DESIGN FOR METAL ADDITIVE MANUFACTURING: PRINTING THE AHRLAC FLIGHT GRIPS

D.C. Bester[1*], M. Vermeulen[2] & J. Prinsloo[2]

[1]National Laser Centre,
Council for Scientific and Industrial Research, South Africa
dbester@csir.co.za

[2]Aerosud Innovation Centre (Pty) Ltd, South Africa
m.vermeulen@aerosud.co.za, j.prinsloo@aerosud.co.za

ABSTRACT

Powder Bed Fusion is a process of building a part, layer-by-layer, using a Laser to melt the cross-sections of a part in a powder layer. Aeroswift is the first South African designed and manufactured PBF machine. As part of its commissioning, two AHRLAC throttle grips were built to show its functionality. The primary achievement being that AHRLAC, a South African designed and manufactured multipurpose aircraft, would be flying parts printed on a South African built machine. This paper discusses the steps that were followed to build the throttle grips; from design changes to better suit the build process, to the strategies used for the support structure design.

[1] * National Laser Centre, Council for Scientific and Industrial Research, South Africa
[2] Aerosud Innovation Centre (Pty) Ltd, South Africa

1. INTRODUCTION

Powder Bed Fusion (PBF) is an Additive Manufacturing (AM) technology which builds a part by utilising a Laser to melt the cross-section of the part onto a powder layer (Sames et el. [1]). The part's CAD (Computer Aided Design) model is sliced into thin layers in order to obtain cross-sections. After each cross-section is melted in the powder layer, the build platform moves down by one layer thickness. A new powder layer is then deposited and the next cross-section is melted.

Aeroswift is the first South African developed metal PBF machine and, at full capacity, it is the largest and fastest in the world. AHRLAC, on the other hand, is a South African developed low-cost, multi-purpose aircraft. As part of the commissioning of the Aeroswift system, it was decided that two flight grips from the AHRLAC aircraft will be built in Titanium (Ti6Al4V). The end goal being to show the functionality of Aeroswift and to show that the produced parts can be implemented on an aircraft.

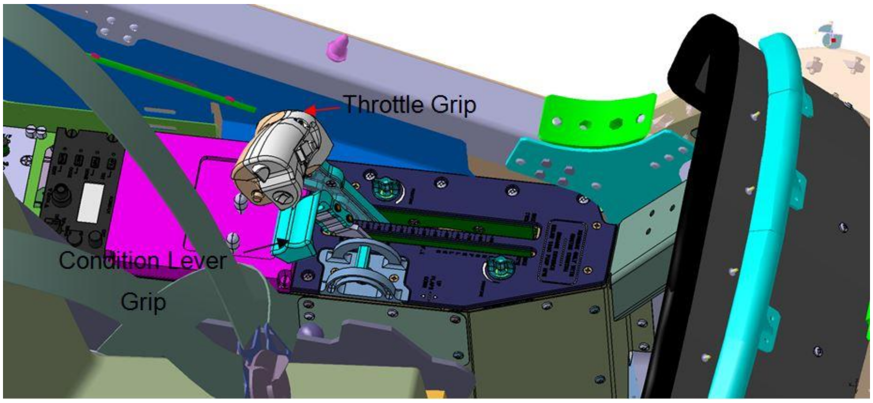

Figure 1: AHRLAC flight grips

The throttle grips were selected due to their complex geometries and that they are not high load bearing parts. The one is the throttle lever grip (figure 3) and the other is the condition lever grip (figure 2). The condition lever grip is a single part, where the throttle lever grip is composed of two shelled parts that fit together.

Other than building the throttle grips as part of the commissioning of Aeroswift, the aim of this project was to optimise and validate the design for producibility of the parts. This mostly entails the support structure design and will determine what would be needed to be improved or added in the future.

