Making it personal

Creating one-of-a-kind luxurious products with metals AM

Pjotr
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As part of TCT's look at AM in metals we came across a new project by Rein van der Mast — Pjotr pens. Using his 'Cavalry' pen as a proof of concept Rein has been able to demonstrate that selective laser melting in titanium (with the help of other additive and non-additive processes) can be employed to create bespoke high-value artifacts today. With a passion for the project and the 'subject' of his pen, Rein was able to overcome some significant technical challenges while developing novel design, production and finishing methods.

According to Rein van der Mast, additive manufacturing is about to become an important ingredient for product customisation. He would like to demonstrate this proposition with the fountain pen. For this, he has nearly reinvented this precious writing tool.

Supported by Materialise, LayerWise and Innplate, Van der Mast successfully produced an exotically sculptured product in such a way that every single product is one of a kind. This includes unique pieces and small series of pieces, where each item is slightly different. He crossed the borders of known technological solutions multiple times. With the Pjotr pens, he is able to deliver his 'proof of concept'.

Rapid News, Time-Compression Technologies, TCT

"When I was young, I played with Lego and Fischertechnik. My parents took me to various museums filled with paintings and sculptures, which are things I still enjoy seeing. I like mechanical things because of the way in which they interact with their environment, both physically and aesthetically. When something mechanical looks ugly, to me it feels like it will not perform well. So after high school, I studied Industrial Design Engineering at the Delft University of Technology."

Van der Mast became aware of the existence of the 'time-compression technologies' when he came across a copy of Rapid News (nowadays known as TCT Magazine) at the CIM Center of the Mechanical Engineering faculty (CIM stands for computer integrated manufacturing). Van der Mast reminisced: "It was all about building objects 'additively' without moulds or subtractive machining. In my eyes, this was something revolutionary and its potential struck me deeply. Back then, I think it was in '94, it included rapid prototyping and a bit of rapid tooling.

Brittle pieces

After obtaining his degree and completing military service, he lead the engineering department of a manufacturer of sustainable consumer goods for a couple of years. One of his projects involved the redesign of a portable lantern with a solar panel optionally attached to it, designed for the Finnish oil company Neste. This lantern was intended for civilians living in third world countries. Van der Mast explained: "I first introduced 3D CAD. At that time, I had worked with AutoCAD 10 under DOS up to 14 under Windows. So I naturally opted for Mechanical Desktop, which was pretty similar to AutoCAD, for both surface and solid modelling. In '96, this made me one of the first Mechanical Desktop users in The Netherlands." He also introduced rapid prototyping for creating small series of 'functional' prototypes.

Van der Mast continued: "Materialise made them for me in '97 with the .STL files I had FTPed to Leuven. AutoCAD users probably remember the 'facetres' command for determining the average triangle size, as well as the file size. The parts were made in Leuven using stereolithography."

At that time, pieces like that were brittle, sensitive to UV and geometrically instable. Because of all this, Materialise used the prints to create silicon moulds and filled the moulds with polyurethanes to generate realistic parts, including a colorless, transparent lantern 'glass'. The results were much better than he had hoped for, and the items were sent to Neste and were also demonstrated at various trade fairs by Materialise.

Customisation

"After having worked as an employee for a while, I felt it was time for me to become an entrepreneur, to focus on industrial design engineering enhanced by additive manufacturing, to create knowledge and to share it with others. However, in '98 it was too early for me to start a business based exclusively on 'time-compression technologies' as they were still

For the shagreen finish on the bespoke pen case Van der Mast developed a new finishing technique with Materialise

refered to (nowadays better known as 3D printing and additive manufacturing)."

Later, when 'rapid' became 'additive', the focus of his business slowly shifted back to additive manufacturing, mass customisation and on creating suitable business models with both technologies. Van der Mast explained: "Manufacturers of consumer products have finally started listening to individual clients. This is made possible by the Internet. When manufacturers digitally link all their machines and stocks, they can have every single product configured separately. This can, of course, be done without any kind of additive manufacturing. But in some cases it can be rather appealing to have the individual customer decide on the final shape of a part, as he probably prefers this, rather than opting for a general design. In this case, additive manufacturing is very well suited."

Digital sculpting and 3D printing

Van der Mast tries to connect additive manufacturing to customisation wherever possible and once proven, he started producing, using the successful methods that he had found.

"I found a product that matched perfectly: an item that is luxurious, certainly when personalised, and well paid for. A product that truly combines art and technology: the fountain pen.

"By creating every single object as something unique means that every piece needs to be designed separately. Of course, the time spent on design may be less if only small aspects vary, the same templates are used, or in the case of relational dimensions or interdependent variables, etc. All of this, however, dramatically reduces the exclusiveness of the output. So in my case, a significant part of the costs lies in the design," said Van der Mast.

