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IMPROVING COMPUTER AIDED TOLERANCING BY USING FEATURE TECHNOLOGY

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Feature Technology, Computer Aided Tolerancing, Vectorial Tolerancing, Simultaneous Engineering

Abstract: The application of feature technology in the field of Computer Aided Tolerancing (CAT) enhances simultaneous engineering during the product development process. The combination of micro-geometrical, topological and other product data within one element enables further integration and processing of tolerance information in different phases of the product life cycle. The designer's functional view can be combined with Design for X information. For example, information about necessary and possible manufacturing processes for a specified tolerance might be attached to the geometry of a workpiece. By using this approach a first choice of manufacturing machines or information about necessary and possible inspection-methods could be achieved.

1. Introduction

1.1 Computer Aided Tolerancing

For a long time the quality of tolerancing in the design process was strongly related to personal experience. Designers have often taken tolerance information used in older drawings with similar problems. Furthermore, they normally have chosen rather tighter than wider tolerances to be sure that the parts will fulfil their functions. To enhance this situation a lot of applications for Computer Aided Tolerancing (CAT) have been developed for different CAD-systems recently. Although they are often advertised as „one press button“ applications, in reality specialists are needed in most cases to use CAT-technology efficiently. Hence, in small and medium sized companies these CAT-applications are useless for a casual usage [Salomons97]. The traditional method of „tolerancing by personal experience“ is often the only possible way.

1.2 Feature Technology

A feature is a collection of knowledge combined with geometrical data. Features can be defined from different viewpoints. Hence, there are various types of feature classes such as form feature, assembly feature or manufacturing feature [Shah95]. Different types of features can be classed into a matrix representation introduced by the FEature Modelling EXperts group "FEMEX" [Weber96]. This matrix consists of different stages of the product life-cycle, different classes of properties like requirements, geometry and tolerances and views of special features.
The designer’s point of view is primarily the functional view. Parts fulfil special functions like bearing seat or sealing. A feature can combine this functional view with the manufacturing view for example. By this way an oversight of functional requirements from another point of view is given. Thereby a

designer gets more information about the following (manufacturing) processes. If problems occur and criteria can not be met in later stages of the product life cycle, he might reconsider his decisions.

2. Tolerancing using feature-technology

According to the design method of German guideline [VDI 2221] the design process can be split into several phases (denoted in figure 1) systematically.
After creation of a function tree, which symbolises the whole product structure from a functional point of view, single (sub-) functions (e.g. transfer of a torque) can be detailed by applying adequate solution principles (e.g. transfer by friction). After that a further development of a detailed solution (transfer by certain cylindrical mating parts) can take place. During the design process the designer has to find the best solution principle out of a catalogue of possible solutions. Besides the functional view other views like the economical view (e.g. costline in figure 1) have to be considered.
Tolerancing is part of the late phase of detail design. In this paper two possible ways of tolerancing using feature-technology are presented: Feature-based Modelling, Dimensioning and Tolerancing (FbMDT) and Feature-based Dimensioning and Tolerancing (FbDT).

