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KEY TECHNOLOGIES FOR SUSTAINABLE MANUFACTURING

Innovative production techniques require an efficient utilization of human, material and energetic resources to ensure competitive manufacturing positions. The aim of modern industrial production processes is to provide products with a higher added value in a shorter time-to-market. On the other hand, shorter life cycles of products are contrary to the necessity of expanded service time of manufacturing systems. Moreover, the whole life cycle of products is accompanied by customer related service provisions. Flexible and adaptive as well as self-organising means of production are a considerable key to solve this conflict of objectives. Here, man with specific technological knowledge has to be integrated with it's permanently newly defined role in production. This paper presents production technology related new developments and strategies to fulfil the requirements of sustainable manufacturing.

1. SUSTAINABILITY IN PRODUCTION TECHNOLOGY

The sustainability thought goes back to results of the work of the Brundtland commission, which described solutions for the linked and depending economic, social and ecological questions. They were the basic idea of today's understanding of sustainability, which has the maintenance of the need satisfaction of today's and future generations in

a global context as a goal. There is a need to transfer the sustainability thought to production. Superficially, there are partially conflicts between the individual sustainability dimensions. It is a challenge to dissolve these conflicting aims by new technological developments which are today not yet state of the art. In contrast, some solutions support two or three of the sustainability dimensions at the same time. An example is the technology authority of enterprises and their resources productivity (Fig. 1).

Economic production is still based on the minimization of production costs, however also increasingly on a transformation ability of the production, which aims at a fast conversion of new products if possible with existing plants. The efficient use of resources in

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the sense of the resources productivity shows equally positive effect under economic as well as ecological criteria. Substantial driver for the improvement of the ecological dimension in enterprises is the life cycle extension of operating and consumption goods. In the sense of the cycle economy the re-use of materials, the use of regenerating raw materials for materials as well as of regenerative sources of energy have a direct influence on the eco-efficiency. It is still a large challenge to avoid or minimize emissions. An increase in value of the sustainability is reached in particular by the existing technology authority in the enterprise, which has positive effects on the economic, ecological and social characteristics of the enterprise. The system factory must be able to promote social aspects as employee's satisfaction, health, security and education as well as to secure a minimum social standard of the employees.

