DANISH
TECHNOLOGICAL
INSTITUTE

SELECTIVE LASER MELTING
&
RAPID MANUFACTURING

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Abstract

Selective Laser Melting is one of the latest Rapid Prototyping and Manufacturing Technologies. The technology is able to weld metal powder layer by layer and achieve the same quality as within the traditional metal technology. Like all new technologies, this is opening many new possibilities, but unfortunately many questions as well. The presentation will describe the technology as well as some of the parameters which can influence the results. Powder disparity, density or temperature can bring some quality problems in the final part, the power of the laser, the speed and the focus can have advantages, but are they that easy to control?

These parameters will also be presented compared to a special product that Danish Technological Institute has developed for a company. This product produced in AISI 316L is presenting some of the advantages of the SLM, a world between sintering and welding. The presentation will try to answer some of the questions of the future of these technologies, also in relation to a quality and production perspective.

Introduction

The dream started a few years ago when the first diagrams representing the production of plastics parts compared to the production of the same parts on a RP machine emerged in an EU project. The most fascinating thing was that the curves of that diagram were crossing about 1000 parts and at that precise moment, everybody started to believe that RP machines were going to produce millions of plastics parts. But nothing really happened afterwards. Materials were partly responsible, but the opening to the east and the reduction of the mould prices also occurred in the equation. Another important point in the equation was and still is the manpower necessary to finish the parts on RP machines.

Danish Technological Institute (DTI) has been involved in many projects concerning Rapid Tooling and Rapid Manufacturing, and DTI history started with a success; a customer who produced for thousands of € on our Actua, then Thermojet and finally SLS. The interest was suddenly not only the price but most of all the function. The manufactured parts were corresponding better to the production, the reduction of the delay; reduction of stock and the continuous optimization were also mentioned as advantages. And all together, the equation was presenting the RP production as the best choice. The light was maybe coming, but once more it was a quite narrow industry.

Anyway, the solution was there as well as the equation and the parameters; and anything else was necessary for us to believe in regarding the RP future.

Definition of Rapid Manufacturing (RM)

Rapid Manufacturing (RM) has been used in many different ways which is the reason why it is important to define it.

Rapid Manufacturing: Is the production of parts for the end user, produced directly or indirectly with the help of RP machines. The important point is that the part will be used by the end user, and will be sold as a finished part.

Terry Wohler's definition could have been used as well: Rapid Manufacturing is the direct production of finished goods directly from a Rapid Prototyping device.

Low volume production or one of the other terms emerging on the market could also have been used. Production should be the right term but the name was not responding to the fact that the project was dedicated to RP machines, and customers are still only seeing the RP technologies in a prototyping way.

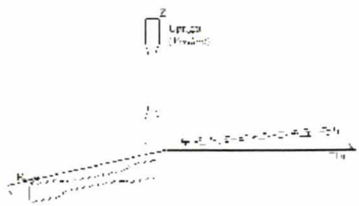
Layer Manufacturing

Most of the RPT/RM machines are based on the layer manufacturing; the production of parts will be made layer by layer. These layers can be from a few microns to a couple of hundred microns.

The part created with the help of a 3D CAD program as ProEngineer or Solidworks for example, will be slices in these layers, then the information will be sent to the machines. In fact the information sent to the machines is quite simple and most of the time it is only a 2D sketch of the contour of the part.

The layer by layer technology has many advantages, but it brings even more equation about the final parts. In some cases we can speak about a direct disadvantage as the final part will have some inhomogeneous mechanical proprieties due to the layer fabrication. As an example, you will notice the difference in a plastic part made in one of these technologies compared to the direction of fabrication.

All the parts built for tests in this report respect the dimensions of the standard ISO 527-2(E) named "Test conditions for moulding and extrusion plastics". Currently, there is no standard concerning the RP materials.



Results of the layer orientation tests:

	Flat	Edge	Vertical	45°
Young's Modulus (MPa)	2972	3160	3130	3232
Maximum Load (kN)	3.11	3.07	2.32	2.8
Tensile strength at maximum load (MPa)	71.83	76.36	59.8	70.29

