

PRODUCT OPTIMIZATION WITH AND FOR ADDITIVE MANUFACTURING

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Abstract

Additive Manufacturing offers a great potential for the optimization of products. Therefore different approaches are feasible to exploit these potentials for elaborating optimal solutions. For example these include optimization of weight or stiffness of structural components as well as the integration of functions and other entities of assemblies. Note, however, that additive manufacturing processes have process specific limitations. Products, components and assemblies, as well as procedures for the design and production preparation must be optimized with regard to a successful additive manufacturing.

The use of already known tools for the optimization and design needs to be reconsidered and adapted to the additive manufacturing. This also includes the production planning with component orientation in build chamber as well as a necessary quality management system.

This paper shows several ways for product optimization with additive manufacturing, often based on topology optimization, and procedures for information gathering, decision making and shape determination for part optimization for Additive Manufacturing.

Introduction

Since additive manufacturing (AM) became suitable for direct manufacturing of products instead of only prototyping, the possibilities for product optimization with additive manufacturing are discussed often. The most often named potential “complexity for free” temporary had become something like a mantra for those who want to sell AM as a promising technology [HHD06]. In the same breath monolithic designs and function integration are named [GRS10]. On top the flexible production of different designs as a consequence of the expendability of tools even in one build process lead to an easy customization of products. Though these potentials and further more often are not discussed in detail and interpreted regarding their redundancy and dependencies.

For a successful optimization of products with additive manufacturing a detailed knowledge and structuring of these potentials is needed. A systematical examination of potentials during product development paves the way for successful products, technical as well as economic. Therefore in the following a hierarchical structuring procedure for clustering of potentials including their detailed description is presented. Based on this structure an approach for a systematic support framework for selection and application of promising potentials is developed. No matter whether additive manufacturing offers potentials like monolithic design, this particular potential is not new and has been discussed many years ago [EKWH07]. Hence an optimized product can only be achieved by means of good designing practice.

Core characteristics of Additive Manufacturing

For a detailed consideration of AM-potentials in a first step the basis of all potentials has to be determined. Two core characteristics of AM can be figured out that are defining and differentiating AM from other manufacturing techniques: from 1D over 2D to 3D and tool less manufacturing as shown in Figure 1. Both are unique characteristics of AM as no other manufacturing technique uses the decomposition of a three dimensional shape over two dimensional layers down to basic single voxels. This can be assigned to laser based technologies as well as to wire based, if the interpretation of a continuous fiber is mentally cut in small sections. In addition

only AM is capable of generating or changing the physical shape of a raw material to another, defined shape without using tools such as molds, forging dies or cutting tools.

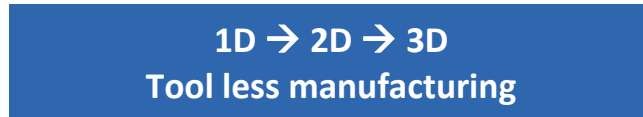


Figure 1: The two core characteristics of additive manufacturing

The six main technical potentials of additive manufacturing

Based on the foundation of the two core characteristics of AM six main technical potentials are named. These are all building up on each other, extending the opportunities of AM and setting the cadre for a pool of technical capabilities of product optimization. These six main potentials are: complexity for free, graded materials, monolithic design, function integration, individualization and product piracy prevention (see Figure 2). Each of these main potentials serves as a container for several derived opportunities that actually can be applied during product conception and design. These containers and their content will be described in the following. Therefore several examples will be used to visualize and explain the actual opportunities.

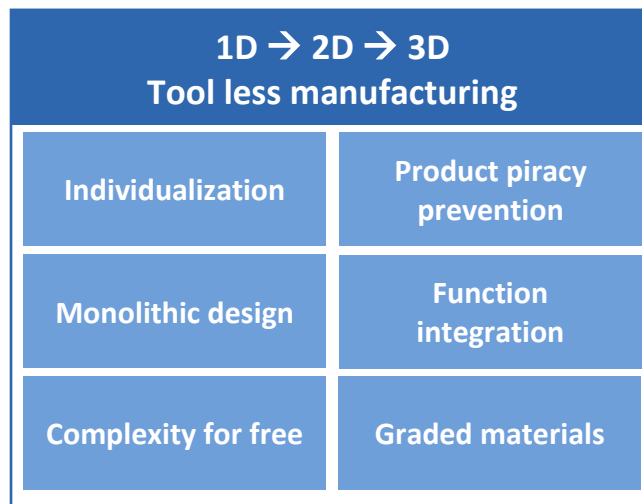


Figure 2: The six main technical potentials of additive manufacturing

The well-known “complexity for free” has to be described in detail as this container name is not directly usable. Therefore this container can be filled with six derived opportunities for optimization of: weight, stiffness, waste, life span, internal cavities and frequency as indicated in Figure 3. While these opportunities are categorized under complexity for free they only offer their full potential if the freedom is used best. To exploit this freedom best, the engineer needs to be supported by computer algorithms like topology optimization (TO) [ALT14]. Especially the combination of weight, stiffness and frequency optimization can be obtained best by these algorithms. A more detailed description will be given later in the description of technologies in section Methodologies for product optimization with and for Additive Manufacturing



Figure 3: Opportunities for product optimization derived from the potential “complexity for free”

As example for the optimization of **weight** and **waste** a link lever from out of a machine for the printing industry is used. It is a simple lever that connects two elements of a scissor lift that has to be moved 400 times per hour and thereby should be most lightweight but still withstand this high number of cycles. For obtaining a design that is lightweight but stiff and still has a long life span a topology optimization was conducted. The process from original design including the raw material over a design proposal of the TO towards the final design is shown in Figure 4. As can be seen in the left a huge block of raw material has to be milled away. For the final design only little additional material for supporting structure is needed. Thereby the waste is reduced by factor 15 while the weight is reduced by 36%. Figure 4 also shows these results in a bar chart for visualizing the waste reduction while only minimal stress risings in uncritical areas due to modelling arise and no change in the displacement thus stiffness. Furthermore the notch factor in the most critical areas was lowered and thereby a higher life span can be achieved.