Van der Mast came up with a concept in which generally the essential parts differ only slightly. Small series and even single pieces would be made based on themes requested by clients. Small series would include several differing elements, such as the user's monogram or initials, in 3D, only much more pronounced than with an engraving.

Cavalry

For the first pen, his proof-of-concept — him being his own first customer — he chose a theme close to his heart, so that he would never feel any adversity to what he was doing because of the theme, even in the case of serious setbacks. As an experienced horseman and mounted cavalry reservist and sometimes escorting members of the Dutch Royal Family, he opted for cavalry as his first theme. He started with charcoal on paper, without using any digital tools. As the patron saint of cavalry is Saint George, he added the depiction of this legend, which includes a princess, a man named George and a dragon that likes princesses for dinner, as well as elements of traditional cavalry (swords, lances, uniforms, horses) and modern cavalry (tanks, regiments), all in 3D. He finally included two lines from an old French adage: "A nos Femmes, à nos Chevaux."

As he had decided to include sculpturing, he needed a sculptor and turned to animation software, in order to generate the type of free form shapes he had in mind.

"I found a very talented digital sculptor in Moscow called Evgeny Bazurov, who knew all about handling software like 3DS Max, Houdini and Z-Brush. The materialisation of virtual geometries by additive manufacturing was new to him. His output had been solely to screen and include things like TV commercials. So I sometimes had to tell him that parts of his model could not be made, and corrections were swiftly effected."

Triangles

Van der Mast expanded on some of the challenges associated with creating the unique geometries of the Cavalry pen: "In case you cannot copy the shapes that surround you by scanning, and you have no access to appropriate digital shapes instead, then you have to rely on software for creating them artificially. This takes time, like it takes a sculptor a lot of time to shape a stone. There is, however, one significant difference: there is no undo button on the stone. But there are various tools to facilitate the task of virtual sculpting.

"Since I needed the geometry in Rhino, we had to export the data in a generative format; the .OBJ format, which not only cuts away all connections with the tools we had applied, but also produced much larger files of over a couple of hundred MBs up to 2 GBs."

In the end, the part including the princess consisted of millions of triangles." He used Materialise's Magics and VisCAM to reduce this number and to manually handle some minor geometrical improvements. Both could deal with the amount of data very well, including their routines for improving the quality of the 3D data. Reducing the number of triangles by replacing numer-ous small ones by a smaller number of large ones wherever possible does hold a serious risk: when morphing segments of the surface — sometimes one needs to do so at a very late stage in the process — those large triangles may become individually visible.

Titanium

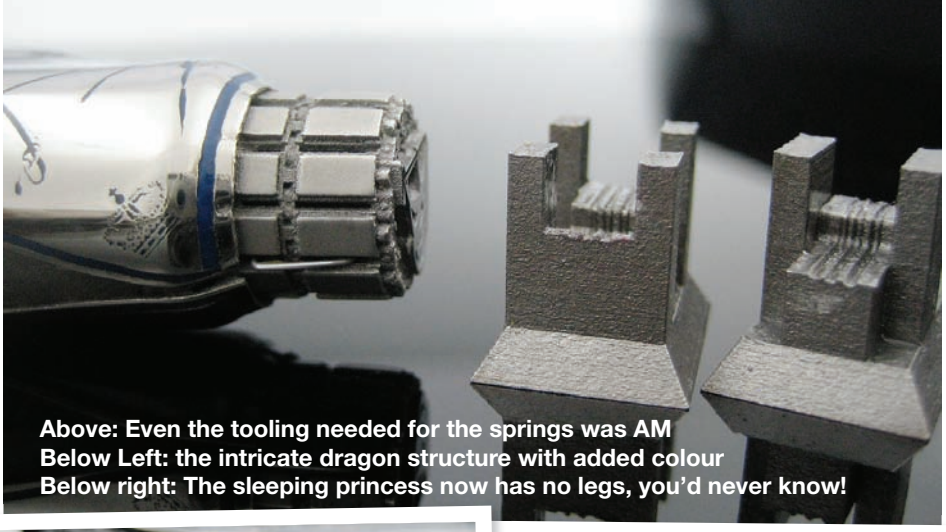
"Of course by then I had already decided what production method and material I would use: selective laser melting and titanium, because of its weight and strength. LayerWise and Materialise, a successful spin-off of the university of Leuven, Belgium, would assist me. I would add enamel to the titanium parts so these would include colours. Tests showed us that filling tiny engravings with enamel is certainly possible, although it costs a lot of time to correctly fill them. As you probably know, enamel has to be applied in an oven. Titanium does not like such an aggressive environment and comes out blackened. Enamel can be very bright, even sparkling, but in general that does not compensate for the time it takes to apply it." He subsequently switched to another pretty hard material. "A little less sparkling, but much easier to apply!"

