Available online at www.sciencedirect.com
SCIENCE DIRECT

Optics and Lasers in Engineering 44 (2006) 1067–1077

OPTICS and LASERS in ENGINEERING

An investigation of pulsed laser cutting of titanium alloy sheet

Lv. Shanjin*, Wang Yang

Department of Mechanical Engineering and Automation, Harbin Institute of Technology, Harbin 150001, PR China

Received 7 June 2005; received in revised form 29 August 2005; accepted 7 September 2005
Available online 13 October 2005

Abstract

Subsequent welding requirement calls for high-quality laser cut surfaces in the laser cutting of bladed ring parts for aeroengines. This paper presents pulsed laser cutting of titanium alloy sheet and investigates the influences of laser cutting parameters on laser cut quality factors including heat-affected zone (HAZ), surface morphology and corrosion resistance. The thickness of HAZ lasers is studied in detail as a function of laser cutting parameters. For different assist gases the surface morphology and corrosion resistance show great differences. In comparison with air- and nitrogen-assisted laser cutting, argon-assisted laser cutting comes with unaffected surface quality and is suitable for laser cutting with subsequent welding requirement.

Keywords: Laser cutting; Titanium alloy; Heat affected zone; Surface morphology; Corrosion resistance

1. Introduction

Titanium alloys are being increasingly used in the aerospace industry due to their high specific strength, excellent corrosion resistance and good high-temperature properties [1–3]. For example, an advanced jet engine generally possesses a forward

*Corresponding author. Tel.: +86 451 891 59 069.
E-mail address: lvshanjin@yahoo.com.cn (L. Shanjin).

0143-8166/$ - see front matter
doi:10.1016/j.optlaseng.2005.09.003

compression section made of titanium alloy working at low to medium temperatures and a rear combustion section made of nickel-based superalloy working at high temperatures [4]. Thus it has been a common process to cut, trim, weld and drill holes in titanium alloy parts.

However, the low thermal conductivity, low elastic modulus and high chemical activity have made conventional machining of titanium alloy a very hard task [5]. With the development of modern aerospace industry, part contours are becoming increasingly complicated and the precision requirements are becoming increasingly strict, which have made this situation even worse. Fortunately, laser cutting can be a promising tool in machining titanium alloy parts. Firstly, laser cutting is a thermal process the effectiveness of which depends on the thermal properties rather than the mechanical properties of the material to be machined. Secondly, laser machining is a non-contact process without mechanically induced material damage, tool wear and machine vibration. Finally, laser machining can be combined with a multi-axis machine or robot to machine complicated parts [6,7]. Therefore, laser cutting of titanium alloy can be performed with high accuracy at high speed.

However, laser cutting of titanium alloy leads to alteration of the surface properties of the machined zone. One of the main phenomena is the formation of the heat-affected zone (HAZ) in the vicinity of the erosion front due the heat conduction resulting from the high density laser beam on the workpiece. Another important point to consider is the modification of the surface material on the machined surface including the formation of new surface morphology and the change of corrosion resistance. For certain applications with subsequent welding requirement, the surface quality of laser cut kerfs is of great importance. For example, after the laser cutting of blade holes in the bladed stator ring for the aeroengine, the stator blades need to be joined with the stator ring by subsequent welding, and the surface quality of the bladed holes is reliable for the weldability and weld quality of the stator ring with the blades and therefore has much influence on the performance of the aeroengine.

Aiming at finding optimum laser cutting parameters for the blade hole cutting of bladed ring parts for a jet engine under development, this paper presents the experiment of Nd:YAG pulsed laser cutting of titanium alloy sheet to investigate the influences of different laser cutting parameters on the surface quality factors such as HAZ, surface morphology and corrosion resistance.

2. Experimental method

A Lumonics JK702H Nd:YAG pulsed laser, with a maximum average power of 350 W and a wavelength of 1.06 μm, was applied in this experiment to cut a 1 mm thick TC1 titanium alloy sheet, as shown in Fig. 1. TC1 is an alpha-beta titanium alloy with 2% aluminum and 1.5% manganese. The laser beam, in a TEM_{00} mode, was focused by a lens with a focal length of 80 mm, resulting in a minimum spot diameter of 50 μm. A conical converging coaxial nozzle with an exit diameter of 1 mm was set at a standoff distance of 0.5 mm from the workpiece. Under the control of an open-architecture CNC system, the worktable was capable of performing 3D