Numerical Modeling for Cold Sprayed Particle Deposition

Jing XIE[1], Daniel NELIAS[1*], Hélène WALTER-LE BERRE[1], Kiyohiro ITO[2], Yuji ICHIKAWA[2], Kazuhiro OGAWA[2]

[1)] Université de Lyon, CNRS, INSA-Lyon, LaMCoS UMR 5259, F-69621, France
[2)] Fracture and Reliability Research Institute, Tohoku University; 6-6-11, Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan.

[*]Corresponding author for daniel.nelias@insa-lyon.fr

1. Introduction

Cold Spray (CS) is a process whereby metal particles are utilized to form a coating by means of ballistic impingement upon a suitable substrate [1]. The numerical method plays an important role in researching the cold spray deposition process. In these numerical methods, the most commonly used space discretization are Lagrangian, Eulerian, ALE, and SPH. In this study, the particle deformation behaviour is investigated by using the four numerical methods mentioned above. The capacities and reliabilities of them are discussed after that. Finally, simulation result of multiple impacts is presented, giving a tool to estimate the porosity rate and residual stress induced by cold spray within the coating and the substrate.

2. Results and discussion

Four different numerical methods, which are Lagrangian, ALE, CEL, SPH, are applied to single impact and then multiple impact simulations. Figure 1 shows the contour of the equivalent plastic strain (PEEQ) for a single 25μm copper particle after impact on an Aluminum substrate at 500m/s by using these four approaches. The other group of materials Al-12Si against Steel was also investigated after impact at 1000m/s by using the four methods. Their PEEQ profiles were given in Fig. 2. The Lagrangian method is computationally efficient (Fig. 1-a), but the severe element distortion located at the contact surface (Fig. 2-a) could lead to adverse effects on the integration step and accuracy. Convergence issues are more pronounced at high temperature and high impact velocity, i.e. when the material tends to flow. An additional computational step of remeshing is employed for the ALE step. The results (Fig. 1-b) largely depend on the choice of frequency and remeshing sweeps per increment. This dependency is more significant when the impact velocity increases, leading to unsound and unreasonable results (Fig. 2-b). The CEL method permits to avoid problems of excessive mesh distortion and unrealistic deformed shape (Fig. 1-c), as for high speed impacts (Fig. 2-c). However, the cost of computing is more expensive compared to the SPH reference frame (Fig. 1-d, Fig. 2-d). In the current version of ABAQUS (v6.11), the analysis step of SPH outputs the stress-strain data without considering thermal effects. Comparing with experimental results (Fig. 3) [2,3], the CEL was chosen for the simulation of multiple impacts for its robustness and despite the computational costs. The modeling results of multiple impacts of two group materials are displayed in Fig. 4. It is possible to reproduce the creation of voids or pores as shown within the red circles in Fig. 4. It will be very interesting to study how the temperature, velocity and contact angle affect the porosity rate of cold spray coatings. One of the promising applications of our simulation work is to simulate the abrasion and erosion of materials.

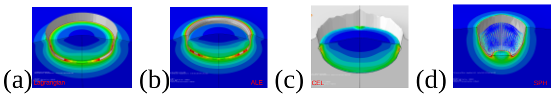

Fig 1: PEEQ simulation results of cu/al by (a) Lagrangian, (b) ALE, (c) CEL and (d) SPH.

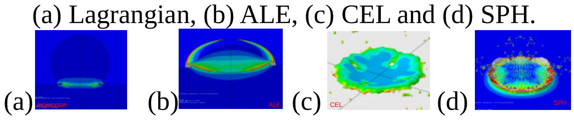

Fig 2: PEEQ simulation results of Al-12Si/Steel by (a) Lagrangian, (b) ALE, (c) CEL and (d) SPH.

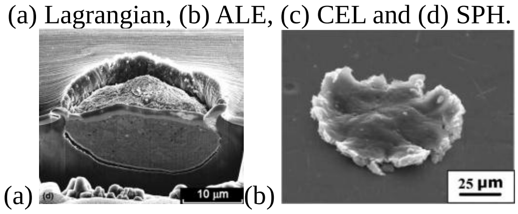

Fig 3: Experimental results of (a) cu/al at 500m/s [6] and (b) Al-12Si/Steel at 1000m/s [7].

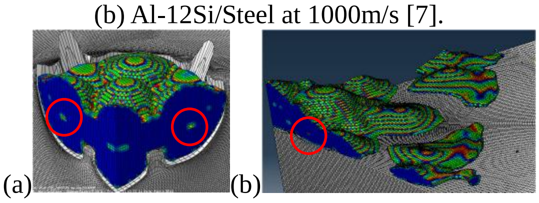

Fig 4: Multiple impacts simulation results of (a) cu/al at 500m/s and (b) Al-12Si/Steel at 700m/s by CEL.

3. References

[1] Ogawa, K., Ito, K., Ichimura, K., Ichikawa, Y., O hno,S., and Onda, N., 2008. "Characterization of low pressure cold-sprayed aluminum coatings". *Journal of Thermal Spray Technology*, **17**, pp. 728–735.

[2] P. King, G. Bae, S. Zahiri, M. Jahedi, C. Lee.2010. "An Experimental and Finite Element Study of Cold Spray Copper Impact onto Two Aluminum Substrates". Journal of Thermal Spray Technology, **19**(3),pp. 620–634.

[3] J. Wu, H. Fang, S. Yoon, H. Kim, C. Lee.2006."The rebound phenomenon in kinetic spraying deposition". Scripta Materialia. **54** (4),pp. 665–669.