Assembly Automation

Rethink assembly design

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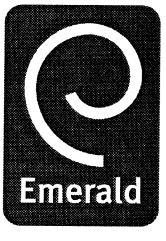

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Tutorial

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Abstract

Purpose – Rapid manufacturing processes provide designers, mechanical and process engineers with a lot of chances and opportunities. It is necessary to show them, how their work and their processes will change due to these new technologies.

Design/methodology/approach – Rapid manufacturing offers the chance to use the additive manufacturing processes to produce not just prototypes but advanced functional parts in small and medium quantities that can utilise a lot of design advantages that are provided by the process. We consult, as a German applied research institute, independent companies, helping them to introduce new product development and manufacturing processes, rethink the design of their products and to be aware of the advantages of upcoming manufacturing technologies.

Findings – Finds that a lot of products of today and especially of tomorrow could be produced by the new rapid manufacturing processes today and at competitive costs, if their design was adapted carefully using the new possibilities. New categories of products will come up too.

Research limitations/implications – The acceptance of rapid manufacturing as a new production technology is still limited by the available manufacturing systems. The number of released materials is still small and the accuracy of the parts and the building speed is still not exactly rapid. The mindset of the decision makers and of the R&D departments has to be radically changed. There is a lot of development going on, so the situation will change...

Originality/value – Aspects of a visionary scenario for future productions and products are shown and some examples are demonstrated based on a customised robot gripper.

Keywords Assembly, Rapid prototypes, Design and development

Paper type General review

1. Introduction

The basic idea of rapid manufacturing processes is to create products directly from digital data without using tools and some pre fabricated materials. Owing to the layer by layer production process there are a lot of advantages arising for the design of the products. It is no longer necessary to follow the strict existing design guidelines. For example, to achieve constant wall thicknesses, no undercuts and no small free formed holes inside. New design advantages are also the possibilities to integrate functionality, combine functions to a lower number of parts in the product and go for more bionic structures inside some parts to meet loads and stresses. Designing is becoming more and more free from these traditional restrictions and because of this; the focus in the design work can be changed towards aesthetic and functional advantages in the early stages of product development.

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2. Rapid manufacturing process

Additive manufacturing processes are not yet established in a large scale in today's productions. Besides the described fields of applications they are still used only as rapid prototyping machines.

The cheaper and the faster the manufacturing processes get, the more it will affect consumer goods. Because of this the next steps of the rapid manufacturing process will be towards individual mass products, freeform design and multi-functional components. These individual mass products are exactly specified by their own set of geometrical data, material data and maybe some comments about the preferred manufacturing process. In addition to these individual mass products there are some questions to be answered such as how to supply customers with spare parts, how to extend the product life and, for example, how to extend the function of the product in use. Another field for innovative solutions will be the focussing on the production processes, for example, towards production on the spot and in place. The materials will tend to combinations of materials within solid objects and also the use of so-called graded materials.

Right now there are only few applications of rapid manufacturing due to the high costs. Like every new technology it came first into operation in the field of aero (and Formula One) engineering where the highest goal is to reduce the weight and to improve the strength of parts and it is also used for implants in the human medical sector to meet the strong demand for individually fitting parts.

Rapid tooling is another field of application where it is already used to build complex forms with ideal cooling channels and without machining a lot of material. This leads to a significantly higher precision and an increased output number of parts due to a faster cool down process.

The achieved surface quality of the existing rapid manufacturing machines is comparable to cast parts. The structural quality depends on the process used but normally also very near to cast materials. Surfaces for bearings or other functions where a very precise surface is needed have to be measured or post processed, for example, mechanically, to give the necessary quality.

'...Be aware of the opportunities brought to you by the new manufacturing processes, do not build the same parts just with other machines. Optimize your processes for the integration of rapid manufacturing processes...'

