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Hybrid moulds – mixture of additive manufacturing by laser melting and conventional machining

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Abstract

Moulds for the injection moulding process at elastomers, thermoplastics and thermosetting plastics are produced by the known material removal manufacturing processes, such as turning, milling and eroding. The subsequently largely hardened moulds and mould inserts presented an elevated finish quality, hardness and permanent strength. The knowledge of the manufacture and use is available from long-term experience, so that products with high tool life of consistent quality can be produced.

Due to the changes in the market to smaller batches, shorter availability but also consistent quality, the mould manufacturer faces a dilemma for the solution of the problem which new processes will have to be used that comply with these new marginal conditions. For accelerating the mechanical removal of material, the high-speed cutting (HSC) has established itself. The generative processes of the rapid tooling provide a supplement.

By means of the rapid tooling, moulds for injection moulding result by which – according to the design – single or several hundred finished parts can be produced. Unfortunately, these moulds only can compete with the hardened moulds with regard to the expenditure of time.

Already now. it becomes obvious: There is no process in the mould construction for the fast manufacture of moulds for injection moulding that could really comply with all requirements. The marginal conditions of the mechanical machining only allow for a limited fast manufacture of moulds for injection moulding. In comparison with this, the rapid tooling indeed is fast, however is detrimental with regard to surface finish and permanent strength.

Driven by the above mentioned problem and willing to comply with the tougher requirements of the market, Messrs. Eisenhuth Formenbau, Osterode, within the framework of the project “Kitkadd”, publicly sponsored by the Federal Ministry for Education and Research (BMBF), have succeeded in developing a combination, the „Hybrid-Moulding“.

Keywords: "Type your keywords (at least 3) here, separated by semicolons ;" Hybrid Moulding, Lasermelting, mould making, additive manufacturing

1. Main text

1.1. Starting point: Mixture of conventional machining and additive manufacturing

At the process of the hybrid moulding of moulds for injection moulding, particularly one aspect is important, here the process mainly consists of a mixture of traditional mould construction and metal laser sintering. The mould inserts are produced of laser sintered steel and are subject to further machining, using different technologie, such as high speed cutting, milled graphite electrodes, sink erosion and final assembly. At the final assembly, so called mould construction automates (master form, guide columns and bushings, etc.) are used.

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There are several machining steps and their application necessary, such as CAD, CAM, Milling, Spark erosion, wire cutting, grinding, laything and moulding-assembley. Each of these elements owns certain material and manufacturing properties, which determine not only the mould for injection moulding but also the manufacturability and the design. Thus, it is necessary to combine the corresponding required positive properties of the single components.

Therefore, it had to be decided already prior to the proper design activities which components should be manufactured by which processes or which other process might be used respectively. The design starts originally with the original data of the part. Here, it is necessary to check whether there are some adjustments necessary. The final aim is to create an optimized insert under consideration of additive manufactured Design Rules. The final result was an article and a mould insert designed with optimized mechanical features, reduced weight and reduced post working efforts.

After completion of the single component design for manufacture, in the corresponding manufacturing process the manufacturing will start, also combining the several manufacturing and reworking processes. At the end, the components will be joined, being available in one set of moulds for production.

The inserts for Lasermelting were produced on a EOS M290 Lasermelting machine, with a process room of 250 x 250 x 300mm, a Laser Power of 400 Watt and a platform heating up to 200°C. As material was used a heat-treated steel (Böhler W360 AMPO) with a very good performance of hot temperature toughness, high temperature resistance and a good compression strength. The tear resitance is arorund 1970-2010 MPa, the Elongation between 6,6-8,1% and the Hardness of 55-57 HRc.

Parallel to the production of the lasermelted inserts, the regular machining of the mould is taking place. In addition, the post-treatment of the insert is necessary: the absolute removal levels are relatively low with HSC, allowing however further machining of materials with high strength without any problems. The rapid tooling shows advantages at complex structures and a high flexibility, also involving some pitfalls and tricks: Here also already at an early stage, a rapid cooling adjusted construction has to be taken care of. This means that e.g. narrow paths, deep groves, delicate structure may hold problems.

All the machined parts are now assembled together to the final mould. Having finished the mould, the next step, manufacture on the plastics machine, may be entered. An injection moulding machine consists of a plasticizer and closing unit. By a filling funnel, the granulate is fed to the machine. Heating elements in the plasticizer unit will heat the plastics and the material will be injected by a nozzle into the tool. The component is cooled and then ejected.

