Summary

The AMRC Design and Prototyping Group (DPG) has developed a technique for using a stereolithography (SLA) machine to embed components that have not been additively manufactured into a finished product that is.

The technique was used to create a USB pen drive and has potential applications for manufacturing electronic and medical products, or for simply incorporating fixtures and fittings into parts. Designing additive manufactured parts to allow components to be embedded during the build process could reduce assembly times, whilst ensuring components are securely incorporated. The SLA process was chosen over other additive manufacturing processes such as fused deposition modelling (FDM) for the initial tests because of the low temperature involved.

Procedure

Generally, when additional components need to be inserted into a part after manufacturing, the part is made in two halves with added features to aid assembly. Encapsulating the components during the SLA build process may not only reduce assembly time. It also allows the components to be permanently and securely incorporated into the polymer, which may help to prevent dust or liquids from getting in and protect against impact in harsh environments. Examples of a part with both the component inserted after manufacture and embedded during the SLA process are shown below in figure 1.

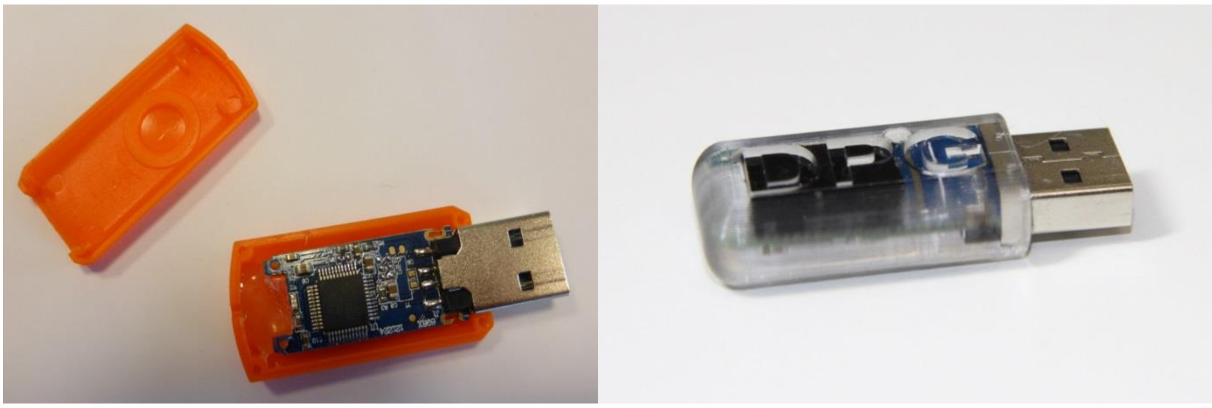

Figure 1 - Component inserted after manufacture vs. embedded component during the SLA process

The SLA process uses a UV laser beam to trace the cross-sectional pattern of the part being built, as shown in figure 2. The process is completed at a very high speed, so the total print time is more dependent on the number of layers within the part (its height) rather than the size of the cross-sectional pattern of each layer. Embedding components during the build process increases the height of the part as it is no longer made in two halves. Consequently, the build time is higher, compared with producing two halves side by side. A typical example of this is shown in figure 3, with the part built in two halves having 55 layers (5.5 mm) compared to 90 layers (9 mm) for the part where the component is embedded during the SLA process.