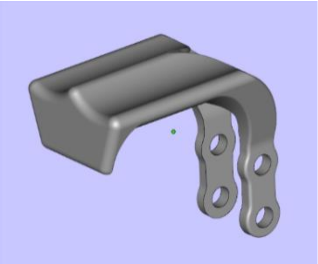

Figure 2: Condition lever grip

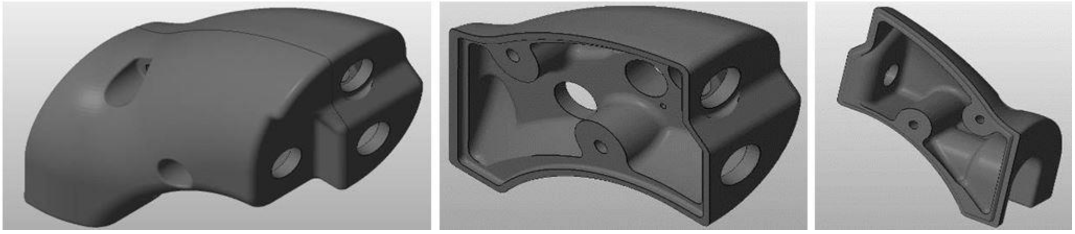

Figure 3: Throttle lever grip

2. METHODOLOGY AND RESULTS

The CAD files for the grips were obtained from the AHRLAC team and the first iteration test build layout and part orientation was done. The part orientation was chosen as such to minimise the required support structures and to minimise the support contact area on the outside of the throttle grips. The reason being that these parts will be implemented as-built and that post processing be minimised. Contact of the supports on the outside surface of the grips will cause rough spots and make these grips wear the pilot's gloves quicker. A compromise was made between minimum supports and minimum outside surface contact because if one was reduced or eliminated, the other one would increase. The layout and support structures were done using Materialise's Magics software with the SG+ module (Materialise [2]).

2.1 First test build

For the first test build, only the throttle lever grip parts were available.

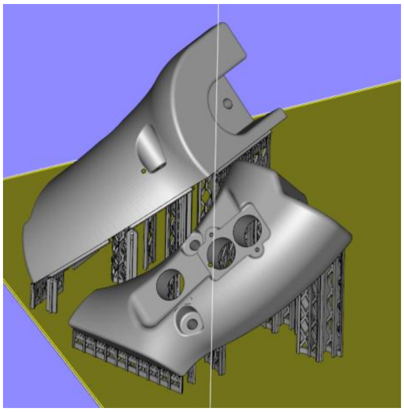

Figure 4: Build layout of the throttle lever grip parts

The support structures are shown in figure 5 and consisted of a combination of line, block and point supports. Line supports are indicated by 5, 6 and 9, block supports by 1, 2 and 3, and point supports by 10 and 11. The supports had a thickness of 1 mm.

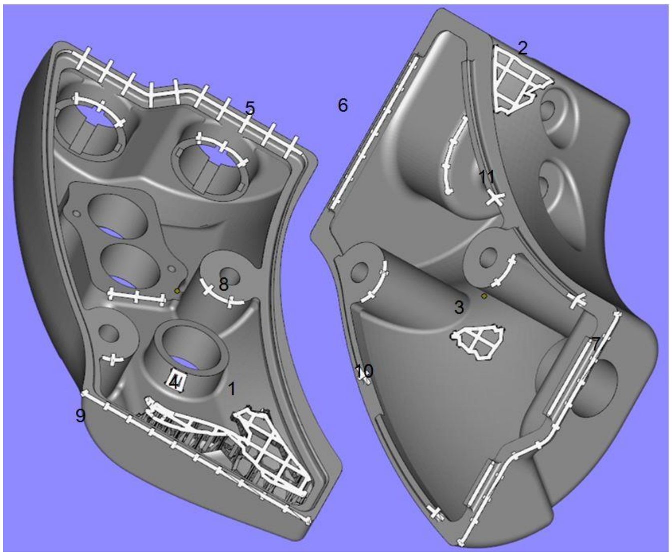

Figure 5: Support structures for first test build

Block support 1 was made an angled block supports to prevent the support from anchoring to the part a second time, shown in figure 6.