In order to get to the future products there is a lot to do. Research and development has to focus several fields of action: on 100 percent quality control of individual mass products, improved precision of surfaces, materials and combinations of materials and also on the logistics, especially on where the products are produced and how they are delivered. In our opinion, the main field of action has to be placed in the development of clear design strategies and the education of the product development staff and the mechanical designers towards thinking beyond the "old" manufacturing processes. This statement was proved by a large scale questionnaire that was made among the German SMEs.

Fraunhofer IPA is currently working on design guidelines for rapid manufacturing, process development and the automation of quality control.

3. The existing processes for rapid manufacturing and their specific problems and advantages

The existing processes are all based on raw materials in a very basic state. They can be sorted in three classes according to their state:

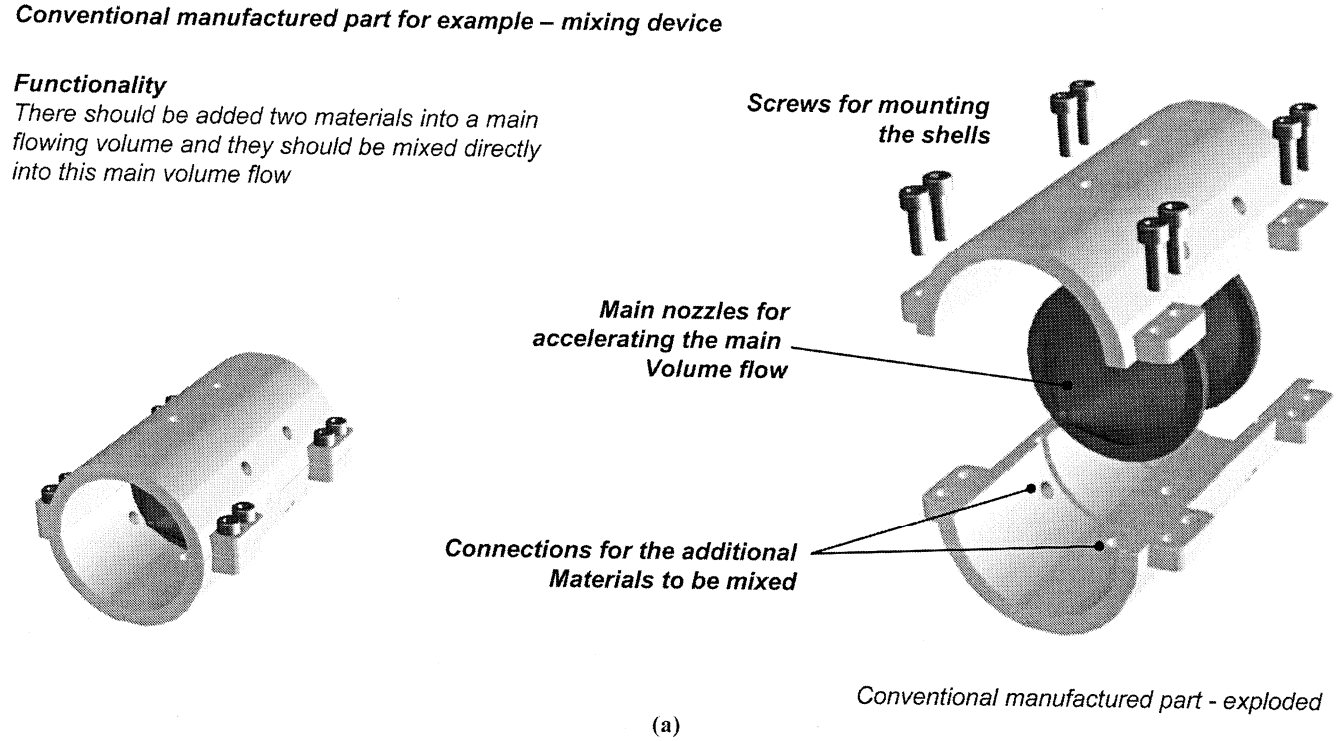
- Solid raw material as a powder. The processes based on powders are of course the ones with the widest range of possible applications because the parts can be mainly designed without support structures and can be used directly without washing, post hardening and so on. The surrounding powder protects even very thin structures from breaking down by their own weight during the building process. The generated parts have very good mechanical properties similar to the properties that can be reached by casting. The problems of these processes are today the long cooling down phase that is needed to avoid geometric changes by thermal stresses and the difficulties of taking thin structures out of the powder. The range of available materials is going from a large variety of thermoplastics like "nylon", for example, to a large number of different metals like titanium-alloy, stainless steel, tool-steel, bronze and so on. The major research and development expenses where made in new additional materials and powder mixtures.
- Solid raw material such as an endless wire. There are different processes available, such as FDM with plastics or wax and also additive welding of metals. The main feature is that you are not restricted to the building plane. That means that it is also possible to use it for repairing parts or build additional parts on an existing object, for example, a functional upgrading feature. Today's processes are not very precise and due to the surrounding air a support structure is needed. This means additional efforts in post-processing.
- Liquid raw material as a bath wherein the geometries of the parts are hardened by an energy beam. The materials for these processes are very special and expensive but the accuracy is the best in class. There are no metal materials available and the used photopolymers have not the best mechanical properties. Support structures are needed when overhanging parts are built to save them from drifting away in the bath.
- Liquid raw material something like an ink that is printed by using a technology similar to the well known office printers. This is a fast evolving and very interesting method for building micro and nano structures out of, for example, living materials like human skin, biochips or integrated circuits like RFIDs. It is a major topic of the research at the Fraunhofer IPA Department 360.
- Gaseous raw material. The processes working with gases as raw materials are normally not mentioned as RM processes but as CVD or PVD surface coating technology. But it is opportune in the days of the nano hype to take them into account to build 3D structures (Figures 1-8).