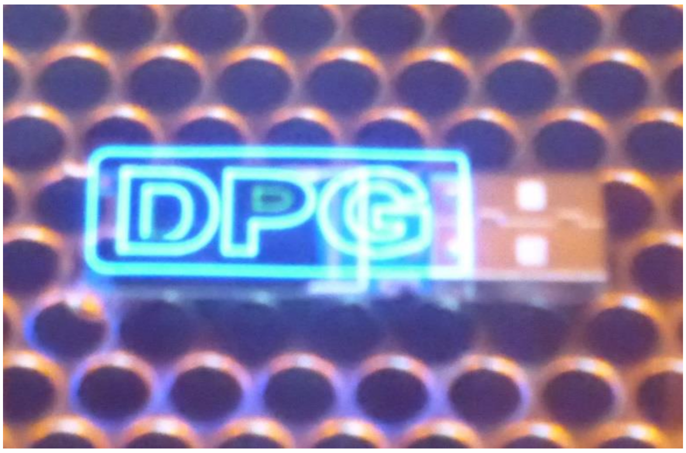

Figure 2 - SLA process encapsulating component

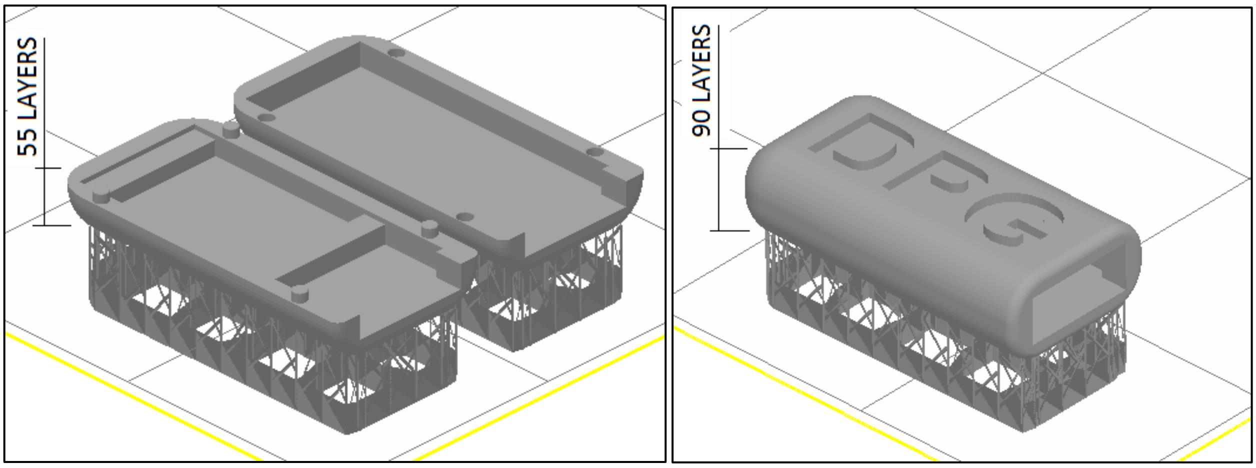

Figure 3 - Typical example showing the number of layers within a part if both built using the SLA process

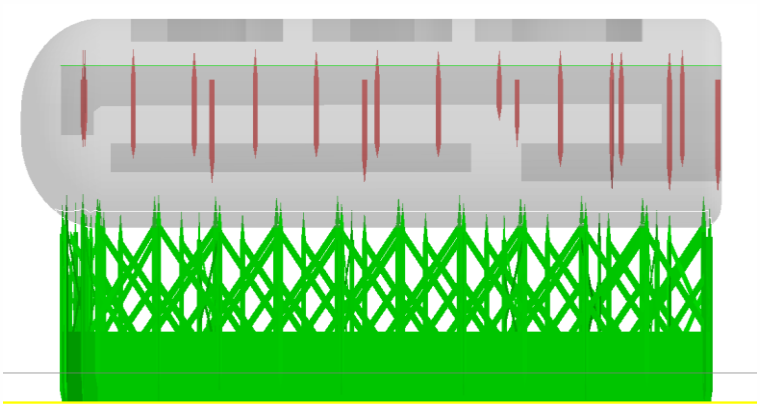

Figure 4 - Supports (shown in red) within part prior to removal during processing in the '3DManage' software

To prevent a build failing, it is recommended that support structures are generated for features with angles greater than 36° from the vertical plane. Consequently, support structures have to be built for any horizontal feature with a void underneath. Inserting the component during the build process eliminates the need for support material in the void where the component will be placed because the component itself acts as the support structure. Figure 4 shows the support material that was removed to allow insertion of the component.

Embedding components is carried out by removing any unnecessary support material within the file processing '3DManage' software, associated with the 3D Systems ProJet 6000 SLA machine. The build is then paused at the relevant layer height to fully encapsulate the component. The ProJet 6000 SLA machine builds in layer heights of 0.1 mm, the build was paused and the component inserted at layer 70 (7 mm) because it provided a clearance of 0.2 mm between the component and the top face of the void. This ensured the leveller did not contact the component and cause part damage or a failed build. A clearance of 0.1 mm was applied to all sides of the part to ease insertion of the component. Once the component is in place, the build resumes. The 0.1 mm and 0.2 mm clearance gaps around the component will be filled with uncured epoxy resin, which remains uncured until the post-processing operation of fully curing the part in the UV chamber. Prior to fully curing other essential post-processing work includes cleaning the part and removing support material. The 'USB pen drive' was then tested to ensure it still functioned correctly, as shown below in figure 5.

Figure 1 - Completed 'USB pen drive' test piece functioning correctly

Conclusion

Embedding components during the SLA process has the potential to reduce post-processing times by permanently securing components into parts without further assembly operations. Components encapsulated within SLA parts may also benefit by minimising the ingress of dust and liquid, or impact in harsh environments. The knowledge gained of embedding components within SLA parts will now be used in future design projects. Further work could include investigating potential protection benefits on a part in service, tests on the effect of reducing clearances to minimise the amount of epoxy resin left uncured within the part before post-processing and insertion of multiple components in a single part.

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