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Additive Manufacturing of Alumide Jewellery

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Abstract

Additive Manufacturing (AM) has been used for various jewellery applications in the recent past - both through direct and indirect use of AM products. The typical trend for direct manufactured jewellery has however, been dominated by metals-based applications. Materialise, through their MGX collection, has helped to set a new trend of doing functional design / functional art through amongst others, direct laser sintered polymers. They have created a significant demand for direct manufactured products that are not possible to manufacture with conventional technologies. More importantly, some of these designs enable an element of personalisation, to lead to "bespoke art".

Within a collaborative research project between De Montfort University (UK), Loughborough University (UK) and Vaal University of Technology (SA), one of the specific research outcomes was aimed at producing designs for direct AM jewellery in Alumide™, an Aluminum and Nylon matrix. The objective was to go beyond complex shapes, to also create innovative techniques for insertion of gemstones in these designs, to result in limited production of "bespoke jewellery series". The paper and associated presentation will report on work in progress from the collaborative project, and will discuss first results, problem areas and future possibilities.

Keywords: Additive Manufacturing, Jewellery, Innovation, Alumide™, Direct Manufacturing

1.0 Introduction

Additive Manufacturing (AM) has been used for various jewellery applications in the recent past - both through direct and indirect use of AM products. The typical trend for direct manufactured jewellery has however, been dominated by metals-based applications. This has largely been driven by the need to create high perceived value products to justify the high cost of using AM. Typically, consumers will see metal jewellery as having a higher intrinsic value than pieces made with polymers. However, it has been shown that high-value AM products can be made using polymers. Materialise, through their MGX collection (MGX, 2012), has helped to set a new trend of creating functional design / functional art through laser sintering of polymers. They have generated a significant demand for direct manufactured products that are not possible to manufacture with conventional technologies. More importantly, some of these designs enable an element of personalisation, to lead to "bespoke art" and higher perceived value.

Having established that non-metallic AM parts can have high value in certain markets, the aim of this work was to transfer this paradigm to the jewellery sector. However, rather than take a complete step away from metals, the decision was taken to use a metal-polymer composite known as Alumide. This was because the material, when polished, takes on an interesting semi-metallic appearance that could provide a novel aesthetic for jewellery design. This paper begins by describing some of the properties and applications of Alumide, goes on to report the design and manufacturing of alumide jewellery undertaken within this project, and finishes with some conclusions and suggestions for future work.

2.0 Using Alumide for Jewellery

Alumide is essentially a 50/50 mix of polyamide and aluminum powders that can be used in several of the laser sintering machines sold by EOS. When alumide powder is processed within the laser sintering process, the polyamide particles are fused together by the laser and the aluminium particles are entrapped in the resultant matrix. Alumide was originally introduced as a stiffer alternative prototyping material to pure polyamide as it has a flexural modulus that is more than twice as high (3600 MPa as compared to 1500 MPa). However, the high stiffness, semi-metallic appearance and good post-processing possibilities of the material soon led it to being used in other applications including simulated metal parts, wind tunnel models and injection mould tool inserts (EOS, 2012). It has even proved to be strong enough for a turbine impeller prototype tested up to 12,000 rpm (Campbell et al, 2011).

Alumide has already been applied to some jewellery pieces, including a necklace, bracelets, earrings and rings (Shapeways, 2012) (Flickr, 2012) (Inekeotte, 2012). However, none of the alumide jewellery found so far has contained any stones. It was the authors' belief that the addition of stones to Alumide jewellery would greatly increase the perceived value of the pieces. With this in mind, a range of semi-precious stones were purchased for incorporation into innovative jewellery designs (Figure 1). The stones varied considerably in size, colour and shape to facilitate a wide range of jewellery concepts.



Figure 1. Semi-precious stones purchased for concept exploration.

