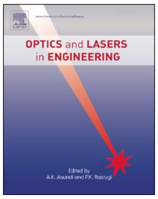
ARTICLE IN PRESS

Optics and Lasers in Engineering xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Optics and Lasers in Engineering

journal homepage: www.elsevier.com/locate/optlaseng



Laser-assisted bending of Titanium Grade-2 sheets: Experimental analysis and numerical simulation

Annamaria Gisario[a], Mehrshad Mehrpouya[a], Simone Venettacci[a], Massimiliano Barletta[b,*]

[a] Dipartimento di Ingegneria Meccanica ed Aerospaziale, Sapienza Università di Roma, Via Eudossiana, 18, 00184 Rome, Italy
[b] Dipartimento di Ingegneria dell'Impresa, Università degli Studi di Roma Tor Vergata, Via del Politecnico, 1, 00133 Rome, Italy

ARTICLE INFO

Keywords:
Laser
Bending
Sharp angles
Modelling
Finite Element Methods

ABSTRACT

External force laser-assisted bending of Titanium Grade-2 flat sheets to achieve sharp bending angles (> 140°) with small fillet radii is herein investigated. In particular, the influence of the operational parameters, laser power, scan speed, number of passes, on bending angles and fillet radii of the metal substrates is analysed. The experimental results show that shaping of the substrates can be performed with great reliability, being springback largely minimised in broad operational ranges. Exploratory Data Analysis (EDA) allows the design of first approximation technological models and, in turn, the development of 3d processing maps. Based on the experimental findings, numerical modelling of the bending process by the Finite Element Method (FEM) through ABAQUS/Explicit software is also developed. The numerical model is found to match with great accuracy the experimental results, being it also extremely flexible and responsive to the change of the operational parameters.

1. Introduction

Titanium alloys are of great interest in aerospace, automotive, marine and chemical industrial domains because of their good combination of high stiffness and mechanical strength to density ratio [1,2]. Nevertheless, titanium alloys are extremely difficult to process, being rather brittle, scarcely compliant to external loads and featuring high springback and work hardening at ambient temperature as well as high reactivity if processed at elevated temperatures [3,4]. In recent years, several alternatives to conventional forming of titanium alloys have been explored in the literature. However, incremental forming processes such roll forming [5], in which round tools minimise interfacial frictions between tool and workpiece, represent, at the present stage, the best route to achieve accurate shapes, limit springback and reduce the onset of defects or alterations in titanium. In contrast, incremental forming can be extremely slow. Other attempts include shock processing, which are implemented through a number of thermal or mechanical source [6,7]. Indeed, shock forming are often suitable only on small parts, might involve tricky operational procedures and be implemented only through extremely sophisticated set-up with expensive moulds and high-tech machinery.

Among non-conventional shaping technologies, laser bending is certainly considered an excellent alternative that has often prevented or reduced most of the aforementioned shortcomings in many other industrial segments, especially on steel and aluminium alloys. Laser bending belongs to the class of Laser Forming (LF), which has already found applications in manufacturing of tridimensional components in aerospace and automotive industries [8]. Laser bending can be therefore included among rapid prototyping techniques. It is a thermo-mechanical, non-contact and easy-to-control process, which is able to deform metal sheets by irradiating them with a concentrated laser beam. Recently, applications of laser bending assisted by external forces and, vice versa, external force laser-assisted bending have been attracting a remarkable interest [9]. It is a hybrid manufacturing technique where simple combination of laser irradiation patterns with a basilar holding/pressing device can allow the achievement of tridimensional shape on many metal alloys, included those characterised by sharp bending angles with small filet radii. These hybrid techniques are therefore reliable alternatives to conventional shaping process, which prevent expensive moulds, massive presses and big loads to be involved in the process [10].

As earlier mentioned, springback is the other main drawback in bending process which is always hard to control, since it might impair the final shape of workpiece due to lack of appropriate control [11,12]. Managing of springback is known to be extremely troublesome since it depends on multiple concurrent variables such as the material properties of workpiece (especially, yield strength, elastic modulus and hardening coefficient), interaction between mould and workpiece (especially, frictions) and design of the loading device [13]. However, in hybrid forming techniques, laser irradiation allows metal shaping

---

[*] Corresponding author.
E-mail address: barletta@ing.uniroma2.it (M. Barletta).

http://dx.doi.org/10.1016/j.optlaseng.2016.09.004
Received 29 January 2016; Received in revised form 14 August 2016; Accepted 10 September 2016
Available online xxxx
0143-8166/ © 2016 Elsevier Ltd. All rights reserved.

Please cite this article as: Gisario, A., Optics and Lasers in Engineering (2016), http://dx.doi.org/10.1016/j.optlaseng.2016.09.004

with lower typical loads, stress barriers in Heat Altered Zone (HAZ) and, therefore, a reduced impact of springback. Oppositely, the thermal flux to the material being bent can be accurately managed through the setting of laser parameters to avoid causing oxidation, affecting negatively metals microstructure or decreasing their mechanical and physical properties [14,15]. For this reason, empirical methods [16] and modelling analyses [17,18] can also be applied in shaping of metallic and non-metallic sheets by hybrid techniques to set the best ranges of the laser operational parameters and calibrate accurately the auxiliary machinery.

