The effect of localized surface preheating in laser cladding of Stellite1 on AISI 4340 steel

Automated Laser Fabrication (ALFa) Laboratory

Department of Mechanical and Mechatronics Engineering
University of Waterloo
Research objective and challenges

Objective

*Deposition of Stellite 1 on AISI-SAE 4340 alloy steel using the laser cladding process*

- As a well-known group of hardfacing materials, overlays of cobalt-based/carbide type alloys, also known as “Stellite” alloys, have shown excellent performances in severe wear applications.

Challenges

- In spite of all demonstrated advantages of laser cladding, because of its layer-by-layer material deposition and thermal distribution characteristic, the process are subject to thermal stresses which are the main cause of possible delamination and crack formation across the deposited materials.

- High volume fraction of carbides in Stellite 1, although contributes to its excellent wear resistance and hardness properties, it also results in high susceptibility of this material to crack formation during hardfacing processes.
Numerical and experimental analysis

- A numerical model is developed to study the effects of preheating on the temperature distribution and thermal stress fields as well as to define a set of optimum process parameters for the preheating and deposition processes.

Numerical and experimental parameters and specifications

- Substrate: a 35×25×8.5 mm block of AISI-SAE 4340 alloy steel

<table>
<thead>
<tr>
<th>Main process parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder feed rate (g/min)</td>
<td>6</td>
</tr>
<tr>
<td>Laser Power (W)</td>
<td>900</td>
</tr>
<tr>
<td>Radius of the laser beam-dep. (m)</td>
<td>7e-4</td>
</tr>
<tr>
<td>Radius of the laser beam-Preh. (m)</td>
<td>38e-4</td>
</tr>
<tr>
<td>Process speed-dep. (mm/s)</td>
<td>6</td>
</tr>
<tr>
<td>Process speed-preh. (mm/s)</td>
<td>8.3</td>
</tr>
</tbody>
</table>
Numerical results

Temperature Profiles of three points along the deposition path b) of two points on the bottom of the substrate under the deposition path

Numerical results show:

- that the preheated substrate is being cooled significantly slower than the non-preheated substrate
- that the temperature gradients and consequently the thermal stresses are larger for the non-preheated substrate
Experimental results – crack formation

- Same process parameters
- A crack-free deposition for the preheated sample
- More consistence deposition (better geometrical specifications) for the preheated sample (due to a shorter transient time for the formation of a well-developed melt pool)
Experimental results – microstructure examination

Deposition of Stellite 1 on AISI 4340: Backscatter SEM images of Stellite 1; (a) A uniform dendrite network develops in the preheated sample, (b) A highly uneven microstructure containing also a higher fraction of brittle inter-dendritic phases causing formation of cracks in the non-preheated sample.

- The melt pool characteristics during the solidification for the non-preheated substrate cause a lack of intermixing in liquid state due to insufficient diffusion and convection.
- Contrary to a non-uniform microstructure formed within the coated of non-preheated substrate, a well-distributed uniform dendritic structure was observed across the coated layer for the preheated substrate.
Conclusions

- As a result of preheating, a thicker cross-section with a smoother surface profile and a narrower range of hardness forms in the Stellite 1 claddings.

- In the preheated sample, a uniform dendritic structure forms, whereas the microstructure of the non-preheated sample reveals a macro-scale repetition of dendritic and lamellar (eutectic) morphologies resulted from solidification of a melt pool with an inhomogeneous composition.

- The preheating process prevents crack formation in the subsequent deposition of Stellite 1 by enhancing the evenness of the temperature distribution and chemical composition throughout the process domain and melt pool, respectively.

Automated Laser Fabrication (ALFa) Laboratory

Department of Mechanical and Mechatronics Engineering
University of Waterloo