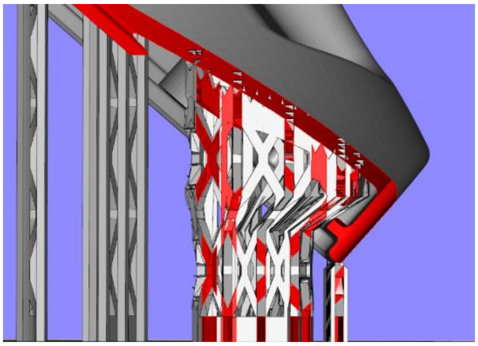

Figure 6: Angled block support

There was, however, one support that could not be prevented from intersecting the part twice. This support is shown in figure 7.

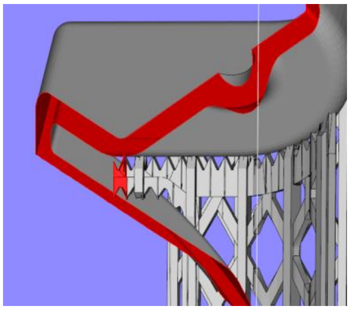

Figure 7: Intersecting support

The build was performed but failed with 200 layers remaining due to a large powder leak which was starting to interfere with the build. Even though the build did not finish, the uncompleted parts were investigated and much was learnt. It was seen that only one point support broke loose from the one part, the rest were still intact. The following is what was learnt from the first test build:

1. The left part in figure 4 was placed too high in the build processor and this had the effect that the support structures were unnecessarily high, which added to the build time.
2. Supports were too solid and thick. This would make them difficult to remove.
3. Supports need to be "cleaned". Cleaning refers to removing small features, for instance were two walls of a support are close enough that the gap is almost non-existent. Refer to support number 1 in figure 5.
4. Supports add a significant amount of time to the processing time and should be minimised even more.
5. With some design changes to the Computer Aided Design (CAD) model, the intersecting support could be eliminated.
6. Due to the Laser spot size, the hole diameters were smaller than the CAD model.

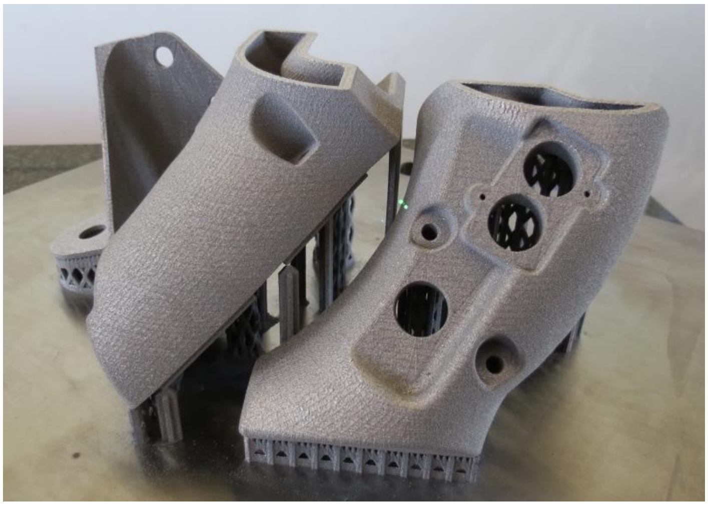

Figure 8: First test build

2.2 Second test build

For the second test build, everything that was learnt from the first test build was taken into consideration. The condition lever grip was also added. The following design changes were made to the original models:

1. Critical holes' sizes were increased by 200 μm to account for the laser spot size.
2. Added material to the part where supports could not be angled to avoid intersecting the part.
3. Added material to the part to eliminate the need for block support 1 to be angled.

During the build processing, the parts were all set at a height of 5 mm before adding the support structure. This addressed unnecessarily high supports of the first test build. The support structures were also broken up to make removal easier.

The second test build completed successfully. A few times during processing, it could be seen that some of the parts moved, most likely due to residual stresses. After removal of the build parts it was observed that some support structures broke free, shown in figure 10.