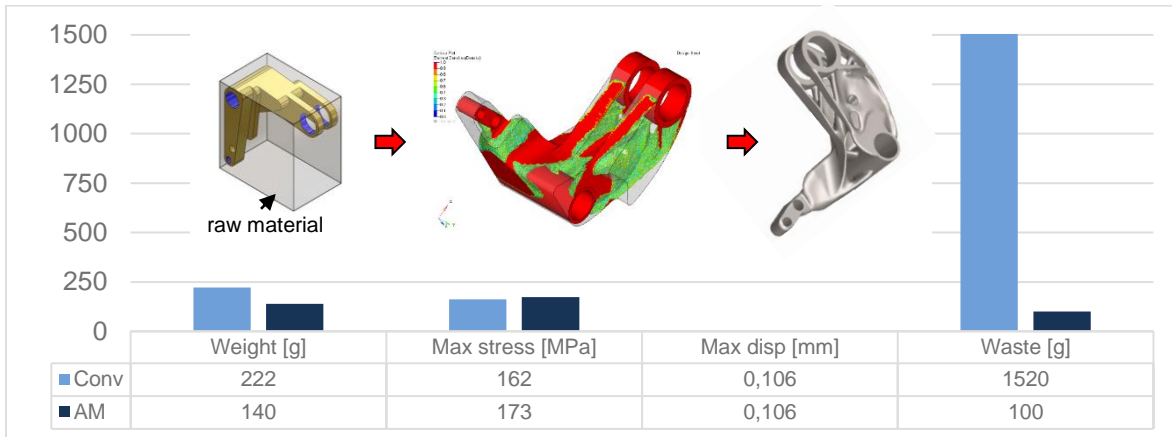


Figure 4: Process and outcomes of design optimization of a link lever (Developed by Author in cooperation with Krause DiMaTec GmbH)

Another example for remarkable waste and weight reduction but as well for **stiffness** and **frequency optimization** is the Reaction Wheel Bracket (RW-Bracket) as shown in Figure 5. This is a structure part out of a satellite to mount a mass that can be set in rotation to adjust orientation of the satellite without using propellant.

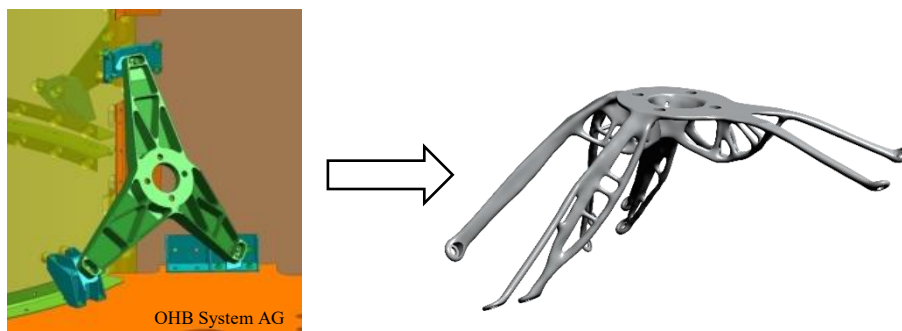


Figure 5: Example RW-Bracket (Development funded by ESA under Artes 5.1 Contract No.: 4000107892)

Again a topology optimization was used to obtain the optimal geometry, but with special objectives to ensure not only a weight reduction but also enough stiffness and a high 1st Eigen Frequency mainly needed for the launch of rocket. During the TO the material distribution is adapted to optimize the Eigen Frequency by +20% (180 Hz → 216 Hz) and the maximum displacement during launch by -37 % (0.076 mm → 0.048 mm) while the weight was reduced by -59% (1114g → 456g) [RK15].

The last opportunity derived by complexity for free is the optimization of internal cavities as by complexity for free not only perpendicular, straight drill holes with sharp direction changes are possible, but complex shapes for flow optimization can be realized. This includes optimal routing as for cooling next to surfaces in molds. An example therefore is the “impossible” crossing (see Figure 6) as developed in the project “COMPOLIGHT” with a weight reduction from 20 kg to 1 kg and a pressure loss reduction by factor four [COMPO13]

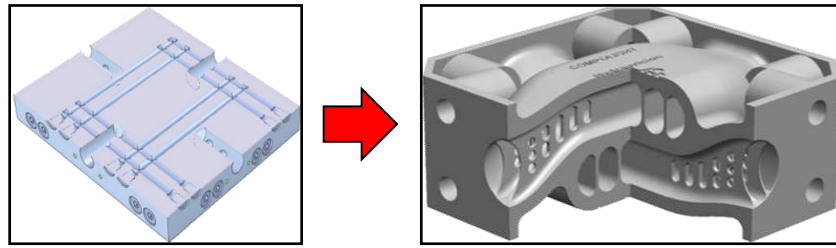


Figure 6: "Impossible crossing" from project COMPOLIGHT [COMPO13]

These examples show different advantages of complexity for free. The part design can be optimized easily without extra costs due to the complex shapes. By weight and thereby material reduction sometimes even a cost reduction can be realized as less material and machine time are needed for production.

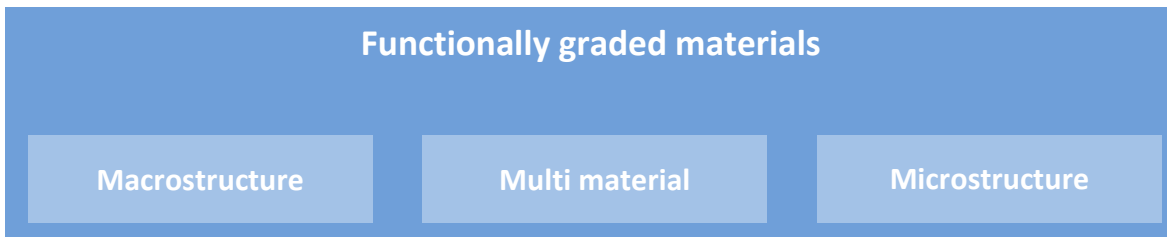


Figure 7: Opportunities for product optimization derived from the potential "Functionally graded materials"

The next main technical potential of AM is the possibility of changing material properties inside one part for optimal fulfillment of the parts requirements. These variations can be made on three levels: macrostructure, multi material and microstructure.