3.0 Jewellery Design Process

The project was approached as a multi-disciplinary design project with team members coming from backgrounds in fine art, jewellery design, industrial design and mechanical engineering. A brief was set to create innovative jewellery designs that incorporated novel methods of fixing stones into the pieces. An initial “round-table” discussion was held in which various aspects of the brief were expanded, including the target market, alternative stone fixation methods and what finishing methods could be applied to Alumide. Following this, the team members worked alone to generate some initial design concepts. Some members started their designs as paper sketches whilst others preferred to use digital tools such as software driven by a Wacom pen and tablet interface. Eventually, all of the designs had to be converted to 3D CAD models to facilitate laser sintering of the pieces. A number of the most interesting designs are discussed below.

3.1 Design 1: Tron pendant

This pendant design took its inspiration from a Sci-Fi movie and consisted of a hollow wheel within which a single spoke held a semi-precious stone in a tube setting (Figure 2). The wheel also contained several ball bearings that were free to rotate.

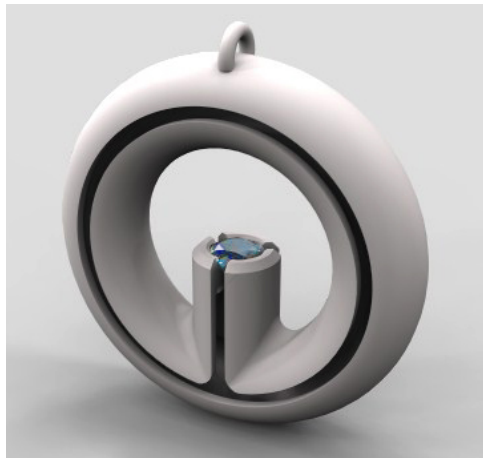


Figure 2. Hollow wheel pendant design with tube setting

3.2 Design 2: T.Rex versus the gorilla

This series of five ring designs was inspired by monster movies and each ring consisted of two figures locked together in mortal combat (Figure 3). The circumference of each ring was generated by the tail of the dinosaur being grasped by the right foot of the gorilla. The stone setting was achieved through the fingers and thumb of the gorilla's right hand grasping the stone, as if it were a weapon. The rings were designed alongside an animation that showed the fight sequence with each ring in the series depicting a different stage in the sequence. As a consequence, the poses of the creatures are different in each design iteration. The computer graphics industry technique of rigging was used to animate the sequence. Using CAD, skeletal frame rigs were constructed within character polygon meshes derived from freehand tablet-based digital sculpting (Figure 4). The monster characters were then manipulated via the skeletal rigs through a series of key strike positions previously established using human actors in costume. A key frame animation was then used to extrapolate between these orientations creating a seamless movie clip. Five key frames in particular were identified as poses from which tangible design iterations would ultimately be generated.



Figure 3. Inspiration sketch for fighting monsters design

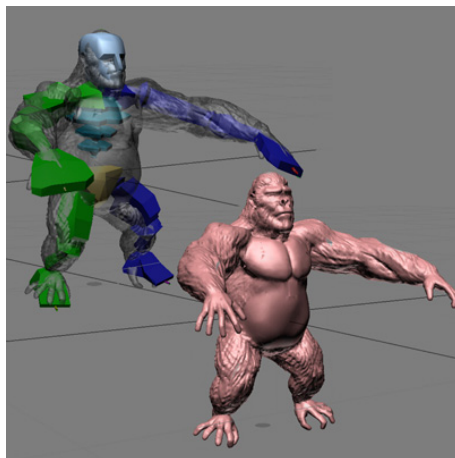


Figure 4. The rigging of the gorilla mesh

3.3 Design 3: Memories

This series of ring and pendant designs consist of interlinked assemblies of rings bunched in seemingly random clusters. The design facilitated a degree of personalisation in that customers could select from a range of individual rings that would be assembled into the composite piece (Figure 5). The ring components would exist as 3D CAD models in a digital repository which would be perused by would-be buyers in an on-line experience. A selected collection of rings would be virtually assembled to form a composite geometry that could be “printed” as a physical object. The rings selected could have some sort of personal relevance to the customer, e.g. in evoking memories of past events. Alternatively the buyer could attempt to steer the design direction e.g. by favoring more ornate components and avoiding minimal ones. In this way the designer seeks to engage the consumer in the creative process which, it is hoped, could lead to higher emotional attachment and perceived value (Schifferstein and Zwartkruis-Pelgrim, 2008).

