel consumption targets. In order to meet these targets, manufacturers have focused on weight reduction via the use of lightweight materials [1]. In the aerospace sector, high strength structural components are made from titanium alloys. However, the forming of complex-shaped components from titanium alloys is time, energy and cost intensive. One promising solution to overcome these difficulties proposed in the literature is using the hot stamping process to form complex-shaped components from sheet metal with cold dies, and rapidly quenching the workpiece in the dies simultaneously. The hot stamping process promises to reduce the tool wear commonly found in conventional hot forming processes and be an overall more efficient and economical process when compared to conventionally used isothermal hot forming techniques [2].

Results

In this work, different techniques were proposed to form titanium components. Firstly, a novel hot stamping process for titanium alloys using cold forming tools and a hot blank was studied and a complex shaped wing stiffener panel component was successfully formed from rectangular-shaped TC4 titanium alloy blank at 900°C, demonstrating the great potential of investigated technology in forming complex shaped titanium alloys components (Fig. 1). Secondly, Fast light Alloys Stamping Technology (FAST) was proposed for titanium alloys, where fast heating of a two-phase titanium alloy sheet with equiaxed microstructure was employed [3]. Furthermore, a novel process including solution treatment-hot gas forming and stress relaxation aging was proposed to form titanium alloys component with high precision and improved strength simultaneously [4]. This technique enabled the successful forming of a a TA15 alloy nozzle and the final formed part obtained a diameter deviation less than 0.25 mm and post-form hardness increase of 8.6%. Finally, the qualified Ti-55 alloy component was successfully formed at 850°C by using hot gas pressure forming (HGPF) [5]. The microstructure of such part was slightly refined after forming, and the average post-form yield strength and ultimate strength were increased by 8.7% and 6.9%, respectively.

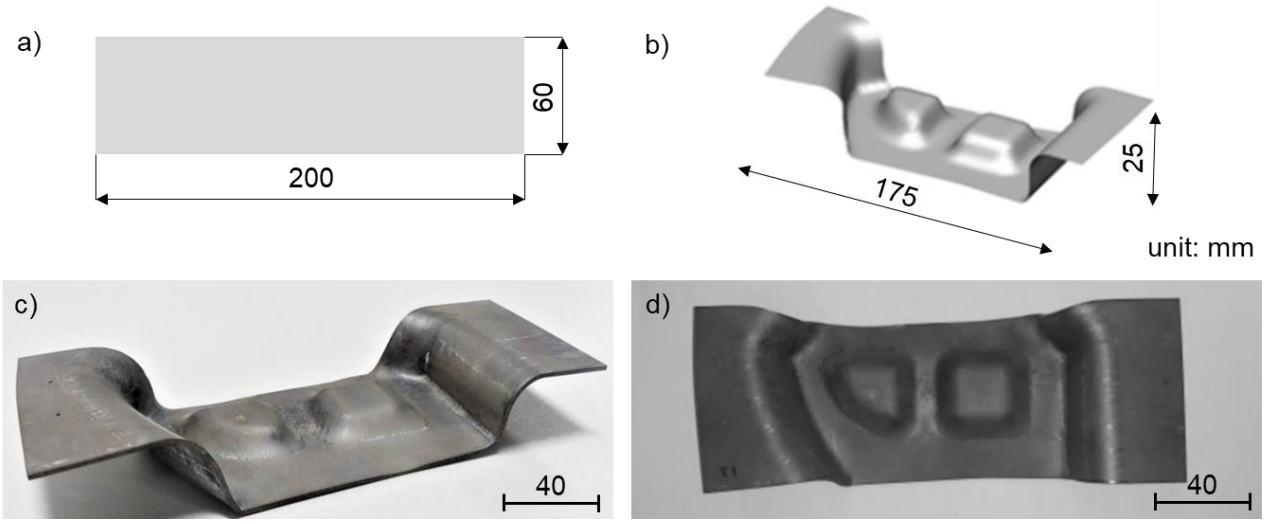

Fig. 1. Initial sheet metal blank dimensions (a); geometry of the wing stiffener component (b); the side (c) and the top (d) view of FAST formed wing stiffener.

Conclusions

Complex thin-walled components from titanium alloys could be efficiently formed under a new processing window involving lower temperatures and higher strain rates, to achieve a more uniform thickness distribution and higher component strength. Furthermore, the strain rates involved are up to ten times greater than superplastic forming or hot pressing, which could significantly improve the production efficiency, enabling the process to be a robust potential technology for volume production of high-quality titanium alloy components. It should be highlighted, that high-efficiency forming processing involves a variety of key technologies, such as rapid heating, rapid cooling and rapid pressurization. The current resistance heating and induction heating technologies have shown some applicability in rapid heating of titanium alloys. However, in order to realize the industrial application of high-efficiency forming, itis necessary to systematically develop high-efficiency forming equipment with digital and intelligent control system, so as to meet the needs of multi-objective parameter control.

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