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Influence of process parameters on the process efficiency in laser metal deposition welding

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Abstract

Conventionally manufactured tools are often completely constructed of a high-alloyed, expensive tool steel. An alternative way to manufacture tools is the combination of a cost-efficient, mild steel and a functional coating in the interaction zone of the tool. Thermal processing methods, like laser metal deposition, are always characterized by thermal distortion. The resistance against the thermal distortion decreases with the reduction of the material thickness. As a consequence, there is a necessity of a special process management for the laser based coating of thin parts or tools. The experimental approach in the present paper is to keep the energy and the mass per unit length constant by varying the laser power, the feed rate and the powder mass flow. The typical seam parameters are measured in order to characterize the cladding process, define process limits and evaluate the process efficiency. Ways to optimize dilution, angular distortion and clad height are presented.

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Keywords: laser metal deposition; process efficiency; distortion

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Nomenclature

A_1	crosssectional area on substrate
A_2	crosssectional area in substrate
AG	degree of dilution
c	specific heat capacity
E_L	energy per unit length
h	specific heat enthalpy
Δm	additional mass on substrate
m_L	mass per unit length
$\dot{m}$	powder mass flow
P_B	supplied laser power
P_{MP}	melt power of powder
P_{MS}	melt power of substrate
P_V	power losses
s	material thickness
t	processing time
T_m	melting temperature
T_0	ambient temperature
v	feed rate
ρ	density
η_E	process efficiency

1. Introduction

Powder-based laser deposition welding is a well-established generative manufacturing process for the production and repair of components in toolmaking. Tools which have been manufactured conventionally, for example by machining semi-finished parts, are usually made entirely of expensive, hardened and tempered, highly alloyed tool steel. With laser deposition welding however, tools can be constructed by applying functional layers locally, specifically aimed at the interaction zone of the tool. This type of coating can be applied on inexpensive, easily weldable substrate material. Additionally, there is the possibility to restore worn or defective tools using laser deposition welding.

In an industrial setting, the following approach is frequently used in order to increase the cycle efficiency of the deposition welding process. In order to reduce processing times as far as possible in 2d oder 3d applications, the aim is to reduce the number of welding tracks (Tuominen, 2003). Therefore, the process parameters need to be adapted with the objective of maximizing the track width. These adaptations result in large focal diameters, improved power and energy per unit length as well as comparatively slow processing speeds. Additionally, the substrate materials are subjected to immense thermal stress.

Laser deposition welding is characterized by thermal distortion of the component, which is typical for thermal processing methods. Thermal distortion of the component cannot be eliminated, but it can be reduced by thermally adapting the process management. The resistance against thermally induced distortion of the component decreases with the reduction of the material thickness (Schulze, 2010). As a consequence, there is the necessity of a thermally adapted process management particularly for the laser-based coating of thin-walled parts or tools with reduced material thickness in order to reduce temperature-induced component distortion.

The approach of increasing the process efficiency by maximizing the track width (as outlined above) can therefore not be adapted to suit the needs of laser deposition welding of parts with reduced material thickness. An alternative approach to increasing process efficiency is increasing the processing speed. High processing speeds have the advantage of reducing the energy input per unit length as well as reducing the processing time. Temperature-induced component distortion is therefore reduced as well.