Selective Laser Melting Technology from MTT

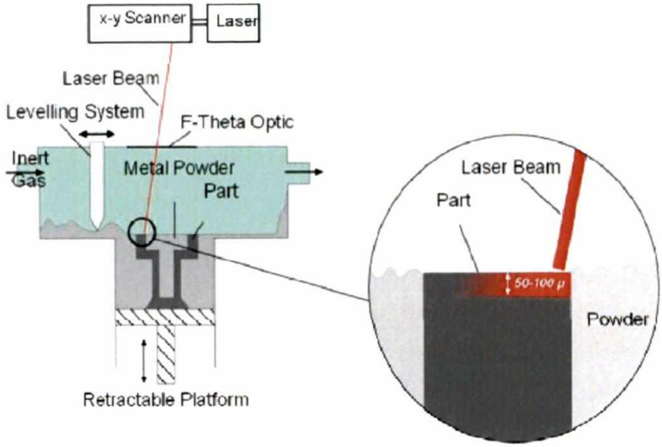
Within the last few years, and due to the development of the power of the lasers, it has become possible to weld metal together. Not only sinter it, but get beyond the melting point.

There are two tendencies in the metal layer manufacturing. Europe has chosen to produce in a metal bed, whereas the US and Canada decided to explore the projection of the powder during the process.

The main advantages of the powder bed are the accuracy and the surface of finish but it gives some restriction in the dimensions. On the contrary of the deposition of metal which permits to produce much bigger parts, but have some issue about the accuracy. In fact these technologies are producing Near Shape, meaning that finish by machining will be necessary.

The following point will be representing the SLM technology from MTT, former MCP-HEK, but most of the other technologies from EOS, Concept Laser or Phenix will have the same parameters. The company Arcam from Sweden is differencing by using an Electron Beam Melting technology.

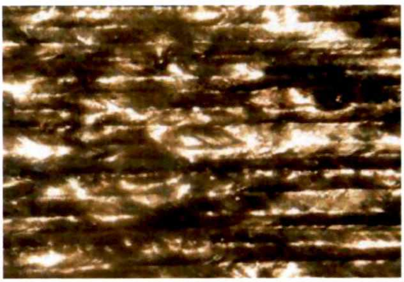
Principle of a SLM machine with IR Fiber Laser:

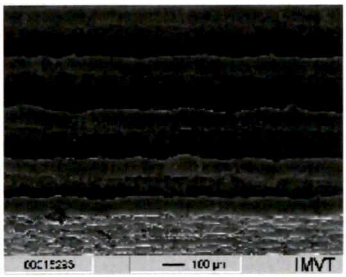


The material

The good point about the SLM technology is that the material is completely standard. Like all the other RP technologies, it is not developed for the process.

Most of the metal that can be welded can be used on one of these systems – today the most common are stainless steel (Aisi 316L), tool steel, inconel, titanium and aluminium. The point is not so much which material you want to run, but most of all to find the right parameters to run it, the right application, and to find the powder. It is a welding technology, so welding lines will be visible on the parts.





Parameters

Typically, technologies involving laser bring a lot of adjustments and possibilities, but laser also brings an unstable system when talking about a regular production. Danish Technological Institute is actually working on developing a system to regulate these parameters, and to bring a better understanding about the complexity we will bring some of them. We can classify parameters into three kinds.

Parameters related to the material:

- Process of fabrication of the powder (atomization, gas)
- Chemical composition
- Purity of the powder
- Geometrical form of the powder (most of all spherical)
- Surface propriety of each particle
- Humidity
- Density
- Thermal coefficient
- Fluidity.

Parameters related to the machine:

- Chamber temperature
- Inert gas in the chamber (or maybe no gas at all)
- Layer thickness
- Volume of powder.

Parameters related to the laser:

- Power
- Speed
- Beam expender
- Diameter of the laser spot
- Welding strategy
- Length between two points
- Time of exposure of each point.

RP technologies as a production

The repeatability is almost impossible to obtain. The position of the part on the platform, the power of the laser and many other parameters are against it. The point is that the parts are in the dimensions respecting the specifications of the constructors and that is what should be presented. But there is much more in it than just being able to produce it: the finishing of the parts compared to the specification of the customer. Most of the RP machines are developed to produce prototyping. This involves that the manual work has been accepted as the only solution to finish the part. The point is not a problem itself but it will become a problem when the economical equations are made. A solution could be to develop machines to clean and finish the parts automatically.

Naturally, you have many advantages from using RP machines as production. Moulds can be forgotten, stock can approach zero and products can always be better in the next series.

The freedom of fabrication is also an important matter. This means that you can produce almost the form you wish without thinking about the production process. The only problem is that many engineers do not think of the possibilities of RM until they are almost ready to order the moulds. This was actually a reason mentioned by many of the people we interviewed. When they approached deadline and the project was about to go into production, which way would they choose? The secure way or the risky way? Even if the risky way is ten times cheaper, most of them will take the traditional way, the one they have been using for the last 20 years, and somehow it is easy to understand that they are not taking the risk. This reason leads us to the next parameter and the worst enemy of RM today: Ourselves!