The variation of **macrostructure** is near to the potential "complexity for free" and shows why the potentials are depending and building up on each other. One of the most popular results of this opportunity is the generation of small lattice structures resulting in very lightweight but still stiff structures. These could be used for areas in parts where only semi dense material is needed. Nowadays optimization tools are gaining the capability of including lattice structures in the optimization process as shown in Figure 8. During TO those areas highly burdened and thereby important will be defined as full material, while less burdened and thereby less important areas will be represented by a lattice structure with changing strut diameters. Another example for load dependent optimization of lattice density is shown in Figure 9. In this case the force flux can be seen clearly as full dense material while the rest of the part is represented by lattices. This could be useful in case of unclear contact conditions or as safety margin for unexpected loading conditions.

Furthermore the lattice elements increase the surface area immensely what could be useful for heat transmission or catalytic effects and are fail-safe if single elements may get broken.

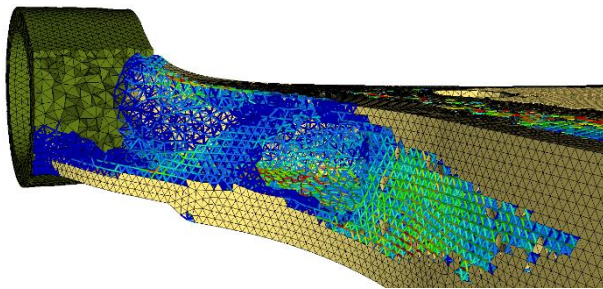


Figure 8: lattice generation inside topology optimization for semi dense areas [ALT15]



Figure 9: Load dependent optimization of lattice density [LC15]

With regard to the "1D-2D-3D" core characteristic it is possible to produce parts with **multi material** properties and changes of alloys between different layers or even inside one layer as each "voxel" in 1D

theoretically can be made from one specific alloy / material and the next on in another. For metal based processes this potential is still in the beginning but successful tests with for example change of Aluminum content inside an Aluminum-Titanium alloy or the combination of different steels or aluminum and copper where made [SLZ+15]. Furthermore for wire based plastic processes like FDM this is even already standard if soluble material is used for support while another material is used for the actual part production. As well for other processes like for ceramics [PK15] or plastic based Polyjet multi material parts are already state of the art.

Finally, for metal based processes like SLM, the **microstructure** can be varied in process, as well. Depending on the process parameters like laser power and pre heating, different microstructures inside the material appear. Samples of 316L built with 1000W instead of 400W show the establishment of coarse and strongly textured microstructures directly from the powder bed [NLR+13]. This might be useful in case of material based marking of elements as described later on in the discussion of potential “product piracy prevention”. Furthermore these highly anisotropic material behavior might be useful for complex loading conditions wherein high strength and stiffness in specific areas towards high elongation at break in other areas of one part are required.

By microstructure variation based on process parameter variation specific material properties can be adjusted, perfect fitting for the intended purpose, even varying between different regions of a part.

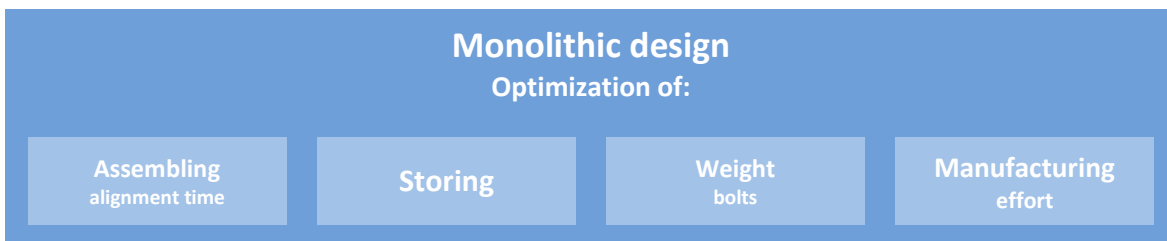


Figure 10: Opportunities for product optimization derived from the potential “Monolithic Design”

The third potential “monolithic design” as well is an often spoken of potential of additive manufacturing. Thereby complex assemblies are manufactured in one shot instead of multiple parts that have to be aligned and mounted and underlie tolerance problems with increasing tolerance zones. Whereas the monolithic design of assemblies is not a new thing as it is already discussed since years [EKWH07], AM offers new levels of monolithic design. Based on the potential “complexity for free” with AM the optimal design is not impeded by a necessary accessibility for a cutter or restrictions due to huge raw material consumption or complex tool clamping and aligning processes inside a conventional machine.

Based on these basic characteristics of the potential “monolithic design”, four opportunities for optimization of: assembling, storing, weight and manufacturing effort arise. In case of complex assemblies the different tolerances of each single part arise in a time consuming alignment procedure in which each single element has to be aligned towards the other elements. In case of monolithic manufacturing this effort is reduced as all single elements are produced in one shot and afterwards only the actual relevant interfaces have to be milled according to tolerance specifications.

Figure 11 gives an example for such an assembly which consists of 12 parts where each one has to fit precisely to mount thrusters for satellite. By a monolithic production only one alignment of the overall assembly has to be made what optimizes the **assembling** of the overall satellite. Furthermore many bolts can be saved what reduces the **weight** of the assembly and the product. Of course, a redesign could reduce the weight further.

