Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 81 (2014) 44 – 53

Procedia Engineering

www.elsevier.com/locate/procedia

11th International Conference on Technology of Plasticity, ICTP 2014, 19-24 October 2014, Nagoya Congress Center, Nagoya, Japan

Some advances in plastic forming technologies of titanium alloys

H. Yang*, P.F. Gao, X.G. Fan, H.W. Li, Z.C. Sun, H. Li, L.G. Guo, M. Zhan, Y.L. Liu

School of Materials Science and Engineering, Northwestern Polytechnical University, 127 Youyixi Road, Xian, 710072, P.R. China

Abstract

To satisfy the ever increasing demands of high performance and light weight in high-end equipments, the titanium components are designed to have complex shape and specific performance. Research and development of advanced plastic forming technologies are of great importance to manufacturing these titanium products with low cost and short cycle. The local loading forming technology with advantages in reducing forming load, enlarging forming size and enhancing forming limit and precision through control of unequal deformation provides a feasible way to manufacture the high performance and light weight titanium components (large-scale, integral, complex, thin-walled) widely used in aircrafts and shows a good developing prospect. This paper presents the state of the art of local loading forming technology and its applications in manufacturing titanium components in the authors' laboratory, including the isothermal local loading forming of large-scale complex TA15 bulkhead, and heat rotary draw bending of large-diameter thin-walled titanium tube.

Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University

Keywords: High performance and light weight titanium components; Locl loading forming technology; Multi-scale through-process modelling; Unified control of shape forming and microstructure evolution; Through-process optimization and technology application

1. Introduction

The titanium alloy is an advanced light weight metallic material with high strength, low density and excellent corrosion resistance. It has been gaining extensive applications in aviation, marine and medicine. 70% of the

* Corresponding author. Tel.: +86-29-88495632; fax: +86-29-88495632.
E-mail address: yanghe@nwpu.edu.cn

1877-7058
Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University
doi:10.1016/j.proeng.2014.09.127

titanium is used for aerospace applications (Boyer and Williams, 2011). To satisfy the ever increasing demands of high performance and light weight in aircrafts, the titanium components are designed to have complex shape and specific performance. Plastic working is the most applicable forming method as it can tailor the microstructure while shaping. However, the titanium alloy exhibits relatively low ductility, low elastic modules, high yield stress and strong anisotropy, which reduce the forming limit and precision in plastic forming. Meanwhile, the microstructure of titanium alloys is sensitive to processing. It is difficult to control the microstructure evolution to obtain the desired service performance.

Much works have been carried out for fabrication of titanium components with high precision, high performance and low cost. Part of these studies focus on the plastic deformation behaviour and constitutive modelling of titanium alloys. Khan et al. (Khan and Yu, 2012; Khan et al., 2012), Nixon et al. (2010), and Ghosh and Anahid (2013) quantified the plastic anisotropy behaviour of titanium alloy under different loading conditions and established different anisotropic constitutive models. Khan et al. (Khan et al., 2007; Khan et al., 2004) successfully modelled the response of titanium alloy under various strain rates from quasi-static to dynamic loading regimes using a modified Khan-Huang-Liang (KHL) equation. Fan and Yang (2011) developed an internal-state-variable based self-consistent constitutive model considering solution strengthening, Hall-Petch effect, dislocation interaction and dynamic recrystallization, which is capable of predicting the flow stress and microstructure evolution simultaneously during hot working of two-phase titanium alloys. Another popular research field is the microstructure and texture evolution during deformation. Zhang et al. (2012) investigated the microstructure and texture development during cold deep drawing of CP-Ti and found that the deformation twinning weakens the initial texture by randomizing the orientations of crystals, especially for the recrystallization texture. Lin et al. (2013) carried out series of tensile tests to study the microstructure and texture evolution of a near-α titanium alloy at high temperature. They found that the initial textures were weakened or eliminated by the dynamic recrystallization process. Gao et al. (2012) obtained four types of microstructure (widmanstätten, bi-modal, tri-modal and basket-weave microstructure) under different temperature routes and analyzed their development processes in the isothermal local loading forming of TA15 alloy. These basic researches lay the theoretical fundament for the prediction and control of shape and microstructure during plastic forming of titanium component.

For the plastic forming technology of titanium alloy, higher precision, more force-saving, and higher efficiency have become the new development trends (Yang et al., 2008). Although traditional plastic forming technologies, e.g. free forging, isothermal forging and extrusion, etc., still play an important role in the plastic forming of titanium alloy, some innovative plastic forming technologies were proposed recently to satisfy the ever increasing requirements in performance and shape of new titanium components. For example, the severe plastic deformation (SPD) technology, including equal channel angular pressing, hydrostatic extrusion, accumulative roll bonding, etc., have been developed to produce Ultrafine-grained titanium alloys which possesses better comprehensive properties (Yang et al., 2011a). Besides, the local loading forming technologies including continuous local loading forming and intermittent local loading forming, e.g. isothermal local loading forming, tube bending, hot ring rolling and spinning, have attracted much more attention in recent years. This technology with advantages in reducing forming load, enlarging forming size and enhancing forming limit and precision through control of unequal deformation provides a feasible way to manufacture the high performance and light weight titanium components (large-scale, integral, complex, thin-walled) widely used in aircrafts and shows a good developing prospect (Yang et al., 2011b).

However, the local loading forming is a complicated process with coupling effects of multi-die, multi-parameter and multi-field, which brings challenges for the integrated control of shape forming and microstructure evolution, and the through-process optimization and robust control of forming process. To solve the challenges, Lab of Precision Plastic Forming from Northwestern Polytechnical University have done systematic and in-depth investigations on the multi-scale through-process modelling, regulation and control mechanisms of microstructure and macro-defects under unequal deformation and through-process optimization in local loading forming of titanium alloy component, and made some progress. The present paper reports these developments which not only enriches the advanced theory in plastic forming of titanium alloy, but also promote the manufacturing technology of high-end equipments.