Doctoral thesis in Cluster G "Intelligent Production Systems":

Off-line generation of robot trajectories for Thermal Spray processes with respect to heat and mass transfer

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Abstract:

Thermal spraying processes are characterised by intense heat and mass transfer to the substrate. The thermal history of the coating and workpiece in terms of temperature gradients, but also absolute temperature values, strongly influence the development of residual stresses in the composite and its reliability and in-service lifetime. The properties of the resulting coating composite do not depend therefore only on the intrinsic properties of coating and substrate materials, but also on the applied process parameters. Among these, the process kinematics, which define the relative movement between the spray torch and the substrate during deposition, are of high relevance. The spray distance, velocity, angle, and spray path determine to a great extent the thermal history on the composite as well as the residual stress distribution, and they influence coating microstructural features such as void content, roughness or dimensional accuracy. A precise control of the process kinematics is thus required for the production of high quality coatings which fulfil functional and dimensional requirements.

Industrial robots are normally used in thermal spraying to guide the spray torch during processing. Although on-line robot programming approaches have been often used in thermal spraying, the increasing demand of coatings applied on substrates with complex geometries has led to the necessity of applying off-line programming tools for robot trajectory planning, which support an accurate definition of the process kinematics. An appropriate robot trajectory should lead to the production of a constant coating thickness with homogeneous microstructure over the substrate surface, but also to an adequate thermal guidance in order to avoid strong temperature gradients and the development of critical residual stresses.

In this work, concepts were developed for the planning of the robot trajectory for thermal spraying processes, which by controlling the parameters defined by the process kinematics and the related phenomena, like the heat transfer to the substrate, lead to a better control of the coating properties. Two approaches of off-line programming were considered to give solution to the problem exposed above. A model to minimize the temperature gradients within the substrate was developed considering the coating of planar substrates. The heat transfer to the substrate during spraying was modelled and used for the optimisation of the spray path in order to produce low temperature gradients in the composite, which led to reduced residual stresses in the coating. Furthermore, trajectory generation for coating of complex shaped components was regarded as well. For that case, an increase in the degrees of freedom of the handling system was carried out by implementing an external rotational axis, which positions the substrate during the deposition process and allows maintaining constant kinematic parameters in order to obtain homogeneous coatings. Numerical simulation of the heat transfer process during deposition was coupled to the robot programming tools and the models were validated with experimental work.