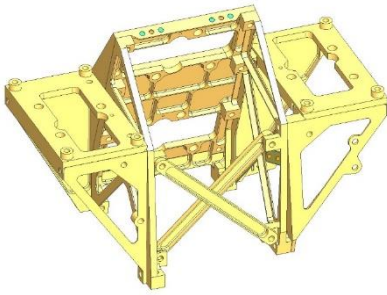


Figure 11: Example for complex assembly of 12 parts that could benefit from monolithic design [Image courtesy: OHB System AG]



Figure 12: AM produced monolithic design Fuel Nozzle [Image courtesy: General Electric]

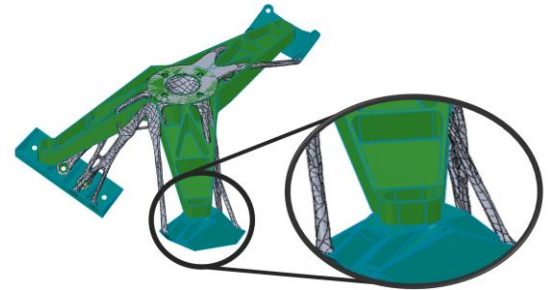


Figure 13: Example for weight reduction made possible by monolithic design [Author]

Another aspect of optimization is the **storing** of several different parts. For example the GE Fuel Nozzle as shown in Figure 12 was produced out of many different parts and is no designed as one AM-part. Beside the reduced **manufacturing effort** of the assembly (reduction of welding and aligning etc.) as well the **weight** was reduced by 25% [3DP16]. On the one hand thereby only this part has to be stored, what reduces the storing and organizing effort. On the other hand this leads to more expensive parts that have to be stored, as no longer simple small standard parts need to be stored. Thus a careful trade-off of advantages and disadvantages for a complex and expensive monolithic design has to be made.

For the opportunity of **weight reduction** due to a monolithic design again the Reaction Wheel Bracket is used. As indicated in Figure 13, the additive manufactured design enables a direct connection from the force input to the mounting points of the RW-Bracket. Thereby a huge virtual cross section with a high area moment of inertia is realized. In the original design shown in green, all forces have to be concentrated from a huge cross section to only a small connection point for connection with two bolts. The direct connection was not possible to be made in the conventional design and manufacturing process. Thereby the material can be used best and no further connector elements are needed what reduces the weight remarkable whilst stiffness was increased. Furthermore the **manufacturing time** was reduced by 18% (49h → 40h) and the **waste** by -97% (55 kg → 0.4 kg). The original part was milled out of a huge 56 kg Aluminum block, what comes to a lot of waste and a long manufacturing time, extended additionally by complex clamping procedures during milling. Further the additional manufacturing of the small brackets need extra time and production capability planning.

By a monolithic design many organizational procedures such as assembling time, storing complexity, manufacturing effort and production capability planning can be optimized. Further weight reduction due to dispensation of connector elements as well as better design can be achieved.

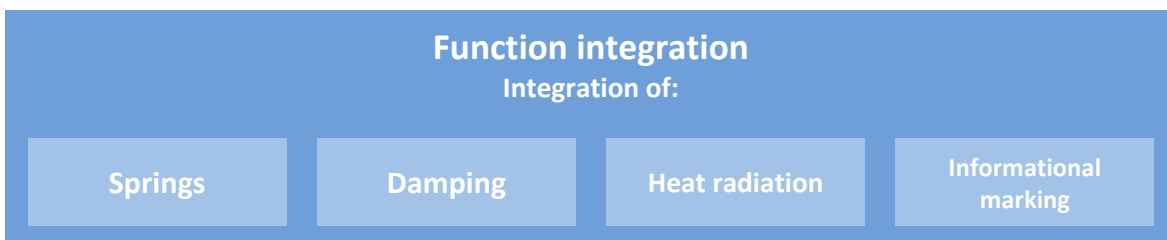


Figure 14: Opportunities for product optimization derived from the potential “function integration”

This potential is the fourth one in the hierarchic structure as it is a combination of complexity for free, functionally graded materials and monolithic design. The complexity for free offers new geometric freedom to include complex elements as no accessibility for cutter is needed whilst graded materials even offer the integration of completely different elements and functions that nowadays have to be manufactured in a different manufacturing process and then assembled. The different towards monolithic design is that before only different elements were produced in one shot meaning assembling during production. Function integration is one step further as: different and / or additional functionalities are included in one part and the product efficiency is

increased. The derived opportunities of this potential are multifarious but for example springs, damping mechanisms, heat radiation and informational marking shall be listed.

Based on the underlying potentials for example the integration of springs inside a complex assembly is possible. While in conventional design additional springs are mounted, with AM it is easier to integrate flexible geometry elements as springs and torsion springs or cantilever elements that directly integrate the spring mechanism. This can be realized by use of complex geometry with regard to potential “complexity for free” or by use of macro- and microstructure with lower stiffness from potential “functionally graded materials”. For powder bed based processes as well damping mechanisms are in research. The idea is to include loose, unmolten powder in internal cavities that can reduce vibrations by several internal effects [DMRC15].

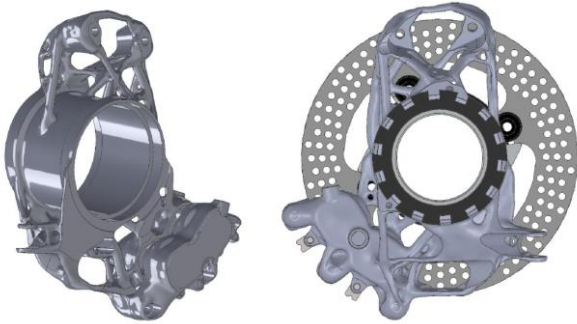


Figure 15: Upright from Formula Student racing car with integrated brake caliper for function integration and monolithic design (developed by author in cooperation with UPBracing Team e.V.)

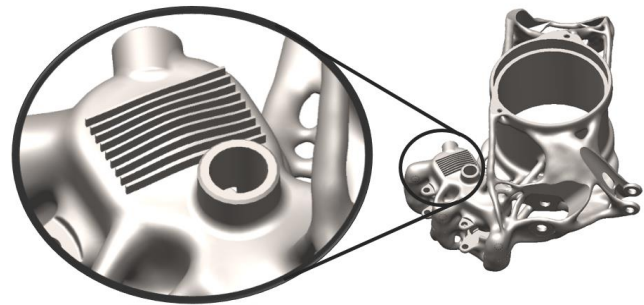


Figure 16: Upright from Formula student racing car with brake caliper and additional ribs for heat radiation (developed by author in cooperation with UPBracing Team e.V.)

An example for additional heat radiation integrated in the original design without additional parts, mounting elements and heat sink compound is illustrated in Figure 16. During development of the structural parts of the suspension of a Formula Student racing car of the UPBracing Team, a monolithic design was chosen for integration of the brake caliper (see Figure 15). Thereby no mounting elements are needed and the force flux can be optimized, as described for the potential “monolithic design”. Additionally to this optimized design, additional ribs were built on the hot surface of the caliper for better heat dissipation. Because of the integrated design of the ribs they can also lead to a more stiff design and thereby are “for free” in terms of cost and weight.