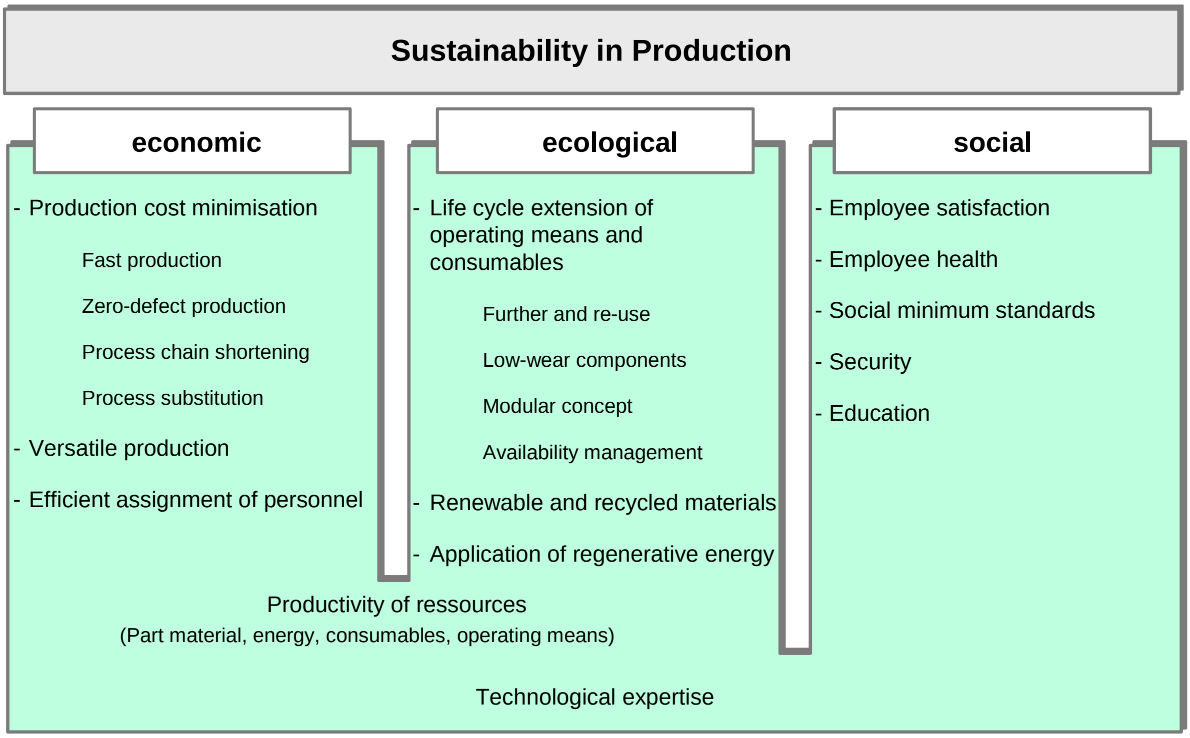

Fig. 1. Sustainability in production

2. KEY TECHNOLOGIES FOR MANUFACTURING TECHNOLOGY

The overcoming of current technological borders for reaching the set economic, ecological and social goals of sustainable production engineering is the central motivation for the development of hybrid manufacturing methods. Hybrid procedures are characterized by the combination of a conventional manufacturing method with an additional thermal, chemical or mechanical mechanism, which is responsible for a significant increase of the productivity in relation to the conventional procedures. The temporal and spatial superposition of the effect mechanisms result in an increase of productivity, an extension of the application scope on new groups of materials as well as the increase of the product quality by better surface properties, surface layer damage or smallest form deviations. For the increase of the energy efficiency mechanical hybrid procedures, which are characterized by a launched secondary kinetics, as well as chemically hybrid procedures, which aimed modifying the material properties, make a contribution to a sustainable handling of natural resources.

Not only for recycling but also in the context of production and part repair the cleaning technology exhibits a special meaning. The multiplicity at different contamination on most diverse substrates requires an extremely flexible cleaning technology. In particular removing hard coatings on parts for the protection from wear and thermal loads represent a special challenge, which can be usually solved only with high efforts [1]. Laser-supported dry ice blasting is an example of a thermally supported hybrid procedure (Fig. 2). The combination of the laser beam and dry ice blasting causes an increase of the material removal rate between 50 % and 700 % in comparison to pure dry ice blasting by a reinforcement of the thermal effect. The obtained decrease in process time faces the necessary additional equipment technology and their energy consumption. In further variant sensitive surfaces can also be cleaned and even structured by the dry ice jet prepurifying in connection with the laser fine cleaning. In both cases only the removed coating or contamination has to be disposed. Contaminated chemical liquids, as they appear during the wet-chemical cleaning of parts and have to be demonstrably disposed, do not longer arise. Beyond that, the conventional cleaning is frequently combinable with a pre-treatment procedure, whereby a further process can be saved.