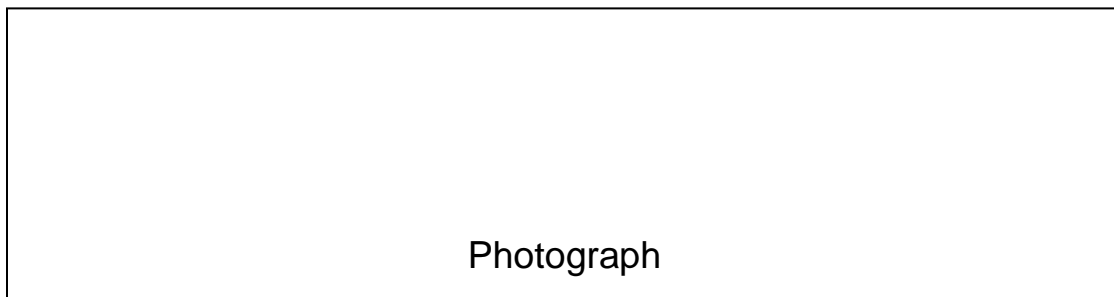


Figure 5. Assembled collection of 3D ring models

3.4 Design 4: Storm

Storm was inspired by a type of percussion instrument used by African Bushmen in which dry seeds tied to the legs are used to make sounds whilst dancing a “Rain Dance”. The concept featured gems rolling inside a tube that would be periodically revealed through viewing holes. The stones represented the seeds of the tribal percussion instruments. This concept was combined with a further African influence: the bulky metal designs of Trade or Currency jewellery that serve as commodity money.

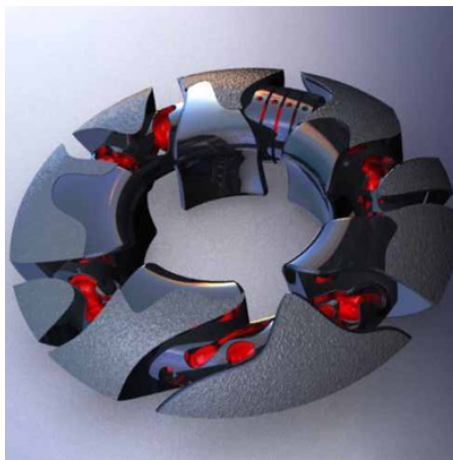


Figure 6. The Storm kinetic bracelet

4.0 Manufacturing Issues

All of the jewellery pieces designed were manufactured in Alumide on an EOS Formiga laser sintering machine. Each presented its own set of challenges both during manufacture and in the processes which followed. As each of these challenges was addressed, the knowledge gained helped to indicate the limitations of this approach together with the directions in which future research should proceed. The most important issues encountered are discussed below.

4.1 Alumide material in a jewellery context

Alumide has a higher density than PA2200, giving parts greater mass. In a jewellery context this contributes to a perception of higher value in itself. Weight becomes a significant factor in pendant pieces such as necklaces and earrings where the mass tensions a chain or orientates the design. The manner in which the designs lie or hang and their movement contributes further to impressions of quality and value.