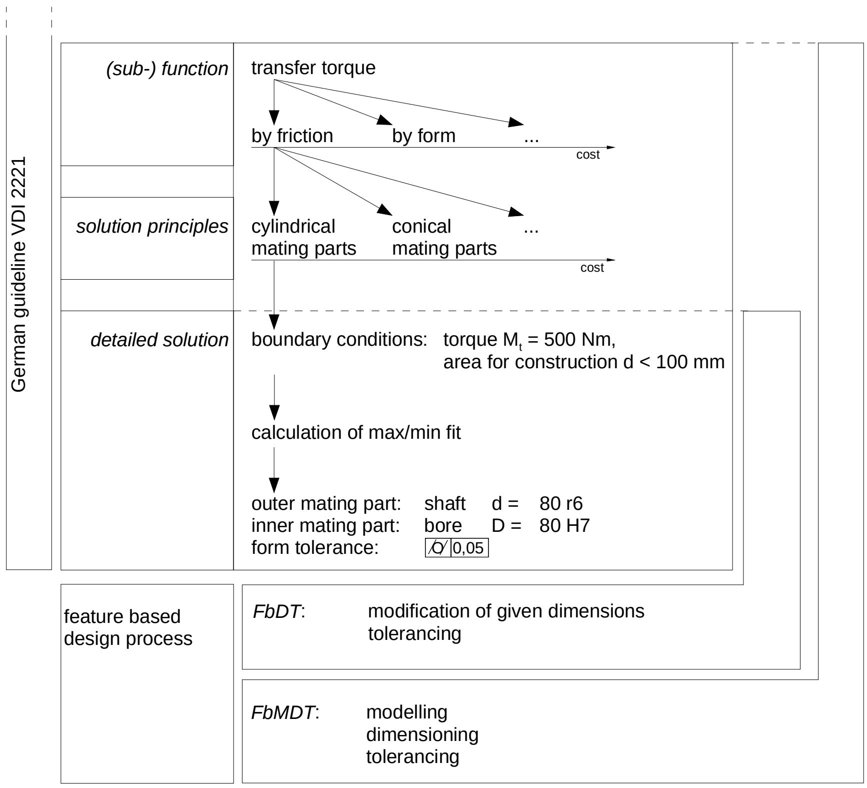

Figure 1. Classification of feature-based tolerancing methods

2.1 Feature-based modelling, dimensioning and tolerancing (FbMDT)

The FbMDT approach comprises almost the whole design process. The designer starts with functions to be fulfilled, e.g. „transfer a torque of 50 Nm“. Then he has to find appropriate solutions for these functions.
He chooses a certain way within a structured table containing different function-principle-solutions (see figure 1) to generate the detailed design (semi-) automatically. The principles and solutions in figure 1 are listed by cost. Hereby an easy possibility for selecting problem solutions as cheap as possible is given. In the case shown in figure 1, the principle „transfer by friction with cylindrical mating parts“ has been selected. After this decision, calculation starts to verify the solution under consideration of boundary conditions given in the design task (e.g. torque 20 Nm, d < 100 mm). If the calculated result is unsatisfying, the solution is abandoned. The designer has to take a step backwards

and might select another function principle (e.g. „transfer by friction with conical mating parts“) or another possibility of transfer (e.g. „transfer by form“).
After a sensible solution was found, the FbMDT approach generates a design feature consisting of model data, calculated dimensions and specific tolerance information. The feature data can be read by every engineer who is involved during the production process. Thereby, the attached tolerance data eases the communication between the departments. Since every engineer can retrieve the current status of the product data, the process of decision making is accelerated and modifications of e.g. the boundary conditions are easier to establish.
After selecting the cylindrical fit shown in figure 2, the geometry of the inner and outer mating parts are generated automatically in the CAD system. The thickness of the generated hub is calculated with reference to the stress, imposed by the press fit on the ring. The designer has to complete the hub, bearing in mind the task the hub has to fulfil. For example, if the ring will be used as basis of a gear wheel the missing gear geometry has to be generated around the ring.
Besides quality improvement of functional tolerance specification the presented approach helps to save time during the CAD based design. To take further advantage of the method, it is imaginable to expand FbMDT from the form features approach (part related) to an assembly oriented approach.

