Methodological investigation of the product development in micro technology

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Abstract

Both in micro technology and in macro technology the early phases of product design are of considerable importance. However, unlike the conventional design process in micro technology the function achievable by means of product design is rather technology-driven than subjected to requirements. Especially multidisciplinary influences such as production processes, material characteristics and micro-specific effects have a restrictive impact on the design of the machine element.

On the basis of the product development process for primary shaped micro components from metallic and ceramic materials a method is presented, which makes it possible to detect the know-how provided by disciplines subsequent and adjacent to the design process, having influence on the design of the machine element and interpret this relevant to design. The computer-aided availability of knowledge is carried out via a knowledge-based design environment.

Micro-specific product design

Components and systems of micro technology are multi-technology products. According to a definition a micro system is based on the common "use of different, at least two basic technologies" [6]. Only in an all-embracing integration of technology, process and product development, material sciences and simulation optimal, innovative micro systems can be realized.

Multidisciplinary influences on micro-compatible design

Multidisciplinary influences in micro technology such as material anisotropy or limited possibilities for manufacturing micro structures due to unavailable tools (figure 1) cause an alteration of the approaches for development and design known from macro technology. Thus almost every design can be realized according to the conventional approach, unless it infringes general design axioms, even if this requires great technological and financial efforts. In micro technology the product designer frequently deals with the question which products he can manufacture and which kind of behaviour the machine elements will show. However, it is rather

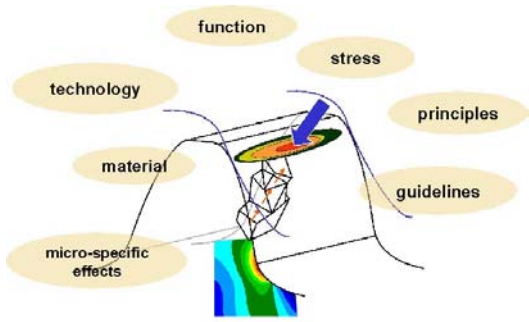

Fig. 1: Multidisciplinary boundary conditions influencing the micro-compatible design.

difficult to assess the large amount of expertise, separate it according to its relevance to product design and project it on the current development task.

The methodological penetration of the product design process in micro technology will lead to a specifically adjusted approach and supply the designer with micro-specific methods and tools.

Methods

In order to adapt and provide the presented multidisciplinary influences on the product design, design rules are applied as an aid accompanying the process of product design. As a result, the product designer is supported at the different abstraction levels of product development until the embodiment design of the component respectively system within the 3D CAD.

Design rules

Design rules are detailed instructions for micro-compatible part design. They are derived from multidisciplinary basic requirements.

In the process steps of product planning and conception they guide the designer by pointing out restrictive characteristics in the decision making process and have a direct influence on the embodiment design within the 3D CAD being mathematical, geometrical expressions.

The following figure 2 shows the steps for deriving design rules from multidisciplinary boundary conditions.

Firstly, potential influences from existing disciplines need to be detected. These influences are based on the production process chain for producing primary shaped micro components from metal and ceramic, where they are primarily included in the technology for manufacturing the mold insert by means of micro milling as well as in the molding process during micro powder injection molding and micro casting.

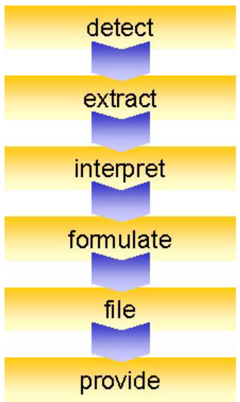

Fig. 2: Steps for deriving design rules from multidisciplinary boundary conditions.

As a second step all relevant machine and process parameters are extracted from the production process and are systematically collected in a technology specification sheet. Concerning the production preparing process of three-axis micro milling these parameters are e.g. type and size of the milling cutter, the tolerances of tools, setting and machine tool or the realizable wall roughness.

In the next step these parameters are being interpreted relevant to design. Thus in our example it is not possible to produce cavities with a width smaller than the diameter of the milling cutter plus its tolerances. Apart from that also the possible aspect ratio of the cavity is determined by means of the relation between length of the milling cutter's edge and diameter of the milling cutter.

For the formulation and the systematic filing - the next steps – a classification scheme has been specially defined, which particularly allows the computer-aided filing in a database as well as access via an information portal and an adjusted 3D CAD system.

Example for technology-related design rules

In order to illustrate the support for the designer during the development by means of design rules, the design rule **KR_FE_MF3_x_002** for the development of a micro planetary gear is explained.

According to the classification scheme the code **FE** indicates that the type of machine element is a mold insert. The technology applied for manufacturing the mold insert is the three-axis micro milling (**MF3**). As the next step a specification of the tool group is given. In this case the „**x**“ means that the rule is valid for several types of milling tools (end mill cutter and radius form cutter). At the end this includes a continuous numbering. The rule as a mathematical relation is as follows:

$$R_{\text{inner edge}} \geq d_{\text{milling cutter}} / 2 + T_{\text{mill}}$$

Due to the circular cross section of the milling cutter no sharp inner edges or radii can be manufactured, which are smaller than the milling cutter’s radius plus tolerances. For the detailed machine element geometry of a gear wheel (figure 3) this means a tip rounding of at least 50 µm. The smallest end mill cutter used for repro-

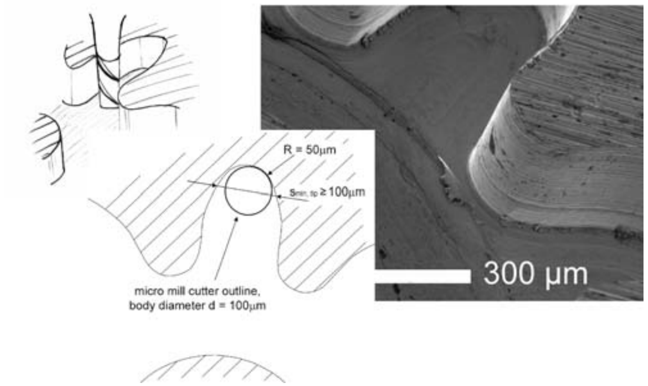

Fig. 3: Rounding of inner edges of the mold inserts due to the used micro milling cutter

ducible results at the moment has a diameter of 100 µm. This results in a loss of supporting tooth length and therefore a reduction of the effective transverse contact ratio.

This technological fact shows the necessity to move forward knowledge relevant to design from the process of mold insert manufacturing into the conception and the embodiment design. Especially this production-oriented restriction formulated in the design rule has considerable effects on the miniaturisation of the gear wheel component and the gear as a whole.

In this sense the design rules can be understood as a methodical aid in order to make multidisciplinary knowledge available for one discipline.

Tools

For the computer-aided availability of design rules a knowledge-based design environment is built. This implies a united information and design unit, which have access to the same data record (figure 4).

Fig. 4: Knowledge-based design environment.

Information unit

Via the information portal „Design and Methodology Database – KoMeth“ developed at the institute of machine design and automotive engineering the designer can retrieve the specific design rules necessary for the application by means of different access methods.

Embodiment design unit

For the application of design rules to embodiment design the KBE (Knowledge-Based Engineering) – module of the 3D CAD system Unigraphics V18.0 [5] has been extended by specific functionalities. In a prototype it was possible to check a part concerning irregularities and have them partly corrected automatically.

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