The tool that forms the plastics is composed of the mould basis and mould insert modules. Some modules, such as mould sets and ejectors for completing the tool, may be mounted to the mould basis. Due to the design adaptation of the mould inserts, the latter meanwhile still can be manufactured in addition. The component complexity has increased due to the realization of the close contoured cooling channels.

1.2. Cost analysis

For determining cost and time in the production, a computing tool has been developed for Messrs. Eisenhuth. Input data can be modified at any time, thus being able to show their influence on the output data. The setup of the various production chains is the basis of the computing tool. All data and parameters influencing the tool and injection mould parts as well as production times can be derived from them. There are three possible production chains: the conventional one, the hybrid and the additive one.

After setup of the production chains, the tool cost for the two variants, the single and double tool, shall be determined. In this respect it is noticeable that the hybrid cost .is abt. 63% less than the additive tool cost for the double tool. The reason for this is based on the fact that the mould basis is manufactured in the conventional and hybrid production chain on a conventional basis. At the additive production chain, it is assumed for the additive production chain that the mould basis is manufactured by addition and therefore will increase the cost.

	Standard Mould with 1 cavity	Hybrid Mould with 1 cavity	Standard Mould with 2 cavities	Hybrid Mould with 2 cavities
Moulding cost	3.500,00 €	4.800,00 €	4.300,00 €	5.400,00 €
Net production time for one cycle	40 seconds	22 seconds	40 seconds	22 seconds
Net production time for one cycle	1.111 h	611 h	555 h	305 h
Material cost for 100.000 parts	585,00 €	585,00 €	585,00 €	585,00 €
Net Production cost for 100.000 parts	6.055,00 €	3.330,00 €	3.025,00 Euros €	1.495,00 €
Total production cost	10.140,00 €	8.715,00 €	7.910,00 Euros €	7.480,00 €

Fig. 1. production cost and machine parameters based on one part and for 100.000 parts

Fig. 1 shows production figures, moulding cost and the production cost for 100.000 parts. After determination of the tool cost, the cost of the injection mould part for the two tool variants as well as for the three production chains has to be determined. For the selection of the cost model, not only the pure cost of the mould basis or mould inserts will be considered but all cost items, such as the influence of the cycle time. At mould inserts from additive manufacture the latter is lower than for conventionally manufactured mould inserts due to the close contoured cooling. A time reduction from 40 seconds to 22 seconds can be measured. This knowledge as well as the different number of cavities at the tool variants will result in different machine capacities.

For 100,000 components, the unit cost of the production chain of the tool produced by hybrid manufacture is by 50.5% more favourable than the unit cost of the tool manufactured by additive manufacture. Looking at the total cost, the saving is about 5.5% lower than the complete cost of the production chain of the conventionally manufactured tool. The higher cost of the additive production chain can be justified by the additive manufacture of the mould basis being more time consuming and at higher cost.

2. Acknowledgements

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3. References

Adam, G..Systematische Erarbeitung von Konstruktionsregeln für die additiven Fertigungsverfahren Lasersintern, Laserschmelzen und Fused Deposition Modeling“, Forschungsberichte des Direct Manufacturing Research Centers, 2015, Dissertation, Paderborn 2015

VDI Richtlinien 3405 & VDI Statusreport „Realität in der industriellen Fertigung“, November 2019

Gebhardt, R..Detaillierte Roadmaps weisen Additive Manufacturing den Weg in die Smart Factory, published in the VDMA network, Sept. 2019, Frankfurt

Klemp, E.: „Prozessketten der Additiven Fertigung – Möglichkeiten und Chancen“, publication at the Hochschule Lemgo, Lemgo 2019

Hickmann, T., Klemp, E.: The Potential of Redesign and Part Consolidation - Additive Manufacturing and Hybrid Molds in Combination with Conventional Machining, in Kunststoffe International, Munich, Hanser Verlag, 66-68

Langefeld, B..: “Advancements in metal 3D printing – Additive manufacturing on the brink of industrialization”, paper of Roland Berger, Munich 2018

KIT / WBK (editor): Projekt KitKAdd – „Kombination und Integration etablierten Technologien mit Additiven Fertigungsverfahren“, gefördert durch das Bundesministerium für Bildung und Forschung, Karlsruhe 2020, ISBN 978-3-00-065337-7