Figure 10: Second test build

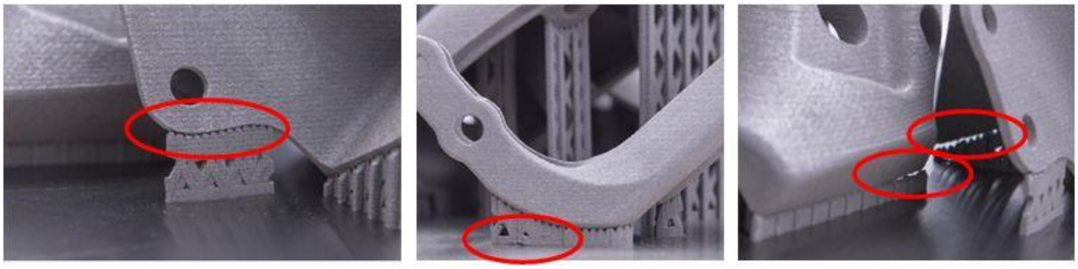

Figure 9: Partially broken support structures

Some supports were too thick and some of them difficult to remove and much post processing was needed in those areas where they were remove (indicated in figure 11). The parts moving during the process caused dimensional inaccuracies, which resulted in more post processing requirments to get the two throttle grip shells to fit together. This can potentially be fixed with better support structures and different support structure parameters, together with optimisation of the build orientation. For instance, one area where the supports were difficult to remove could be improved by changing the offset of the break point (teeth) of the support into the part. If this offset is decreased, the support would be easier to remove.

Figure 11: Areas with difficult support removal

These test parts were sent for microCT (3D x-ray imaging) to compare the actual parts to CAD data. The results are shown in figure 12. The black wire frame is the CAD model and the different colors show the difference in distance from the CAD model.

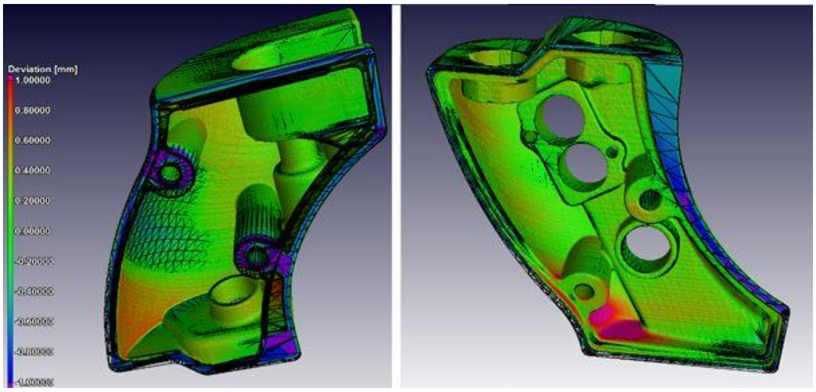

Figure 12: Comparison of microCT to CAD

3. CONCLUSION

From the test builds, many issues were encountered, for instance supports structures that were difficult to remove and parts moving during the process due to inadequate supporting. These issues will be addressed and a third build will be attempted in the future. Even though the second test build was successful, a lot is still to be learned regarding the support structure design strategies. However, it has been proved that the Aeroswift system is capable of producing functional parts.

Future work will be to optimise support structure design for Aeroswift and to have a set of design rules as a guideline to use when doing build preparation. Also, higher preheating temperatures will be investigated to reduce the residual stresses during a build. Build prediction software could also be considered and used to detect the possible build issues in a simulated environment.

REFERENCES (HEADING 1 ALL CAPS)

[1] Sames, W. J., List, F. A., Pannala, S., Dehoff, R. R., Babu, S. S. 2015. The metallurgy and processing science of metal additive manufacturing, *International Materials Reviews*, 60(6), pp 1-17.

[2] Materialise, viewed on 15 June 2017, http://www.materialise.com/en/software/magics