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Improvement of the laser direct metal deposition process in 5-axis configuration

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Abstract

The implementation of the continuous 5-axis configuration can extend the limits of the Laser Direct Metal Deposition (LDMD) processes, especially when the complexity of the parts to be built is growing. In order to follow the profile of a part, we use the orientation of its growth axis. Although 5-axis machining is well known nowadays, LDMD processes require a specific optimization that depends on many parameters. Unlike conventional machining, it has to be noted that the speed variation tool tip affects the stability of deposition. Thus, we have to smooth trajectories in order to provide fluid movements and also to ensure the stability of deposition.

This article describes the method and results in the optimization of trajectories to build metallic parts with freeform. Optical sensors have been implemented in the focusing unit in order to follow the variations of the laser-powder-substrate interaction and also to detect the process instabilities. Thanks to the right use of a new and large 5 axis machine and specific setting trajectories, manufacturing parts in 5-axis, with no concession on the construction rate has been possible.

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1. Introduction

There is no need to demonstrate the advantages of the Additive Manufacturing Processes in industry any more. Among those, the Laser Direct Metal Deposition (LDMD) processes have shown very promising applications for the manufacturing of large parts [1], and parts repairing [2]. They are also good candidates for the processing of functionally graded materials parts [3-4].

These processes allow the manufacturing of parts directly from CAD files without any specific tool. In order to manufacture more complex parts however, a 5 axis configuration is necessary [5, 6, and 7].

Unlike machining, the process requires good stability of the operating conditions. Indeed, the parameters such as the laser power and the deposition velocity have a great influence on the geometry of the deposit [8, 9 and 10]. The main challenge is to keep the deposition velocity as constant as possible. But in the 5 axis configuration, several problems in relation with the tool velocity can be observed.

Singular points are one of those problems. Several authors mention that Computer Numerical Control (CNC) data can generate unexpected movements of the rotary axis. This phenomenon is due to the Inverse Kinematic Transformation, which generates singular positions during the calculation of the machine coordinates [11]. These singularities lead to large movements of the rotary axes through short displacements along the tool path. As a consequence, a significant drop in the tool velocity can be noted.

As illustrated in the drawing on fig.1, we can identify geometric errors as a source of instability. Indeed, the presence of chordal errors can lead to excessive variation of the tool orientation between two successive points of the trajectory.

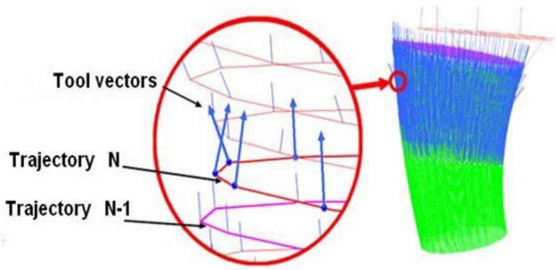

Fig. 1. Variation of the tool vector on a trajectory.

We can see many papers on the trajectory generation in multi-axis configuration, but, as far as we know, there is no report of a method that could optimize the construction rate for a 5-axis tool path.

In this work, we present a method that gain smooth trajectories with stable processing conditions. In this respect, the stability of the laser-material interaction has been checked using a commercial optical system for process monitoring. The relevance of this work has been shown by the manufacturing of specific parts for the aerospace industry.

2. Devices and methods

The laser deposition tests were carried out on a 5 axis LDMD machine specially designed by IREPA LASER (fig. 2 (a)).