Van der Mast: "As I was used to laser sintering in PA12, I wanted to see if with laser melting I could print an assembly of all parts at once, including hinges. But I had underestimated what melting titanium powder does on top of unmelted powder. It sinks! It is quite difficult to remove such a support structure from inside a tiny hinge, situated in the small space between the hole and the axis. So nothing rotated in the resulting pieces, not a single thing!" He finally had to conclude that a lot relates to the applied scanning method. It would be better to combine multiple methods within the same print job and have it automatically selected, based on what part of the geometry's surface needs to be 'materialised', even multiple methods within the same layer, if required. The print direction has significant effects on faces and edges, as well as on temperature related deformations.

"One must carefully consider all of these effects when designing such geome-tries."

Surface

"I had to come up with an alternative for the printed hinges that came out of the machine and which were completely stuck. In the case of the tiny spring used for holding the cap on the other end of the pen whilst writing, I created a little press for deforming a piece of steel wire. LayerWise printed this press, and it works



Above: Even the tooling needed for the springs was AM
Below Left: the intricate dragon structure with added colour
Below right: The sleeping princess now has no legs, you'd never know!

perfectly." For connecting the clip to the cap with an axis and a spring inside the cap, Van der Mast designed a part that is printed using stereolithography. Van der Mast: "This part is inside and holds the axis. It does not leave scratch-es on the polished parts covered by the cap, instead of having to use some kind of solution with titanium sliding over titanium."

The titanium surface proved to be very hard to flatten. Van der Mast: "Tiny sculptured faces are particularly hard to polish accurately. Because of the applied scanning method, individual layers were quite visible. So I had to find an effective method for eliminating this problem.

Someone I knew at TNO advised me to call Robbert de Greef, owner of Innplate." Innplate's business lies in adding precious metals to surfaces, as well as polishing objects with chemical and galvanic processes. Together, they found various new and potentially robust methods for flattening printed metal surfaces, but these all turned out to be insufficient for dealing with the titanium parts due to the applied scanning method.

As he was experienced in injection moulding, he decided to manually fix the surface, using methods that are commonly applied for pre-hardened steel moulds. After polishing, some parts were glass bead blasted.

Pen case

For the case, Van der Mast came up with a cavalry-related shape, the first theme: the giberne, close to its actual size. It is a silver attribute of today's ceremonial cavalry uniform.

"For the inner part, I turned to rapid tooling. Materialise provided me with a negative, which I used to build a mould." He treated this mould with a release agent and filled it with silicon rubber, after adding pigments and hardener, and removing all air.

Van der Mast applied a manifold hinge of 16 parallel sword blades and combined the box, the hinge and the cover into a single 3D print.

"The most thrilling aspect related to the box," he continued, "was however not the hinge, but its surface finish. After my experience with the surface of the titanium parts, I did not want to spend a lot of time on that. So I needed a texture to mask all laser sintering related roughness. In cavalry, there is only one appropriate texture: shagreen, made of the skin of the stingray, a fish closely related to the shark." He ran various tests with Materialise and found a new way of surface finishing.

Pjotr pens start at €7,000.00, depending on the complexity of the design and additional materials applied, like precious stones. Van der Mast: "In this concept, the customer decides what his or her design should look like. Or better even, the customer can tell me exactly what he wishes. With his preferences, I can demonstrate how the theme can best be depicted, also considering the budget, and if he agrees, it can be made."

Explaining the scope of the concept, Van der Mast explained: "Perhaps one has no connection with cavalry whatsoever. Well, that is part of the concept. Pjotr pens are either unique or one of a small series, with at least one significantly differing element."

Conclusion

Was it worth many hundreds of unpaid hours? Van der Mast concludes: "It most certainly was! I have come up with a pretty significant proof of concept, for which I am grateful to the people who have contributed. If I have to rebuild it, the result will surely be even better, as a direct result of all the lessons learned. I will start producing these pens very soon and sell them worldwide. I admit that this project was driven by a technology push, rather than a market pull. I believe this to be the only way, with so many new elements in one product. I have found some new ideas and methods and have acquired a tremendous amount of knowledge. It is now time to capitalise on this!"

Pjotr is a trademark of SOLide (a consultancy and research organisation dedicated to customisation and additive manufacturing including on-demand part and spare part production) and covers its activities related to producing high quality fountain pens using digital sculpting and 3D printing.

Rein would like to thank the following people:
- Bart Van der Schueren, Materialise, Leuven (B)
- Staf Wuyts, Materialise, Leuven (B)
- Marc Duhayon, Materialise, Leuven (B)
- Jonas Van Vaerenbergh, LayerWise, Leuven (B)
- Wilfried Van der Perre, LayerWise, Leuven (B)
- Robbert de Greef, Innplate, Geldrop (NL)
- Christine van der Ree, Amsterdam (NL)
- Paul Rutte, P.W. Akkerman, Den Haag (NL)

... and last but certainly not least:
- Evgeny Bazurov, Moscow (RUS)
- his girlfriend Ellen van 't Zelfde, for her patience (NL)