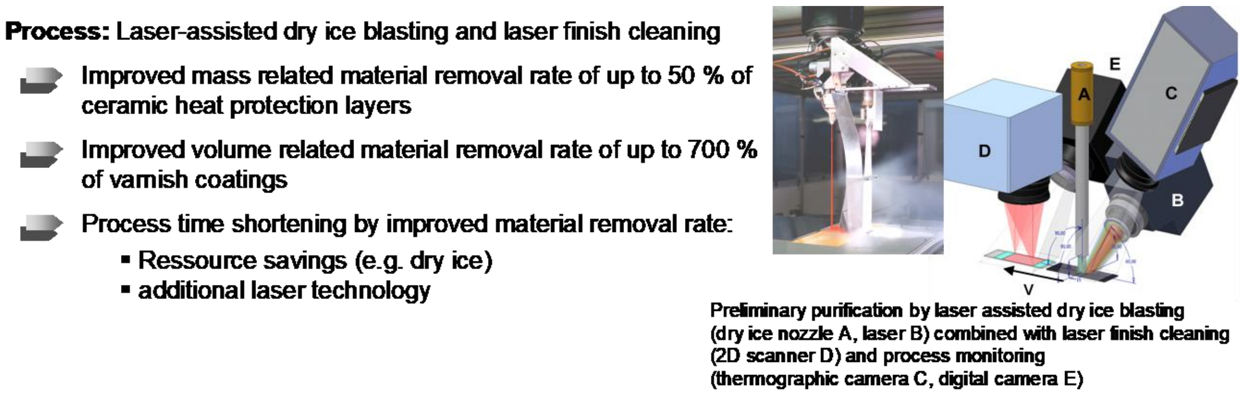

Fig. 2. Cleaning by hybrid laser beam ablation and dry ice blasting

The hybrid combination of conventional deep-drawing with electromagnetic contactless shaping by magnetic field strengths realized by integrated coils saves process steps and individual machines as well as handling the sheet metal components between single process steps, which leads to a decrease of production time. The conventional deep-drawing takes over the task of preforming in the first process step. Following forming of critical zones as well as secondary and special form elements or bringing in blankings is performed by electromagnetic deformation [2]. Thus, simultaneous forming of form elements and bringing in blankings can be accomplished by only one tool. The use of electromagnetic impulses for the final shaping and for local ranges of a component lowers requirements on tools and thus tooling expenses.

Sustainable cutting processes are realized by innovative tool concepts, which lead on the one hand to higher productivity and on the other hand to an increased resource and energy efficiency. The mechanical and thermal loads as well as tribo-chemical reactions during cutting cause wear of the tool. In order to obtain an economic machining result, cutting material and geometry of the tool must fulfil a broad requirement profile. Thin wear-resistant layer systems on variable tool-substrates and tool geometries are often technologically and economically the best solutions [3].

Super hard cutting materials based on diamond and cubic boron nitride are conventionally manufactured with high pressure high temperature synthesis. Those composite cutting materials such as Polycrystalline Diamond (PCD) and Polycrystalline Cubic Boron Nitride (PcBN) possess a binder phase, which limits the range of application. In contrast, super hard thin film systems without binder phase can be generated by chemical or physical vapour deposition (CVD / PVD). The development of super hard cutting materials both in the case of CVD diamond and PVD cBN shows a strong tendency to thin film in particular on geometrically complex cutting tools. This trend makes the combination of higher mechanical and chemical resistance of the cutting tool material with user-specific geometrical design for the tool geometry possible [4]. Apart from the higher cutting speed for the increase of productivity and component quality, the polluting use of lubricants can be reduced. By this, the material and time minimized production reduces manufacturing costs. At the same time valuable fields of activity for the employees are opened while simultaneously lowering the fixed costs for the tool production and their application.

The use of lubricants to support the heat dissipation and improve of the tribological procedures during the chip formation is common in cutting technology. The so called wet cutting represents an enormous load to the environment and the machine operator as well as leading to high costs. As depicted in Fig. 3, the direct lubrication costs make up 16 % of the whole production costs. The production costs can be reduced by the use of dry processing technologies over up to 45 %. A complete renouncement of cooling or lubrication is often not possible however. While the minimum quantity cooling lubrication (MQL) offers a compromise for the tribological support of the process, satisfying dry processing technologies is not available for many tasks of manufacturing [5].

A much promising proposal for efficient heat dissipation during processing of high-temperature resistant superalloys is the development of inner cooled cutting tools. The release of the cooling lubricant in the manufacturing process is prevented by a closed cooling circuit. At the same time the lubricant is protected against impurities, whereby environmental impacts, lubricant cleaning- and disposal costs are reduced significantly. Apart from the only removal of the process heat such a system offers the possibility of minimizing the thermal alternating stresses to the tool and component by controlled temperature guidance.