4. Principles for the design of rapid manufactured parts

The rapid manufacturing processes are herein seen as the so-called "layered or additive manufacturing" processes. Owing to this processes there are a lot of opportunities coming up. As a small introduction here are some major design rules for rapid manufacturing that will help you to create reasonable and applicable products:

- Use the advantages that are included in the rapid manufacturing processes.
- Do not build the same parts just with other processes. Take the time to rethink the whole assembly, reduce it to the functionality and then go straight forward to the integrated freeform design.
- Do not consider traditional mechanical design principles. There is no need to think about sizes of prefabricated materials, coordinate systems and some possible symmetric axis for the machining.
- Reduce the number of parts in the assemblies by intelligent integration of functions. For example, joints and flexible areas can be built in one step. This greatly reduces the assembly costs.
- Take a look if there are bionic examples that fit to your tasks as these can give a hint towards the design of better solutions.
- Feel free to use freeform designs; they are no longer difficult to produce. We are working on advanced design tools for 3D software to support your wish to develop towards design for rapid manufacturing.
- Optimize your design towards highest strength and lowest weight. The most important design rule is to use as little raw

Figure 1 Example for redesigning an assembly to take advantage of the opportunities of the rapid manufacturing processes



material as possible and because of this as little energy as possible. Think parts as a connection between two or more functions with the required strength and optimised weight.

- Use undercuts and hollow structures if they are useful. Do not waste time thinking about a design and how it could be machined or cast.
- Do not consider tooling, because it is no longer needed. All parts and forms for casting can be generated in one step without planning and designing tools with a huge amount of time and money. Changes in function and improvements in design are no problem because there is only the set of data to be changed.