The natural finish of the Alumide material was a grainy, matt, light grey appearance, not dissimilar to sand-cast aluminium. Amongst the design team there was general agreement that this finish was unsuitable for jewellery, both from an aesthetic viewpoint, and because it would tend to trap dirt over time. As a result, a number of finishing techniques were applied to the Alumide to make it smoother and to create an interesting appearance. Alumide exhibits a metallic lustre when filed or polished; this allows an approximation of solid metal parts without the high costs of direct metal laser sintering (DMLS) whilst maintaining the geometric freedom of polyamide. Lustre is a quality associated with jewellery and gives an increased perception of quality over the somewhat dull polyamide. Polishing can be automating using traditional barrel polishing with abrasive media. This process eliminates the need for hand-work although it is not possible to selectively polish and therefore sharp design features will be diminished. Unpolished, the Alumide parts are considerably rougher than those of PA2200. It is also possible to dye the Alumide. As the dye affects only the polyamide matrix, the sparkle is undiminished. Figure 7 shows a series of dyed swatches.



Figure 7. Dyed Alumine samples courtesy of 3D Worknet B.V.

Alumide provides an alternative to metal plating although it cannot match the surface finish of plating on pre-finished parts. It renders a more durable finish, although it is inclined to oxidize rapidly due to the large surface area of the aluminium in powder form. Whilst an aim in additive manufacture has to be the reduction if not elimination of post – finishing, it was noted that Alumide was considerably easier to grind, sand and polish than pure PA2200. The presence of aluminium allows more rapid dissipation of heat during cutting and grinding, leading to less smearing and melting. Weaker bonds between molecules in the Alumide material also allow for easier material removal.

The accuracy of Alumide parts appeared to be somewhat sensitive to orientation in the build volume with certain details being dependent not only on alignment to build strata, but also on rotational placement around the Z-axis. Certain features become deformed compared to identical features placed on the opposite side (front or back, left or right) of the build platform. These deviations are not present when the same parts are sintered in PA2200.

Alumide has a lower tensile strength than PA2200, probably as a result of the lower bonded particle count of the former. It is therefore more likely for small details like claws and clasps to break easily during gemstone fitment or even during cleaning of the parts. Sprung clasps and claws require an amount of flexure which appears to be beyond the capabilities of the Alumide material, when applied to such fine structures. More robust and solid designs seem to fare better, as the bulk of these structures compensate for the lower material strength of Alumide.

4.2 Setting gemstones in Alumide

Setting gemstones is a skilled process involving a plastic deformation of material to entrap the stone on a pre-prepared seat. The process is carried out after the design itself has been created and, as the material is hand-worked to suit the stone, it can accommodate variations in stone size. Alumide cannot be reformed in this way nor can material be added by soldering. Additive manufacture does however allow the integration of mechanisms. A number of different strategies were employed in the jewellery concepts created.

4.2.1 Tube clip setting

An adaptation of the traditional tube setting was used in the Tron pendant design. The concept differs from that normally used in metal jewellery in that there was no plastic deformation of material over the crown of the stone to create the fixation. Instead, there was a slot in the tube which allowed it to expand to receive the stone and then to close again holding it in place. To a degree, this was acting like a conventional tension setting except that the material was returning to its original shape after the stone has been set. In a conventional tension setting, the metal would remain partially deformed, hence exerting a continuous force on the stone. This was avoided in the design for Alumide since it was anticipated that any such force would gradually dissipate over time due to stress relaxation of the material. This could lead to a loosening of the setting.

Several alternative geometries were built in an attempt to balance the force required to fit the stone with the security of the closed clip (Figure 8). Forcing open an excessively tight housing risked damaging the stone or permanently deforming the Alumide. The reduced elasticity of Alumide over PA2200 provided a significant drawback in this methodology.

