Coating Of Polymer Composites Using Cold Gas Dynamic Spraying

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Introduction

Cold Gas Dynamic Spraying is a spray method which coats particles sprayed at sub-sonic and supersonic speeds. It has many benefits over other spray coating methods, it does not need to heat the particles beyond their melting point to achieve adhesion to the surface of the material being sprayed on to (the substrate). For this reason substrates with low melting points such as polymer composites can be coated in a variety of metallic materials. The overall aim of the project was to investigate the behaviour of particles impacting a polymer substrate at the un-cured stage and the cured or co-cured (particles cured into the surface from previous cold spraying) stage. The experiments used 20-50µm tin particles. The carbon fibre substrate was a woven pre-preg, which is carbon fibre with a resin pre impregnated into the fibre sheets.

Cold Gas Dynamic Spraying uses high pressure gas (nitrogen was used in the experiments) to accelerate particles through a nozzle. The particles travel at high velocity and plastically deform on contact with the substrate. The plastic deformation leads to the formation of a compressive coating and due to the nature of the bonding the coating contains very few impurities. This differentiates cold spraying from other thermal spraying techniques.

Method

Figure: 1 Coatings were applied at low pressures (2-5 Bar) to the 100mm by 100mm pre-preg. The tacky substrate resin allows particles to be deposited into the surface. The composite was then cured before further coating.

Figure: 2 Higher Pressure coatings (10-30 Bar) were applied to the cured surface. Different tracks were sprayed in the opposite directions to previous tracks to differentiate successful deposition and coating quality.

Figure: 3 Minimal resin thickness in the co-cured coating

Figure: 4 Poor deposition on the surface of the substrate. Erosion shown in fibre areas

Figure: 5 Parameters that gave the highest deposition efficiency in the first low pressure coating experiment were used to coat a further 50mm by 50mm section. This shows the coating on the tacky pre-preg before curing

Figure: 6 The cured substrate was then coated in the high pressure coating which had the best deposition qualities. The spraying was continued until a thick layer was deposited

Figure: 7 Evidence for particles plastically deforming to form consistent coating

Figure: 8 Erosion seen in the high pressure coatings of the co-cured substrate

Figure: 9 The model shows a low pressure coating particle impact. The uncured resin forming around the particle

Figure: 10 The layer of resin at the surface is only thick enough to contain one particle. Erosion and removal of the pre-deposited particle is caused by the high velocity impact

Figure: 11 The high velocity particle’s kinetic energy is absorbed by the thick layer of three particles, preventing erosion of the carbon fibres.

Results

The initial coating of the pre-preg showed that the thickest coating area was 50µm thick. This only allowed single or double layers of particles to be deposited. Damage of the fibres is not seen in the low pressure coatings. The impact into the viscous resin dissipates the kinetic energy of the particle figure 9

Thick resin and particle coating of the pre-preg is essential, this is because the kinetic energy that the high pressure coating particles have can be absorbed by multiple impacts with pre-deposited particles. Particles form splats where the particles flatten and join. This is shown in figure 7 and 12

The amount of particles that can successfully be deposited in the substrate is dependant on the thickness of the resin coating in the pre-preg. Areas with fibres close to the surface are still prone to erosion. Particles pre-deposited in the fibre areas can be removed such as in figure 10

Figure: 12 The models below are two frames from each animation

Three main situations that were modelled were the impacts of single particles into:

1. The surface of the uncured substrate
2. A pre-deposited thin layer of particles
3. A pre-deposited thick layer of particles

The modelling was done as an animation where the images were layered showing the particle and substrate interaction throughout the process. The pictures below are two frames from each animation

Conclusion

The experiments highlighted the differences in the coating quality’s due to the resin thickness on the surface of the composite substrate. Areas of successful particle deposition were seen in the thickest layers of resin both at high and low pressures. The need for further work on the mathematical modelling or simulation, in packages like LS-DYNA, of the particle impacts and their behaviours is needed to support the theory outlined. Further tests can be made on the thickness of the pre-preg coating and its effect on the subsequent co-cured coatings to further expand the effect of the particle, resin and fibre interaction.

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