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The Inverse Problem in Energy Beam Processes Using Discrete Adjoint Optimization

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Abstract : The inverse problem in Energy Beam (EB) Processes consists of defining the control parameters, in particular the 2D beam path (position and orientation of the beam as a function of time), to arrive at a prescribed solution (freeform surface). This inverse problem is well understood for conventional machining, because the cutting tool geometry is well defined and the material removal is a time independent process. In contrast, EB machining is achieved through the local interaction of a beam of particular characteristics (e.g. energy distribution), which leads to a surface-dependent removal rate. Furthermore, EB machining is a time-dependent process in which not only the beam varies with the dwell time, but any acceleration/deceleration of the machine/beam delivery system, when performing raster paths will influence the actual geometry of the surface to be generated. Two different EB processes, Abrasive Water Machining (AWJM) and Pulsed Laser Ablation (PLA), are studied. Even though they are considered as independent different technologies, both can be described as time-dependent processes. AWJM can be considered as a continuous process and the etched material depends on the feed speed of the jet at each instant during the process. On the other hand, PLA processes are usually defined as discrete systems and the total removed material is calculated by the summation of the different pulses shot during the process. The overlapping of these shots depends on the feed speed and the frequency between two consecutive shots. However, if the feed speed is sufficiently slow compared with the frequency, then consecutive shots are close enough and the behaviour can be similar to a continuous process. Using this approximation a generic continuous model can be described for both processes. The inverse problem is usually solved for this kind of process by simply controlling dwell time in proportion to the required depth of milling at each single pixel on the surface using a linear model of the process. However, this approach does not always lead to the good solution since linear models are only valid when shallow surfaces are etched. The solution of the inverse problem is improved by using a discrete adjoint optimization algorithm. Moreover, the calculation of the Jacobian matrix consumes less computation time than finite difference approaches. The influence of the dynamics of the machine on the actual movement of the jet is also important and should be taken into account. When the parameters of the controller are not known or cannot be changed, a simple approximation is used for the choice of the slope of a step profile. Several experimental tests are performed for both technologies to show the usefulness of this approach.

Keywords : abrasive waterjet machining, energy beam processes, inverse problem, pulsed laser ablation
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