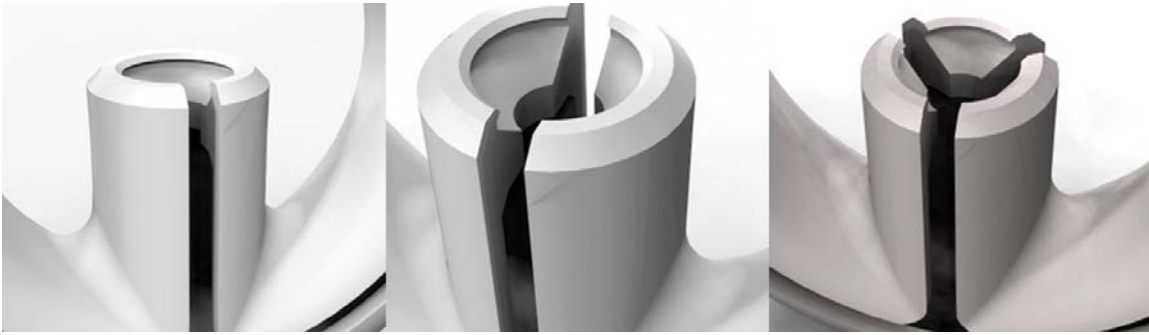


Figure 8. Tube clip experiments

4.2.2 Radial claw clip

This concept was again an adaptation of a metal jewellery technique: the claw tension setting. Once more plastic deformation in the metal was replaced by an elastic clip. The concept was a radial array of claws designed to deform easily in one direction only. This movement allowed the stone to pass within the claws and onto the seat. The claws could then spring back over the crown of the stone securing it (Figure 9). The multiple point fixing of this design coped well with any inconsistencies in stone size and geometry. The concept can be adapted to a wide variety stones though at smaller scales the individual claws become too weak. Tests were conducted in both Alumide and PA220. The Alumide provided particularly prone to failure at smaller scales suggesting that designs in this material will only be successful with larger settings.

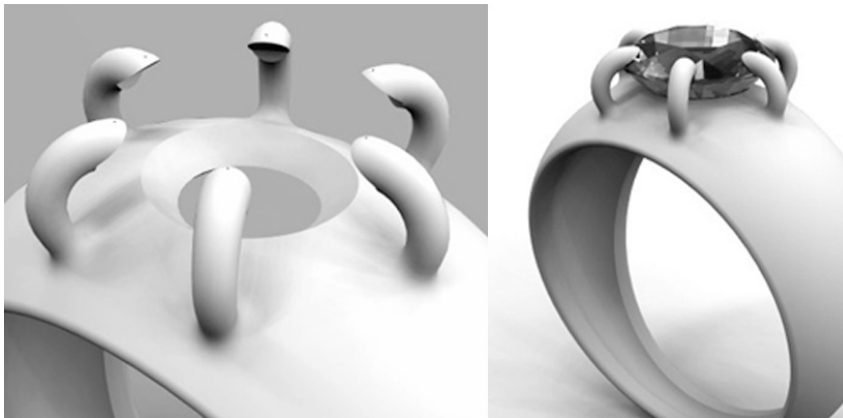


Figure 9. Radial claw clip

4.2.3 Metal setting sub-assemblies

In this case a metal claw was created that would be deformed to grip the gemstone in the traditional manner. The metal claw would then be bonded into the Alumide via a keyed fitting. This methodology eliminated the problems associated with stone tolerances and any conventional setting method could be employed (Figure 10). In the case of larger stones the visible metal detail arguably accented the design and added an extra level of interest. This fitting does not however fully exploit the potential of Additive Manufacture as additional components are needed to achieve mechanical function and it requires post AM production hand work.



Figure 10, Metal setting sub-assemblies

4.2.4 Sliding grid locking mechanism

In the Rain jewellery piece the stones were free to move. This required a closure mechanism to trap the gems within a vessel rather than a setting. This presented an opportunity to exploit the design flexibility of AM and to integrate a complex mechanism into the part. The locking mechanism consisted of a “sliding grid” (Figure 11). The sliding grid consisted of four cylindrical tumblers over a central tube. In order to insert or remove gems the tumblers must be precisely aligned with a hole in the tube. This requires the use of a dedicated tool. Once the gems are loaded the tool is removed and the links rearranged. The gems cannot then be removed unless the tumblers are deliberately aligned.

