# Analysis of Selective Laser Sintering Print Parameter Modelling Methodologies for Energy Input Minimisation

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by

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The author declares that this is his own work, except where due acknowledgement has been given. The thesis is submitted in fulfilment of the requirements of a Masters in Engineering at Massey University, New Zealand.

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# Abstract

Additive Manufacturing (AM) is the name given to a series of processes used to create solids, layer upon layer, from 3 Dimensional (3D) models. As AM experiences rapid growth there exists an opportunity for Selective Laser Sintering (SLS) to expand into markets it has not previously accommodated. One of the ways SLS can accomplish this is by expanding the range of materials that can be processed into useful products, as currently only a small number of materials are available when compared to other AM technologies. One of the biggest barriers to the adoption of materials is the danger inherent to high-energy processes such as SLS. The aim of this research was to identify opportunities to improve current methods for modelling the relationship between material specifications, and printing parameters. This was achieved by identifying existing models used to determine printing parameters for a new material, identifying weaknesses in current modelling processes, conducting experimentation to explore the validity of these weaknesses, and exploring opportunities to improve the model to address these weaknesses. The current models to determine printer parameters to achieve successful sintering include both the Sintering Window (SW) and the Energy Melt Ratio (EMR). These two models are complementary, and both are required to establish all common print parameters. They include both thermal and physical powder properties, but do not include any optical properties. This is significant because the nature of the SLS printing process relies on concentrated delivery of laser energy to achieve successful sintering. Analysis of two similar polyamide powders, one black and one white, identified that the two powders were similar thermally and physically, which meant the models predicted that they should both sinter successfully utilizing the same set of print parameters. Results of the experimental trials showed that no trials involving the white powder sintered successfully, and trials involving the black powder suffered from issues with either insufficient energy to successfully remove parts without damage, or excessive energy causing excess powder to bond to the part.  Further experimentation was carried out to investigate the differences in optical properties using Fourier Transform Infrared Spectroscopy (FTIR) and Spectrofluorophotometry. FTIR revealed that there was a difference in absorption as a material property, indicating that differences in laser energy absorption could explain the results seen in the trials. Spectrofluorophotometry revealed minimal differences in fluorescence of the powders, suggesting it an unlikely source of energy loss. Future work is recommended to research a standardised form of testing setup that can be used to categorize the reflectance of a material, as current work relies on proprietary experimental setups. Finding methods of classifying the laser absorption that is easily available to operators would enable refinement of the EMR equation to reflect the energy losses during printing, and remove another barrier for adoption of new materials.

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Mearns, C., Potgieter, J., Dirven, S. and Joo Le Guen, M. (2017). Experimental analysis of the effectiveness of current modelling methods for SLS parameter determination. In: *Mechatronics and Machine Vision in Practice*. Auckland: 2017 24th International Conference on Mechatronics and Machine Vision in Practice (M2VIP).

## List of Abbreviations

| | |
|---|---|
| 2D | Two Dimensional |
| 3D | Three Dimensional |
| AM | Additive Manufacturing |
| ATR | Attenuated Total Reflectance |
| AU | Absorbance Units |
| DFMC | Designing for Mass Customisation |
| DoE | Design of Experiment |
| DSC | Differential Scanning Calorimetry |
| EMR | Energy Melt Ratio |
| FDM | Fused Deposition Modelling |
| FTIR | Fourier Transform Infrared Spectroscopy |
| ISO | International Organisation for Standardisation |
| MPS | Mean Particle Size |
| PR | Packing Ratio |
| PSD | Particle Size Distribution |
| SE | Secondary Electron |
| SEM | Scanning Electron Microscope |
| SLA | Stereolithography |
| SLM | Selective Laser Melting |
| SLS | Selective Laser Sintering |
| SM | Subtractive Manufacturing |
| SW | Sintering Window |
| TPU | Thermoplastic Polyurethane |