Cultures among engineers

Culture and the locked process of product development are the biggest difficulties when introducing a new process. Of course few companies have started the process, but in most cases it has involved a strategic decision about the product. The question about using RM is involving much more than just deciding to use it. It involves getting to learn new materials, new ways of designing parts and new ways of thinking as well. The decision of using RM technologies should come in the stages of specifications, before the first drawing is made. But to do so, companies will need more information about how to decide the right way to produce parts, including economical and real material specifications. But culture takes the longest time to change – thus RM needs to be patient and proof its advantages.

Danish Technological Institute is coordinator on a European project called Compolight which aim is to deal with some of these issues. The project will work with the simulation of the process to reduce the percentage of scrap produced today with these machines. The project will also work on the reducing the weight of component by making none uniform materials, or hollow. The project will run the next three years until the end of 2011.

Economical aspects

The economical aspects represent the most interesting factor. Many examples are going around the world and some of them will be presented during my presentation. But it is more exciting to be a little more general. The next points will present the different parameters to consider when you will try to evaluate the idea of using RM.

<u>Product lifetime:</u> Products have dramatically been reducing their lifetime on the market. Do you need to have a new product on the market often? And are you bound to wait the breakeven point before introducing a new product?

Time to market: Introduction to the market is really important; and a delay of six months can bring a reduction of the gain by 33% . RM should not only be considered a substitution to more traditional technologies, it could also be used as a shortcut to the market. It can be used in the period when you are waiting for the mould and the first parts to be produced.

Response to the product: Do you know the reaction of the public and are you sure about it? Are you taking a big risk if the product is failing? In this case it could also be interesting to produce the first parts in a more expensive way and earn a shorter margin on them before introducing a product that is cheaper to produce but which involves more heavy investments.

Personalization: Could you get some of your customers interested in getting a product just for them? RM is an easy way to make each of your customers a little more special.

Design: Can the product respond to the specification in a better way? By making complex geometries, could the product obtain a better productivity or maybe longevity? Can you simplify the montage and maybe the number of parts by changing the design?

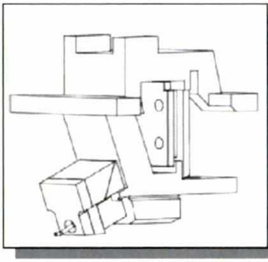
Prices: Maybe the easiest factor to consider, because it only involves numbers. But you should not forget the next points in the equations.

Working hours: It is easy to calculate the price of a mould and the price per part, and then on the other side of the balance the price per part on an RM machine. But it is important to consider the number of hours used to prepare the part, drawing the mould, programming the machines to make the mould as well. On the other hand you may consider the extra hours/ operations used to finish the part after the production of RM. Remember to add possible costs due to revisions of the parts and possible modification of the mould. It does not happen every time but it is still a factor of risk.

All these parameters should be considered during the decision period. It is also important to make the decision at the earliest possible stage to give your engineer the possibility of designing for the right technology.

Revolutionary manufacturing process

The mechanical structure of the SPU 90th Anniversary of Ortofon cartridge has also been re-engineered as well as many of its internal assemblies. At the mechanical heart lies a revolutionary customized-SLM (Selective Laser Melting) manufacturing procedure in which micro particles are laser-welded together, layer by layer. This high technology and high precision process eschews traditional techniques to provide high rigidity and a body density resulting in the further reduction of unwanted resonances while still maintaining exacting figures for cartridge mass. SLM manufacturing also enables the consolidation of components to allow for a design devoid of unnecessary material. In this cartridge, a one piece body makes the direct connection between the generator system and the wooden housing ensuring both a perfect rigid connection and extremely high internal damping. Ortofon has a Patent Pending on this new technology.



Conclusion

RM is ready to take the next challenge but there is still a long way to go. It is not only a dream of tomorrow – it will be used; the only question is when. Metal will show the way as it does not have to fight with new material names and proprieties, but even if you are working with a 316L it does not mean that you will achieve the same results as a traditional. It is important to make your homework and learn as much as you can in order to be ready when the technology fully corresponds to our needs. Culture will change slowly, but a general publication and a bigger introduction in engineering schools as a production possibility is necessary in order to change it. Maybe RM technologies are not completely ready, but maybe it is time to focus on the quality part of the process to do so.

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SEVENTH FRAMEWORK PROGRAMME