NAFEMS UK Regional Conference 2018 - Abstract Submission

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| **Submission Date** | 2018-02-01 09:20:21 |
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| **Job Title** | Doctoral Researcher |
| **Company** | CBM |
| **Department** | Research and Development |
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| **Please identify the event for which your submitting?** | NAFEMS UK Conference 2018 |
| **Will you be the presenting author?** | Yes |
| **Presentation Title** | The simulation of residual stress and mechanical performance of EBM-manufactured titanium test specimens |
| **Relevant Themes / Keywords** | Additive Manufacturing, Electron Beam Melting, Tensile Testing, Finite Element Modelling, 3D Scanning |

**Abstract (plain text)**

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Previous research has shown that the build orientation of additive-manufactured parts can have a significant effect on the mechanical properties of metallic components. This study evaluates the impact of build orientation on additive-manufactured titanium samples through the numerical simulation of residual stress, elastic modulus, and yield stress. In addition, part accuracy is assessed through 3D scanning and distortion modelling.

The Wales Centre for Advanced Batch Manufacture (CBM) employs an in-house ARCAM Q10 Electron Beam Melting (EBM) machine for the fabrication of bespoke medical implants. This research is part of a three-year PhD study that is employing a range of Finite Element Modelling (FEA) techniques to enhance the safety and efficacy of custom-made titanium implants. The methodology for the study reported here used two complementary software tools: Ansys and MSC Additive.

To support the numerical simulation work, a small batch of n=6 tensile test pieces were manufactured in two build orientations: horizontal and lateral. To compensate for the high stiffness of the Ti-6Al-4V alloy, the test specimen was algorithmically designed, which adapted some of the design constraints outlined in the ISO 6892-1:2009(E) standard. Tensile test results for all six specimens demonstrated that the design was successful in achieving fracture within the gauge length with diagonal and linear crack propagation for the horizontal and lateral samples, respectively. Furthermore, the elastic modulus and yield stress for both orientations were in reasonable agreement with the previous published values.

The effect of residual stress on EBM parts has not been quantified by previous researchers – this could have a detrimental impact on mechanical performance. Thermo-mechanical process simulations were conducted to compute the stresses associated with the EBM process. The results from simulations demonstrated that the residual stresses generated were less than 0.5% of the yield stress of the material. In comparison, the Selective Laser Melting (SLM) process produced residual stresses up to 30% of the yield stress. To account for the distortion in the titanium parts due to temperature gradients, the fabricated samples were 3D scanned and inspected to determine the accuracy associated with each build axis.

The physical data obtained from tensile testing were employed to update the material library within the Ansys Finite Element solver. A multilinear plasticity model was employed to observe the transition from elastic to plastic region and to obtain the stress zone where crack initiation occurred. The simulation results for both orientations were in good agreement with the experimental data. The overall results indicate that the build orientation had no impact on elastic modulus but had a significant effect on yield stress.

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