Mechanical Engineering:
The Selective Laser Melting of Metals and In-situ Aluminium Matrix Composites

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The Exeter Partnerships:
An Insider's Comments on Effectiveness

Submitted by **Sasan Dadbakhsh** to the **University of Exeter**
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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature: ……..

Abstract

Selective laser melting (SLM) is an additive manufacturing technique to produce complex three-dimensional parts through solidifying successive layers of powder materials on top of each other, from the bottom to top. The powder base nature allows the SLM to process a wide variety of materials and their mixtures and fabricate advanced and complicated composite parts. However, the SLM is a newly established process and seeks detailed scientific studies to develop new materials systems for the consumption of industry. These scientific studies are particularly important because of many issues associated with the SLM process, such as porosity, balling, delamination, thermal stress, etc, which can be varied from one material system to another.

This PhD project aims to elucidate the fundamental mechanisms governing the microstructure and mechanical properties of the metallic and in-situ Al matrix composite parts made by SLM. The research starts with a preliminary study on SLM of stainless steel in order to explore the usage of SLM machine and related parameters. It illustrates the effect of part layout on the quality of products.

The main research focuses on the in-situ formation of particulate reinforced Al matrix by using SLM of Al/Fe_2O_3 powder mixture. It is a pioneering research to integrate in-situ interaction with laser melting to produce advanced Al composites. It investigates the mechanisms governing SLM assisted in-situ reaction and also the effects of various parameters such as SLM layer thickness, laser power and scanning speed as well as the proportion of Fe_2O_3. It examines the influence of Al alloy powder and it describes the effect of hot isostatic pressing (HIP) post-treatment. The physical, mechanical, and metallurgical properties of the products are extensively assessed using various techniques. The processing windows of the process are sketched. The findings demonstrate unique microstructural features due to combined in-situ reaction and laser rapid consolidation, and contribute to provision of an in-depth scientific understanding of novel Al matrix composites by using SLM assisted in-situ processes.

As part of this PhD project, industrial collaborative research has also been conducted to characterise the surface finish, metallurgical quality, process accuracy and mechanical properties of various SLM made metallic parts using Al, Ti, stainless steel, and super alloys. This part of research has generated scientific data and results for industrial applications of metallic fabrication using SLM.

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List of Publications

Published Journal Articles:

Dadbakhsh, S., Hao, L. , Jerrard, P.G.E., & Zhang, D.Z. (2012) Experimental investigation on selective laser melting behaviour and processing windows of in situ reacted Al/Fe_2O_3 powder mixture, *Powder Technology*, 231, 112–121.

Dadbakhsh, S. & Hao, L. (2012) Effect of Al alloys on the selective laser melting of in-situ formed particle reinforced composites, *Journal of Alloys and Compounds,* 241, 328–334.

Dadbakhsh, S. & Hao, L. (2012) Effect of hot isostatic pressing (HIP) on Al composite parts made from laser consolidated Al/Fe_2O_3 powder mixtures, *Journal of Materials Processing Technology,* 212**,** 2474–2483.

Dadbakhsh, S. & Hao, L. (2012) In situ formation of particle reinforced Al matrix composite by selective laser melting of Al/Fe_2O_3 powder mixture. *Advanced Engineering Materials,* 14**,** 45-48.

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Dadbakhsh, S., Hao, L. & Kong, C. Y. (2010) Surface finish improvement of LMD samples using laser polishing. *Virtual and Physical Prototyping,* 5**,** 215-221.

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Dadbakhsh, S., Hao, L. & Kong, C. Y. (2010) Surface Finish Improvement of LMD Samples Using Laser Polishing. *Proceedings of the 11th National Conference on Rapid Design, Prototyping and Manufacturing*, 79-86.

Dadbakhsh, S., Hao, L. & Sewell, N. (2009) A test procedure for mechanical qualification of additive layer manufacturing parts. *Proceedings of the 10th National Conference on Rapid Design, Prototyping and Manufacturing*, 53-61.

Dadbakhsh, S., Hao, L., Sewell, N. & Jerrard, P. (2009) Direct fabrication of an in-situ Al composite using selective laser melting process. *Innovative Developments in Design and Manufacturing - Advanced Research in Virtual and Rapid Prototyping,* 319-325.

Hao, L., Raymond, D., Strano, G. & Dadbakhsh, S. (2010) Enhancing the sustainability of additive manufacturing. *IET Conference Publications*. 565 CP ed., 390–395.

Jerrard, P. G. E., Hao, L., Dadbakhsh, S. & Evans, K. E. (2010) Consolidation behaviour and microstructure characteristics of pure aluminium and alloy powders following Selective Laser Melting processing. *Proceedings of the 36th International MATADOR Conference*, 487-490.

* Presenting my work in 2nd and 3rd (2009 and 2010) EADS Airbus PhD seminar on Additive Layer Manufacturing - *Airbus/EADS Filton, UK*

Submitted Journal Articles:

Dadbakhsh, S. & Hao, L. Microstructural evolution of Al/5wt.%Fe_2O_3 powder consolidated parts by selective laser melting: Part I. Effect of layer thickness in conjunction with laser power and scanning speed, under submission.

Dadbakhsh, S. & Hao, L. Microstructural evolution of Al/Fe_2O_3 powder consolidated parts by selective laser melting: Part II. Effect of Fe2O3 content in conjunction with laser power and scanning speed, under submission.

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