The fourth example for function integration is illustrated in Figure 17, again shown for the upright of the Formula Student racing car. Informational markings applied on surfaces directly during build job can be used for different purposes. In this example the designer and manufacturer is shown as well as the tightening torque for the different bolts. These information can be used to ease the manufacturing process as the mechanic does not have to keep all values in mind or consult a manual but has the needed information direct in front. Furthermore quality assurance processes can be supported as used parameter sets and building directions can be applied for later tracing.

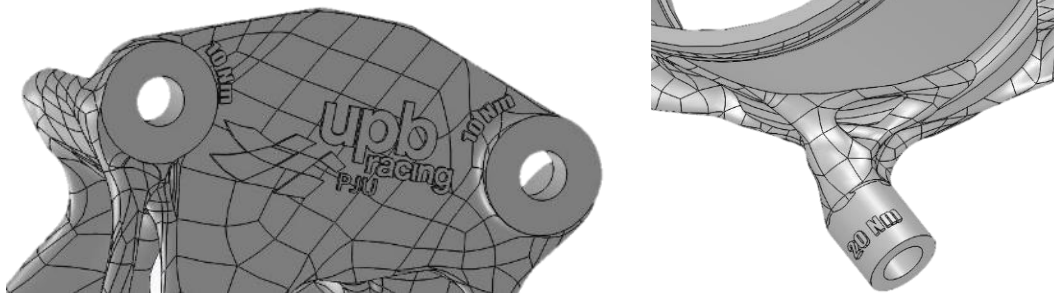


Figure 17: Informational marking as function integration on Formula Student race car (developed by author in cooperation with UPBracing Team e.V.)

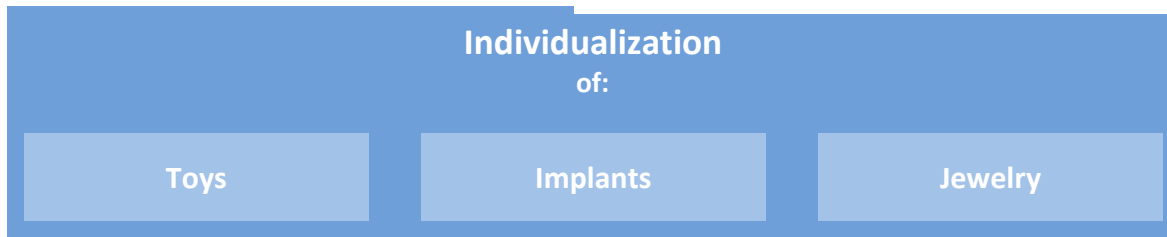


Figure 18: Opportunities for product optimization derived from the potential “Individualization”

Mainly based on the core characteristic “tool less manufacturing” an individualization of products is very easy with AM and thus AM is expected to be the key enabler for the long term predicted “mass customization” of products like toys, implants or jewelry. In 2004 Piller developed twelve prepositions for why mass customisation is not widely spread today. Some of these refer to management or to market capabilities, others on manufacturing restrictions. Regarding the actual manufacturing of customized designs, two main hurdles have to be overcome. Beside the enabling technologies for mass customization as well the customer needs have to be elicited in a simple and direct way and communicated to the production facilities. [PILL04] AM and the ongoing development of easy-to-use 3D design and customizing tools nowadays open new possibilities for enabling mass customization. In the EU-project iBUS an integrated business model for customer driven custom product supply chains is developed. This platform aims at enabling customers to get “prosumers” with individually designed and adapted toys and furniture, partly produced by themselves at home.

From the firm’s perspective, the costs of mass customization include two factors: (i) the cost of providing high flexibility in manufacturing, and (ii) the cost of eliciting customer preferences. Till today, mass customization research and practice is closely connected to the first factor, i.e., the potential offered by new manufacturing technologies to reduce the trade-off between variety and productivity (Ahlström and Westbrook, 1999; Fogliatto, Da Silveira, and Royer, 2003; Kotha, 1995; Pine, 1993a; Thoben, 2003; Victor and Boynton, 1998). But if a firm cannot transfer the customers’ preferences cheaply into a fitting product design, the best available manufacturing technology is of no meaning (Reichwald, Piller, and Moeslein, 2000). In a co-design system, the solution space, i.e., the product architectures and the range of possible variety, is fixed during a preliminary design process (autonomously by the firm). But a second step takes place in close interaction between the customer and the manufacturer, the elicitation process of mass customization (Zipkin, 2001). The costs arising from customization broadly comprise interaction and information costs. They are accounted for by the investigation and specification of the customers’ demands, the configuration of individual products, the transfer of the specifications to manufacturing, an increased complexity in production planning and control, the coordination with the suppliers involved in the individual prefabrication and the direct distribution of the goods. [PILL04]

Mass customization is only possible if flexible manufacturing processes are supported by adequate systems for customer co-design. These systems are known as configurators, choice boards, design systems, toolkits, or co-design-platforms. They are responsible for guiding the user through the configuration process. Different variants are represented, visualized, assessed, and priced with an accompanying learning-by-doing process for the user [von Hippel, 2001 in PILL04]. Such a system will be developed by the iBUS consortium with launch of iBUS platform in “WP3 Customised Product Design Virtual Environment”. This system will have the need to give a possibility for the customer to express its needs and wishes. Following [PILL15] the customer has to be supported in finding his product. Otherwise the “paradox of choice” leads to a reduced value for customer if he has too many choices and is not led in decision process. Furthermore the dataset of customized product has to be transferred into production orders for different techniques. This step is highly important as a cost and time efficient manufacturing of customised designs is only feasible if the customer needs can be transferred to a physical product with minimal administrative burden. Therefore a preferably direct manufacturing technology is needed. For example the design and manufacturing of a special, customised mould for injection moulding is expected not to be feasible due to high costs and time consumption.