Figure 2 Three dimensional CAD model of the product to handle

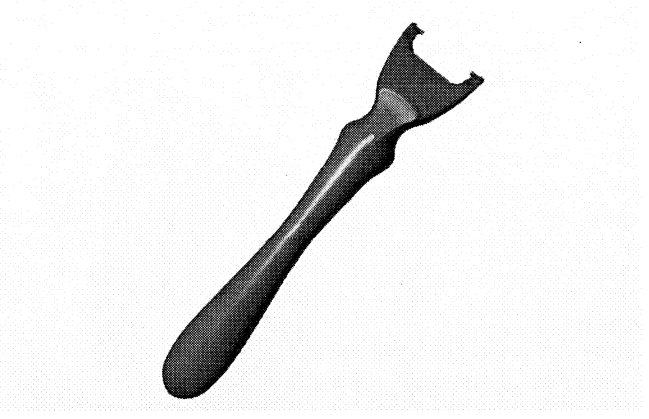


Figure 3 CAD model surrounded by a solid block

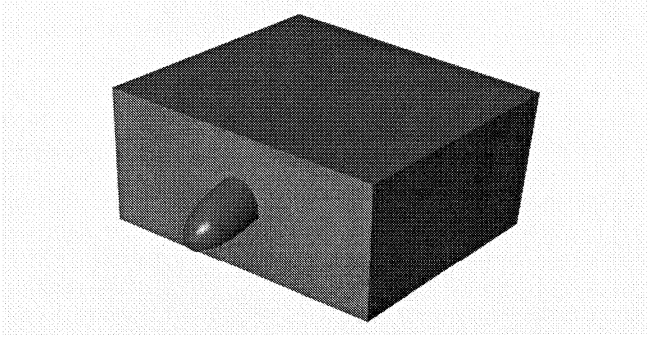
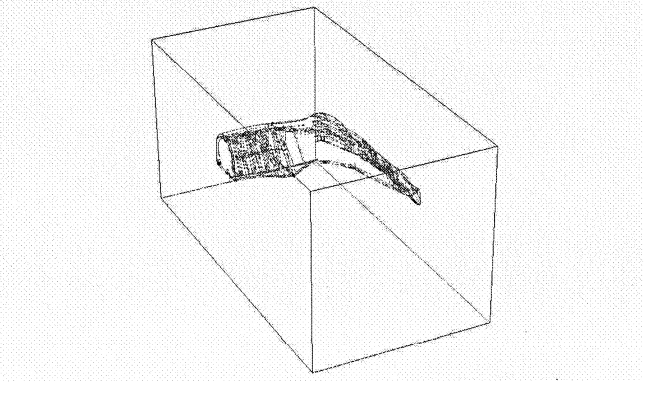


Figure 4 Negative geometry in the solid block



- Meet the loads and stresses by optimal shape. Put some material where it is needed and leave it if it is not needed.
- Go directly for the best solution.

The main advantage of the new processes is that the amount of used material has to be taken into account for the production as the highest design priority together with best functionality and the best aesthetic design. Lightweight design does no longer mean that you have to try to cut