In this respect, the present work deals with the experimental analysis and numerical simulation by the Finite Element Methods (FEM) of an external force laser-assisted bending process of a Titanium Grade-2 alloy. The influence of the operational parameters such as laser power, scan speed and number of passes, on bending angles and fillet radii achievable by processing flat sheets are investigated. Experimental findings show that shaping of the substrates can be performed with good accuracy, being springback under control in a broad operational range of the laser parameters. Application of the Finite Element Method (FEM) through ABAQUS/Explicit software allows a reliable simulation of the bending process. Numerical results and experimental dataset are found to match well, with the numerical modelling being found also extremely flexible and responsive to the change of the laser operational parameters.

2. Experimental setup

2.1. Material and equipment

$50\times70\times1\ \mathrm{mm}^3$ flat slabs in commercially pure Titanium Grade-2 are cut from a $1\times2\ \mathrm{m}^2$ sheet by fine blanking. Laser assistance to shaping process is performed by a continuous mode high power diode laser (DL015, Rofin-Sinar, Plymouth, Michigan, USA), irradiating a beam with a wavelength of 940 ± 10 nm. The elliptical spot of the laser beam features a fast axis 1.2 mm long (the one which runs parallel to the direction of laser pattern) and a slow axis 3.8 mm long. Working distance is set equal to focal distance of the lens (32 mm), thus ensuring the best focalisation of the laser beam on the workpiece surface. A shield gas (argon) is flushed on the titanium sheets during laser processing to prevent oxidation of the highly reactive alloy at elevated temperature, as this could have an influence on size and thickness of Heat Affected Zone (HAZ) [19].

External force laser-assisted bending is, therefore, performed by clamping the workpiece through a tailor-made device. The machinery to perform the shaping process of the workpiece in combination with the laser source is reported in Fig. 1. The bending device is locked on a 1-axis CNC movement system to ensure constant and monitored speed during laser irradiation of the prescribed bending pattern on the workpiece surface. Kinematic of the bending device is schematized in Fig. 2 and, elsewhere, described in detail [9]. Briefly, it consists of a pneumatic piston and bending elements. The dynamic push of the pneumatic piston is converted through the deformable levers of the device to impress a torque on the substrate. The device allows the application of a uniform force on both the sides of the substrate to promote its bending along the direction of the laser pattern. During shaping, the workpiece is submitted to laser irradiation after setting the operational parameters (i.e., thermal source), while the application of the bending torque is concurrently ensured by the action of the pneumatic piston. The clamping device holds the titanium sheets during external force laser-assisted bending process. Synchronous action of the bending device and laser irradiation is ensured by an electric switching system.

To manage the laser irradiation of the workpiece through the subsequent laser passes, the 1-axis CNC movement system drives the laser head along the prescribed pattern. Yet, the pattern is 60 mm long, that is, 10 mm more than the workpiece width. The laser irradiation starts its prescribed pattern 5 mm before the closest workpiece edge. Then, it moves through the workpiece surface, stopping 5 mm after the farthest (opposite) workpiece edge. After that, the motion of the laser head is inverted, driving the laser spot along its way back to the starting point. This process is repeated for each laser pass in order to avoid concentrating too much power density in short time range on the edges of the substrate (that is, the portion of the substrate, which are known to be more sensitive to thermal alterations).

Fig. 1. Laser head and auxiliary bending device with the clamping device to hold the workpiece during external force laser-assisted bending process.

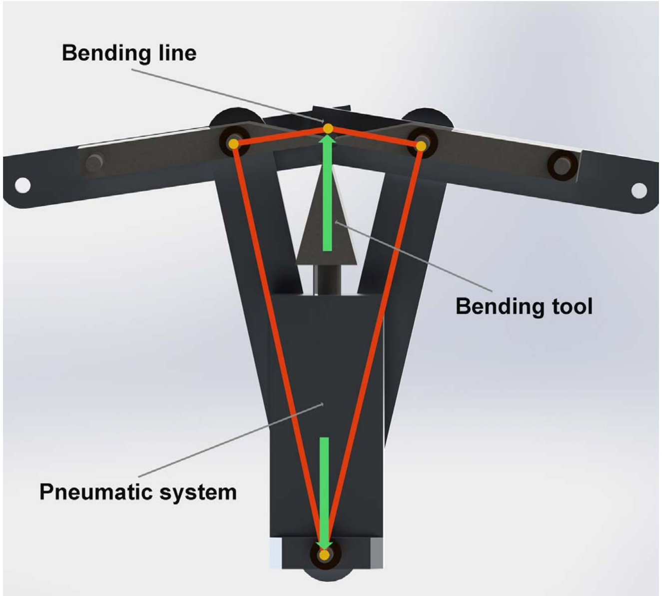


Fig. 2. Kinematic of the bending device.

Preliminary tests were developed to identify the most appropriate setting of the operational parameters. When laser power and scanning speed are taken outside of the prescribed range (Table 1), thermal

Download English Version:

https://daneshyari.com/en/article/5007854

Download Persian Version:

https://daneshyari.com/article/5007854

Daneshyari.com