Figure 19 shows the process of rapid manufacturing of customized designs. In the first step the customer needs are combined with design information coming from a design database. Thereby the customised design data is created which will then be manufactured. For the manufacturing three main paths are considerable, depending

on the batch size. Customized design may either be produced in batch size one, a low batch size or even a combination with uncustomised high batch elements.

The main requirement for an economically successful rapid manufacturing of customised designs is to enable fast design changes. This is only possible if the following requirements are fulfilled:

- Switch of design: the switch between two different designs manufactured has to be made pretty fast and easy. For example the change of a big and heavy mould for an injection moulding machine and the subsequent determination of shot size and heating/cooling time for high quality results may be very time consuming.
- Preparation of next shot: a cost efficient production needs to be able to produce a lot of elements in a short time. Therefore the unproductive machine time between two produced parts is important. For example injection moulding can be very fast in production of high batch production while for FLM labour work is needed between each build job what may hamper a fast production.
- Flexible material change: if there is a high number of different customised designs with e.g. different colours shall be produced, it might be required to change the material very often. This might be faster for FLM or milling than for injection moulding.
- Automated generation of machine code: the code for machine control should be created automatically as use of labour time would take a long time and would be very cost ineffective.

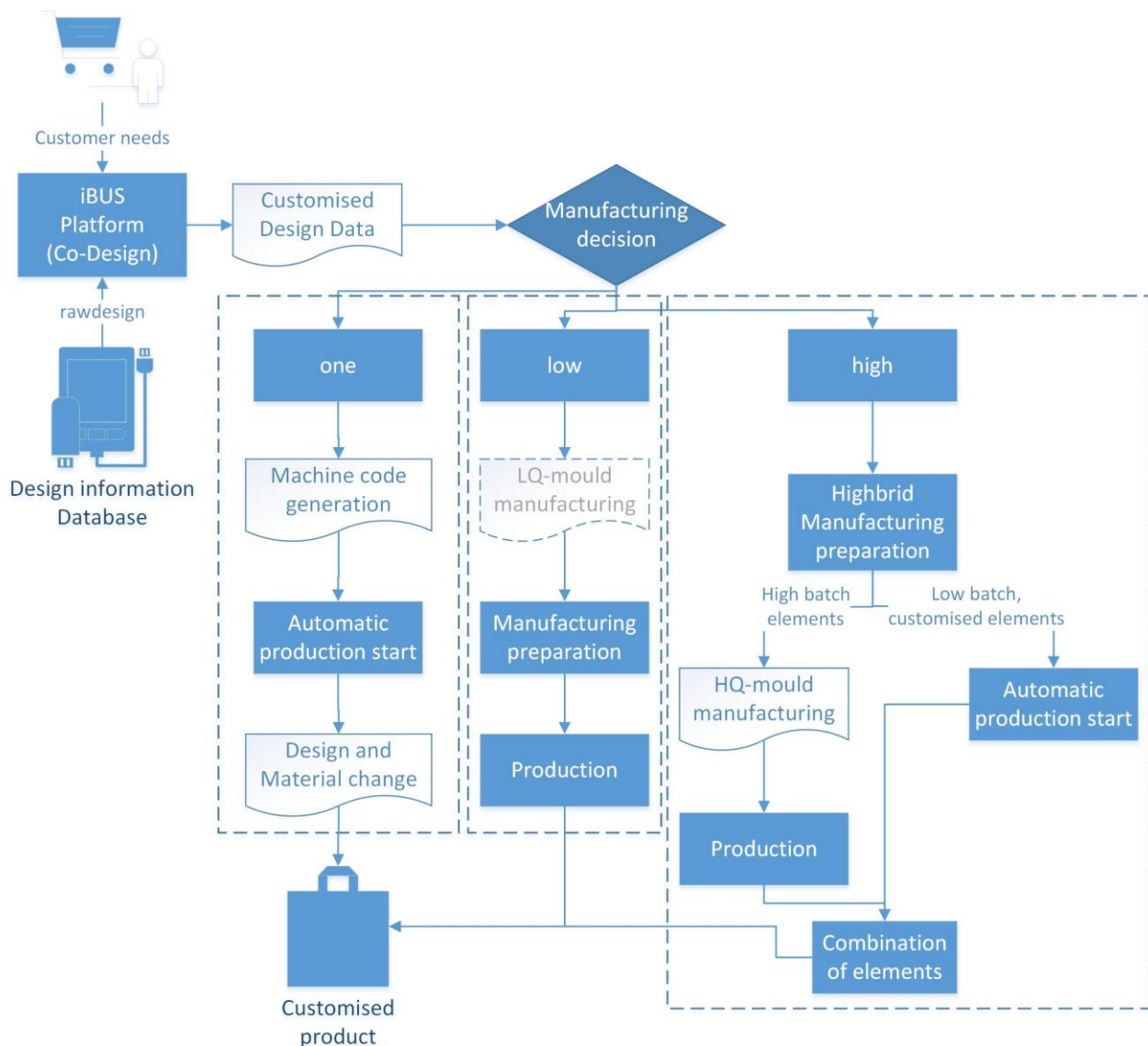


Figure 19: Rapid manufacturing of customized design process

Figure 20 shows one example of individualized toy production. Different chess-men designed by home-users without deep knowledge about design were printed on desktop 3D-printern. Another example for individualization is visualized in Figure 21. Clinical production of customized implants remove the critical adaption of implants from the operating room and bring it to less critical environments in the workshops. Based on CT-scans the implants can be produced in perfect fit before the surgery. As well high complex jewelry can be produced easily by AM (see Figure 22). This can be designed by the customer and then printed in industrial machines.



Figure 20: Individualized chess-men (developed by Author in Project iBUS)



Figure 21: Cranial implant [Image courtesy: EOS GmbH]

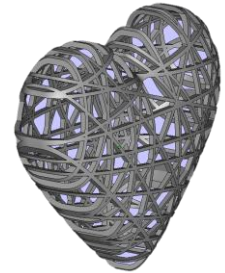


Figure 22: Customized 3D wireframe heart made from titanium [Author]

Individualization thereby offers new business models by involving the customer in the design process. Thereby the customer may get a producer himself and thus can be called “prosumer”.