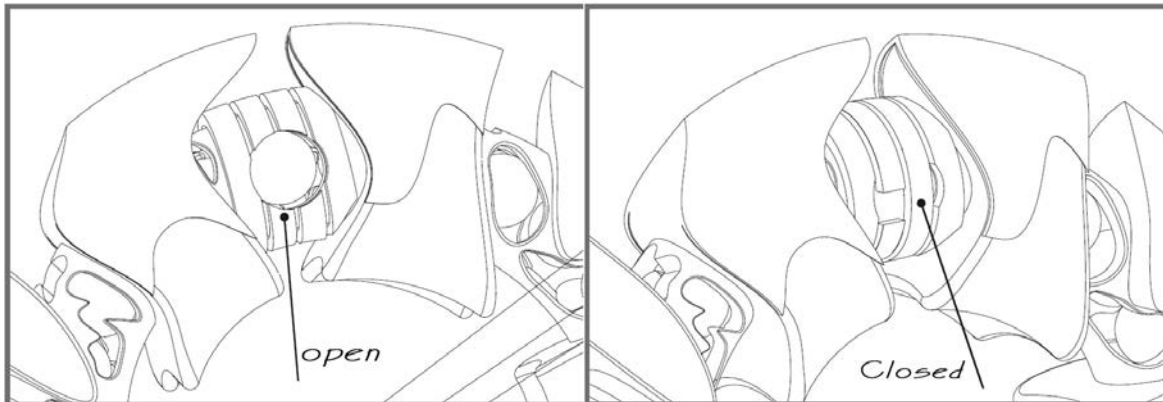


Figure 11. Sliding grid mechanism

5.0 Conclusions and Future Directions

Variants in stone size coupled with the layer thickness resolution of the manufacturing process would seem to mitigate against the use of snap fits for smaller stones; this methodology proved successful for the larger gems however. More substantial details such as the walls of the tube clip fitting proved more reliable than finer details such as the claw clips particularly with smaller stones. This highlights a need to design for the material rather than carry over features from conventional manufacture. The aesthetics of the industry however focus on exposing the stone with a minimum of material used to retain it. Alumide seemingly has weaknesses that limit its application to fine jewellery components. PA2200 tends to be more suited to these delicate components, at least mechanically. Reduction in particle size may improve Alumide's performance in this application. Concerns were expressed by several contributors over the reliability of the snap-fits, in particular their stability over time and resistance to creep. The issue is in balancing the design investment with the material value of gemstones. Clearly, valuable stones must be safely retained. Future work should include testing over extended periods of time. There should be an exploration of more substantial fittings better suited to polymers. As well as increased functionality, this could lead to new aesthetics and to a greater acceptance of Polymer AM products in the market.

There is clearly a need to engage the public with the design process and the creative benefits that new AM materials bring. The Memories design collection sought to elicit a level of consumer-product attachment through time invested in the detailed selection of components. Mugge shows that the amount of effort invested in personalising a product has a direct effect (as a result of the extended period of time spent with the product) and an indirect effect (via the personalised product's self-expressive value) on the strength of the emotional bond with the product. (Mugge et al, 2009). The potential for consumer engagement in this concept goes beyond selections for individual pieces to the content of the library itself. There would be the possibility of users supplying their own models for inclusion. These may be designs created by the customer themselves, models they have acquired or real-world objects that have been digitally captured in some way. Components contributed to the library could be offered to other buyers with an incentive given back to the creator in a business model similar to that of content sharing websites such as Turbosquid or as an open-source format (Dean and Pei, 2012).

The trans-disciplinary nature of the team provided a fruitful collaboration combining novel aesthetics with engineering functionality. The project illustrates the potential for designers to exploit the common digital platform of the creative industries and to adopt and adapt foreign practices. The T-Rex versus the Gorilla for example shows how animation techniques from the computer graphics industry can be exploited as product design tools.

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