Figure 5 Cut free solid block

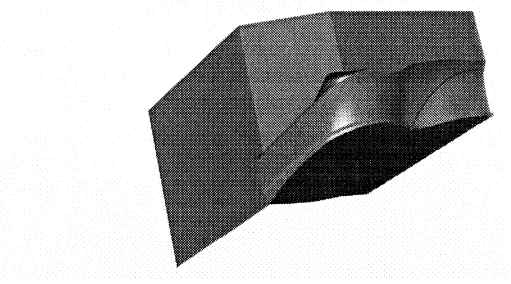


Figure 6 Defined fixing points

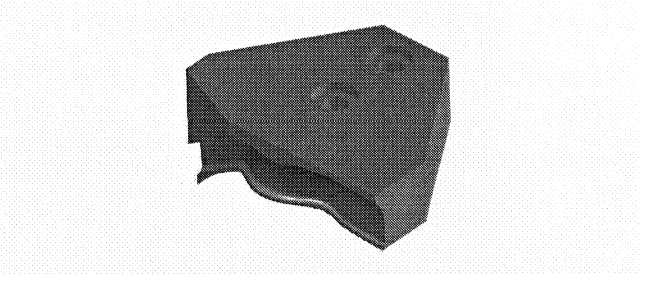


Figure 7 FEA optimisation

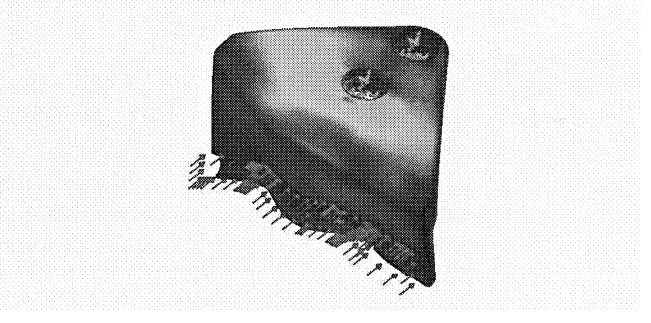
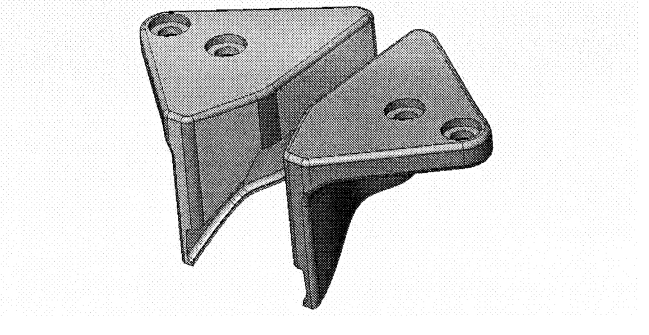


Figure 8 Pair of gripper fingers ready for production



some edges and make some holes with an enormous effort of machining time, by additional manufacturing sequences and by, very often, difficult operations. Lightweight design means in the understanding of the new processes to save money by using as little raw material as possible to provide

the parts with the required strength to withstand all forces and stresses that could be applied. The other main advantage is to save assembly time and minimize the risks of assembly errors by reducing the number of needed parts for the specified functionality. The designer has to rethink their approach towards the best solutions for the given task.

5. Automated creation of parts directly from CAD data – case study robot gripper

Another field of application is to use rapid prototyping to create parts or structures automatically just defined by their expected functionality and geometrical data.

Rapid manufacturing processes work directly with 3D CAD data. There is no tooling or semi-finished part needed. According to this knowledge it is possible to create parts automatically, if their properties are known in detail and if the needed functionality results from the surrounding parts.

One example we are working on is to create the fingers for robot grippers automatically just by putting in CAD data directly from the 3D model or from a 3D scan and some boundary conditions from the application environment. This task is interesting because of the rapidly changing products appearing in small batches that have to be handled, and because of the huge amount of work that has to be made today in the design and in the machining departments to produce such parts.

The following process includes the steps as shown.

1 Input of CAD data, input of boundary conditions, measurements and fixing points.
2 Create a surrounding solid.
3 Subtraction of the solids.
4 Cutting clear the needed volume.
5 Definition of fixing points.
6 Optimisation by FE analysis.
7 Mirror the part and export to a STL File.
8 Build the part.

The steps 2-7 can be performed semi-automatically by a software tool that will be developed by the Fraunhofer IPA.

6. Impact on future manufacturing – visionary scenario

In future business, the point of production and point of use of your designed product can be at a great distance from your company's office. There will be a growing market for local or regional production of individual products out of regional materials. To reduce raw material logistics and to use regional and culturally suitable materials there will be (worldwide) distributed production spots.

Therefore, the product has to be described in all important qualities, like the minimal material properties needed, the quality requirements including some dedicated points for the quality control and a set of parameters for the production process. This set of information will be stored somewhere in the product itself so that, if a replacement part or an upgrade part is needed, the information can be taken directly from there, without contacting the original manufacturer or especially the original designer and asking them about their intentions.

To implement the new possibilities and opportunities in the mindset of the industries decision makers there has to be done a lot of work. We need to think beyond well known step by step improvement of existing technologies and processes towards new product categories made with new manufacturing processes.

The next and very important steps in further development have to be made in material science and in process development. The goal is to introduce more materials and better geometric accuracy in combination with semi, or better fully, automated processes.

We also try to change the education of designers and mechanical engineers towards the new industries.