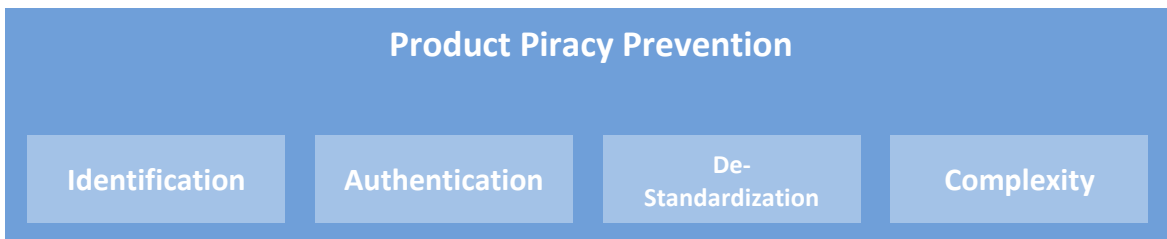


Figure 23: Opportunities for product optimization derived from the potential “Product Piracy Prevention”

The last potential building up on all beforehand mentioned potentials is the “Product Piracy Prevention”. By good use of all the other potentials it is possible to prevent or hamper product piracy. Therefore identification, authentication, de-standardization and complexity are used. Identification and authentication both can be included in the part during build process without extra costs and realized via “complexity for free” with codes printed on-, in- or even under a surface or graded materials with microstructure variations. These will not prevent product copies, but enable a possibility for identification in case of legal reviews. On step more complex is a authentication of products, which is as well possible with the same techniques. De-standardization of standard parts or high complexity of products increase the costs for copies and thereby hamper the product piracy as the attraction is lowered. [JBK16]

Methodologies for product optimization with and for Additive Manufacturing

An optimal use of all the described potentials, opportunities and advantages of AM for product development needs a careful use of methodologies to determine feasible parts and potentials and the actual geometry of a part as well as the correct manufacturing planning including process parameters (see Figure 24).

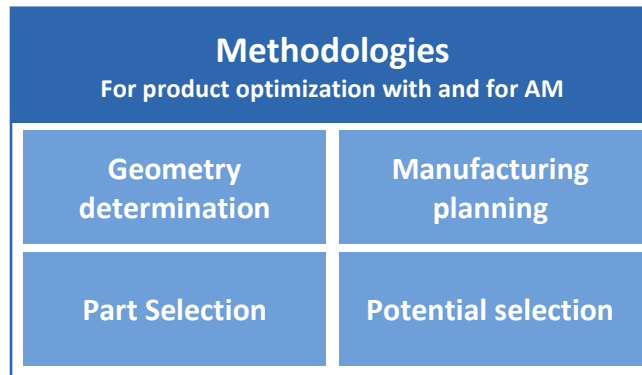


Figure 24: Methodologies for product optimization with and for Additive Manufacturing

For the part selection a methodology called “Trade-off Methodology” (TOM) (see Figure 25) was developed including different phases for screening the product portfolio of a company to select feasible part candidates. In a first step for unexperienced users the information phase gives the company enough knowledge on the technology and its potentials as well as the drawbacks to screen their portfolio internally and thus reduce the number of parts of their overall company to a scale easy to manage in the further process. This phase is followed by the most important assessment phase. In this phase the parts are discussed and checked towards K.O. criteria like size, price, material, etc. For those parts that still seem to be feasible a detailed assessment supported by a matrix is done (see Figure 26). In this matrix different criteria are checked whether the part is feasible and will profit from AM. [LRJK15]

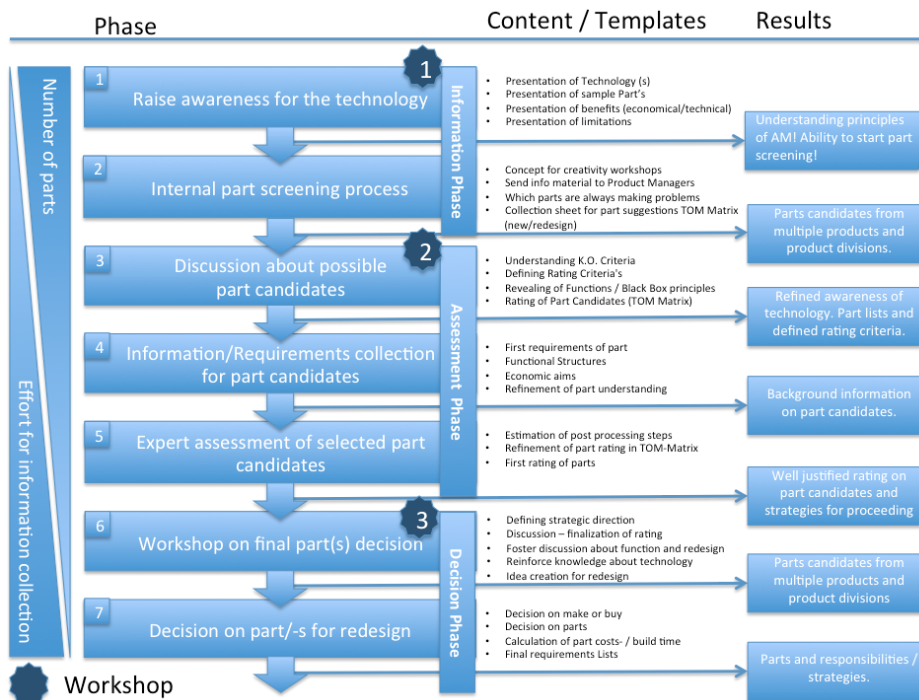


Figure 25: Process of Trade-off Methodology, more readable figure size in [LRJK15]

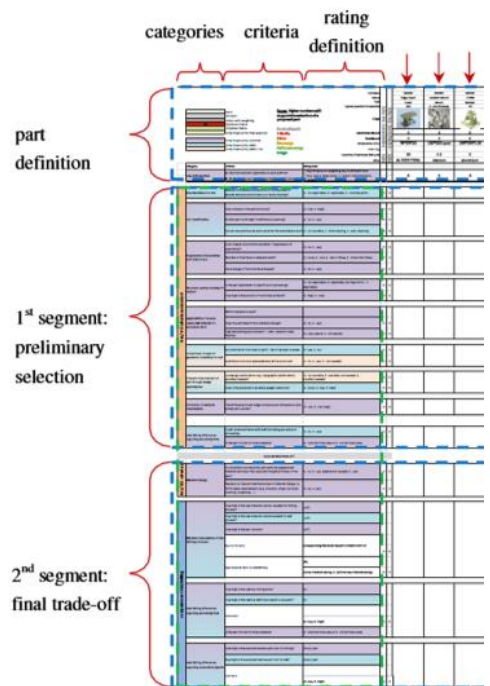


Figure 26: TOM-Matrix for part selection, more readable figure size in [LRJK15]

