Materials and Design 32 (2011) 1814–1823

Contents lists available at ScienceDirect

Materials and Design

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

Generalising fatigue stress analysis of different laser weld geometries

M.M. Alam *, J. Karlsson, A.F.H. Kaplan

Luleå University of Technology, Department of Applied Physics and Mechanical Engineering, SE-971 87 Luleå, Sweden

ARTICLE INFO

Article history:
Received 6 August 2010
Accepted 13 December 2010
Available online 21 December 2010

Keywords:
C. Lasers
D. Welding
E. Fatigue

ABSTRACT

Two-dimensional elastic–plastic finite element analyses was carried out on a laser welded box beam in order to study the impact of the geometrical aspects of the joint type and weld root on the fatigue stress behaviour. Different experimental and hypothetical weld geometries were studied. Characteristic root shapes, measured by the plastic replica method, and critical geometrical aspects were classified and then studied by FE-analysis with respect to their impact on the maximum stress. The simulation of hypothetical transition geometries facilitated the identification of trends and the explanation of part of the phenomena. However, quantitative geometry criteria were only partially suitable to describe the relations. The results have shown that the combination of throat depth, local surface radius and its opening angle determines the peak stress value and its location. Beside extended throat depths, particularly larger toe radii and the avoidance of small opening angles and of surface ripples reduces the peak stress. The explanations were developed in a generalising manner, accompanied by illustrative and flow chart description.

1. Introduction

Welding often has a strong impact on the product value. High quality of the weld for avoiding failure is prerequisite, but a complex issue that needs improved understanding. The weld quality is directly influenced by the process parameters; therefore, welding can be considered as a multi-input multi-output process. A common problem faced is the control of the process via the input parameters to obtain an acceptable welded joint with the required weld geometry and weld quality and with minimum detrimental residual stresses and distortion. It can be divided into research of the influence of the parameters on the process and on the resulting weld quality, and into research on the weld under mechanical load from which the quality standard can be derived and specified. This paper focuses on the latter, but also links to the former. As research is commonly conducted case-specific, it is often difficult to interpret and use the results for other applications, both qualitatively and quantitatively. Although the here presented study is also case-based, it tries to develop approaches for generalising the findings and the explanations behind.

During laser welding, the beam is focused onto the substrate material where its high power density enables to drill a vapour capillary where the beam energy is absorbed over depth, thus typically creating a deep, narrow weld [1]. Laser welding has progressively attracted the attention of engineers during the last decades for its many advantages over more traditional technologies, but suffers from difficulties in controlling the process quality. However, the laser weld quality is often difficult to control because the complex process can be highly sensitive and is not fully understood yet. Also the quality standard specifications are not satisfactory yet [2,3]. The laser weld geometry is mainly dependent on the parameters welding speed, laser power, focal plane position, shielding gas type/flow and the joint gap [4]. Variation of the main process parameters (power, speed) has a strong effect on the bead profile (width, penetration depth, melted area) [5,6]. E.g. relationships between the focal point position, laser power, welding speed and the responses of tensile and impact strength (stainless steel) were established [7], similarly about the shielding gas for aluminium [8]. The effect of laser beam angle, focal point position and focal depth on the weld top and root geometry was systematically studied [9] as a base for the present stress analysis.

The particular technique of hybrid laser-arc welding combines the advantages of laser and arc welding (simultaneously operated), producing deep penetration welds (laser), yet at the same time having an improved tolerance to joint fit-up (burning arc wire-electrode) [10]. From a fundamental analysis of hybrid welds it was shown that sharp root edges lower the impact strength, thus a gap with a rounded root is even favourable to a zero-gap situation [11]. Other works about the effects of the interaction of welding speed and wire feed rate on penetration are examined in [12,13].

Fatigue life is a combination of crack initiation and propagation stages [14] (followed by the fast failure stage). It usually depends on the weld geometry, e.g. toe radii, root radii, weld angle and de-

* Corresponding author. Tel.: +46 (0)920 493917.
E-mail addresses: minhaj.alam@ltu.se (M.M. Alam), jan.karlsson@ltu.se (J. Karlsson), alexander.kaplan@ltu.se (A.F.H. Kaplan).

0261-3069/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2010.12.031