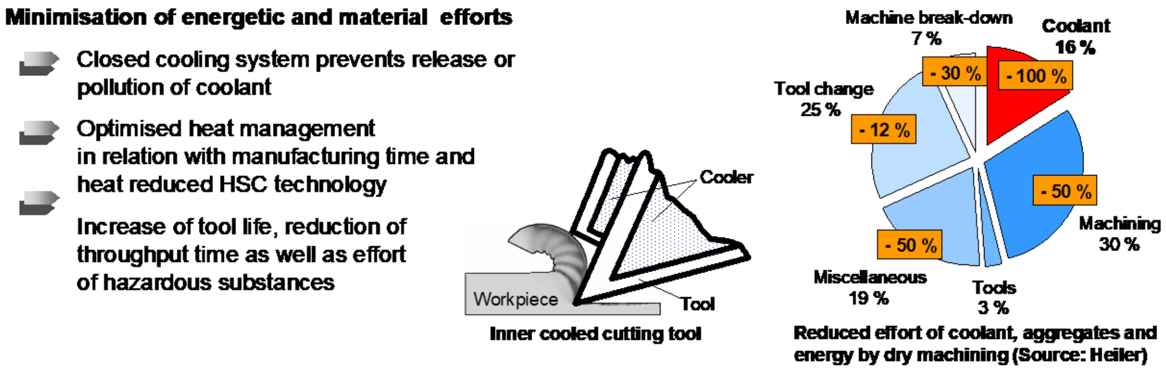

Fig. 3. Reduction of lubricant with inner tool cooling

This tool innovations are the basis for reducing the friction induced portion to the resultant cutting force components, lessening the harmful use of lubricants and thermal as well as speed optimized machining processes. The optimization can result in up to 1000 % faster cutting speeds compared to conventional machining processes. Significant ecological and economic effects are a result of the increased tool life time and component quality.

The classical part manufacturing proceeds from the paradigm that first under high energetic expenditure semi-finished material are manufactured, which still possesses no geometrical similarity with the final parts. The surplus material must be removed energy consuming with cutting or non-conventional machining processes in order to realize the part geometry and quality specified by the designer. Combining material and part production in one step without separating manufacturing processes, the highest measure of sustainability is being attainable by part material as well as operating material and energy savings.

The generative manufacturing methods passed in recent years a substantial boost and became an inherent part in product development. With the consistent advancement of these technologies it is possible to produce coloured plastic models nowadays for example. Concerning metallic materials at present aluminium, hot-work tool steel as well as high-grade steel can be directly laser sintered to operational part units. It is used for example for forming tools with new geometries without the conventional cutting procedures. Even mall series can be realized under economic criteria. Medium-term, from the economical and ecological point of view the generative manufacturing methods represent an alternative to the complex and often time-consuming conventional production technologies. Regarding the indulgence of resources the generative procedures offer advantages. On the one hand only exactly that amount of material is needed, who is necessary for the generation of the part volumes which means chips as well as lubricants are completely void. The production of the necessary parts can take place locally, so that long routes of transportation are avoided just like complex and cost-intensive storekeeping. Rapid manufacturing processes could develop to a quite serious competition for the conventional processes, if it succeeds to reduce production time, improve the reproducibility and the today often insufficient part quality.

The simulation of the machine cutting offers a large potential for the fulfilment of the requirements posed under ecological, economic and social criteria to the sustainability of manufacturing processes. It opens on the one hand new possibilities regarding the selection of the most resources efficient process strategy. On the other hand it contributes considerably to the acceleration of the development process of tools and machines, straight under the criterion of the realization of individual, demand meeting solutions. Thus for example, the simulation-supported adjustment of feed speed while milling complex workpiece geometry with hard-to-chip materials reduces the operating time over up to 40 % [6]. The decrease of the operational funds settles in the saving of costs and energy.

Beyond that, the simulation of the chip formation with the finite element method allows virtual testing from geometry variants [7], [8]. Thus a pre-selection of the considered variants and restrictions are made possible to limit the number of manufactured prototypes. This leads to a substantial temporal saving by the reduction of cutting experiments. In addition, a faster generation of specific technological knowledge takes place, which is absolutely needed for the selection of a favourable component design. The results of the simulations flow conversely into the development of machine tools and promote thus likewise resources-saving development process.

3. CONCLUSION

Market demands for higher quality as well as economic and ecologic efficient manufacturing together with pressure from growing costs call for innovative research and development in production engineering. In addition, shorter product life cycles and rising public awareness of environmental issues force companies to realise their dependency on innovative abilities in order to become or stay successful. This is the core aim of modern manufacturing process lay-out to achieve the leadership in market competition. A strategic consciousness for the conflict of the sustainable aims of economic, ecological and social matters is needed to accomplish the challenge of globalisation.

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