In the third phase, the decision for a part and to be used potentials will be made. This is supported by so-called “InfoForms” that are used to collect as much information on the part as possible. These information can be used for the later redesign process as well as for the selection of potentials (see Figure 27). For each column a rating for the applicability of the six main potentials regarding the parts information can be given as shown in Figure 29. A visual bar chart evaluation directly gives a hint for further development.

Though, best results for optimization can only be achieved if not only the single part but the overall assembly or product is reconsidered. Therefore additional InfoForms for the adjacent parts and for the assembly have to be filled out. Based on the ratings before the assembly function InfoForm gives another diagram summarizes the other parts (see Figure 28). As for the shown example rating, a big conformity of the rating function integration recommends a function integration of the adjacent parts into one part. Furthermore if one part may be not allowed to be integrated, a very low rating for monolithic design would appear. Thus the engineer is aware of all potential applicability in one view.

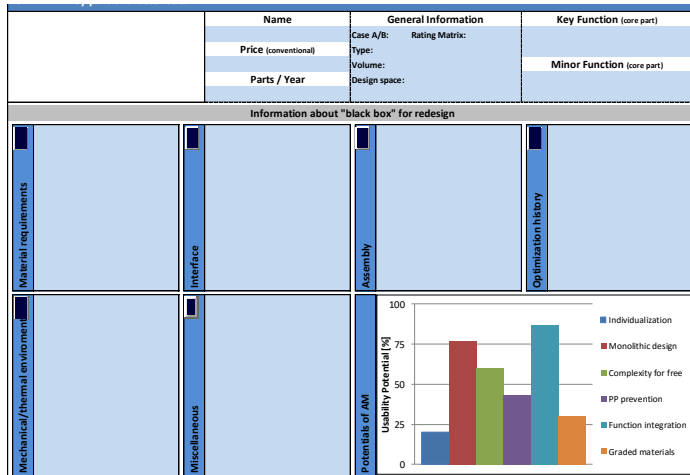


Figure 27: InfoForm “key part characteristic” for gathering of part information and potential selection

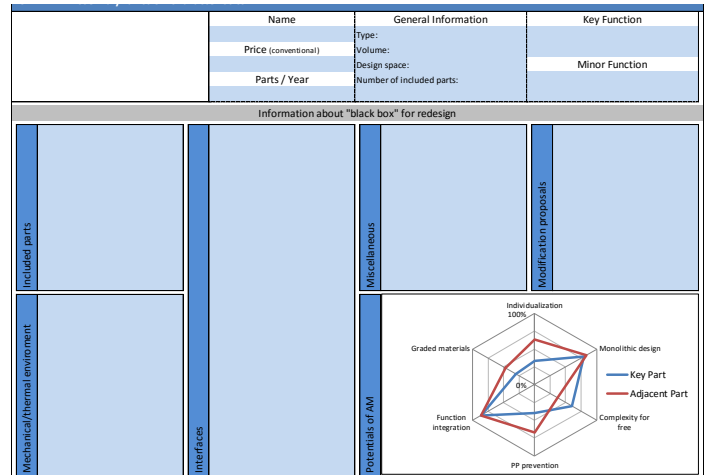


Figure 28: InfoForm “Assembly function characteristics” for gathering of assembly information and potential selection

Figure 29: Rating of the six main potentials for each column for potential selection

The third step of product optimization is the determination of optimal geometry. As described above, topology optimization is a powerful tool to obtain the optimal material distribution in an allowed space. With current tools multiphysic optimizations are possible, to integrate objectives like frequencies, heat radiation or pressure loss. Though, especially for considering all potentials, the engineer has to interpret the results carefully and combine the geometry proposal with the requirements for potential integration. For example special areas for marking should be available outside critically burdened volumes to avoid stress risings due to sharp marking edges.

In the last step a successful product optimization needs a successful build job. Therefore many influence factors have to be considered during build job preparation. Figure 30 shows some of these influencing factors but

is not an exhaustive consideration of all quality influencing factors of an AM-build job. It shows those points that can be influenced by the engineer directly via build job preparation and mainly influences the orientation and positioning of parts inside the build chamber.

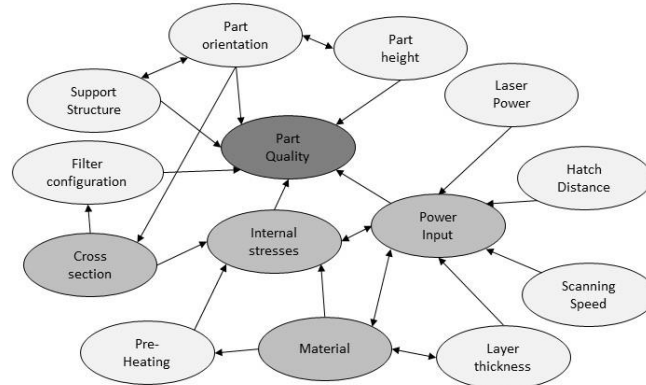


Figure 30: Influencing factors for build job preparation

Summary and Outlook

This paper gives a detailed view on potentials for product optimization with and for additive manufacturing. The number of potentials and opportunities offered by the two core characteristics of AM “1D-2D-3D” and “tool less manufacturing” is very high and thus the product designer needs to be advised and guided during product development. Hence this work has clustered the great number of potentials into six main potentials and ordered them hierarchic, building up on each other. Guidance during product development is outlined by methodologies for selection of right products and appropriate potentials. Further work was done by interpreting the potentials with regard to economic effects. This has to be worked out in detail and to be interconnected with the selection from technical view.

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