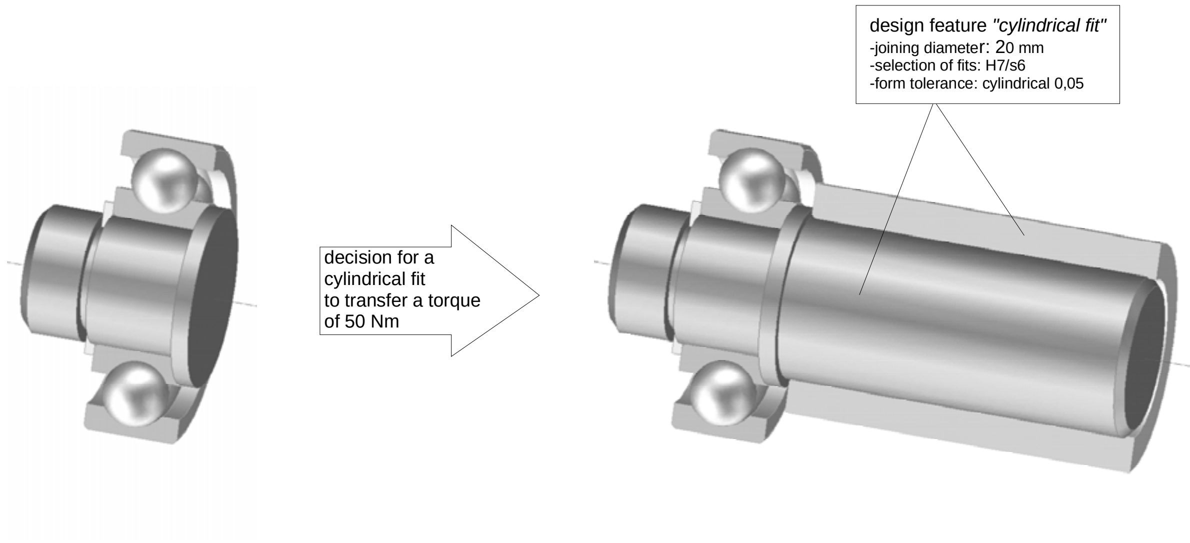

Figure 2. Feature-based Modelling, Dimensioning and Tolerancing (FbMDT)

2.2 Feature-based dimensioning and tolerancing (FbDT)

Our second approach of feature based tolerancing named „Feature-based Dimensioning and Tolerancing (FbDT)“ comprises only those steps which are included in the detail phase of the design process (see figure 1). In this case the embodiment of the solution which has to be toleranced is already existing. Only the details concerning certain functional requirements (e.g. bearing seat dimension, sealing seat diameter) have to be completed.
The designer picks a face on the CAD screen and assigns a certain function to the selected item. In the case depicted in figure 3, the right shaft section should bear a sealing ring to realise waterproofness between shaft and bore of the housing. For this, certain criteria like the correct standard diameter dimension, run-out tolerances and surface quality have to be met.
After the selection of the sealing-ring type the dimension „diameter“ of the existing geometry will be altered to come in line with the standard diameter of the selected sealing ring. Then, a feature called „sealing-ring seat“ will be assembled in a similar way as explained for FbMDT. It consists of geometry data, tolerance and surface-quality parameters, all together attached to the face the feature has been assigned to. For positional tolerances or in this case run-out tolerances additional information about specific datum elements are necessary. These further information have to be queried by the system to complete the tolerance feature.

If later in the design process e.g. boundary conditions change the whole feature information can be checked and modified.

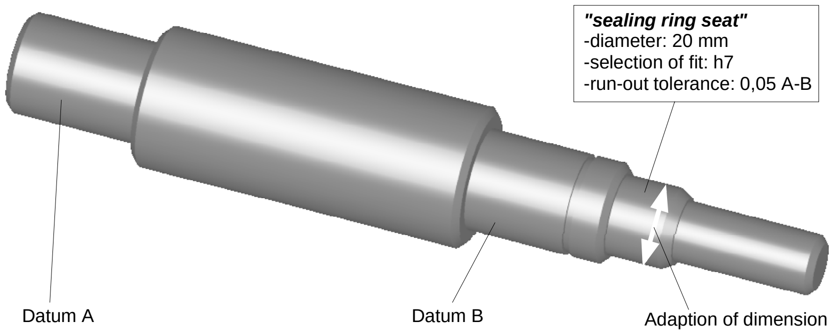

Figure 3. Feature-based Dimensioning and Tolerancing

2.3 Additional design for X feature information

Up to now this contribution has focused mainly on feature-based tolerancing from the designer's functional point of view. Hence, the next step will be the definition of tolerance features which capture more sophisticated design for X information.

For this, work is underway to develop a new tolerance feature (figure 4) in co-operation with the department of manufacturing processes (LFT, Prof. Bley, Saarbrücken) and the institute for information systems (IWi, Prof. Scheer, Saarbrücken). This type of feature is compound of a geometrical form feature (e.g. the geometry of a bearing seat), several views concerning tolerances and the resulting tolerance datums and values.

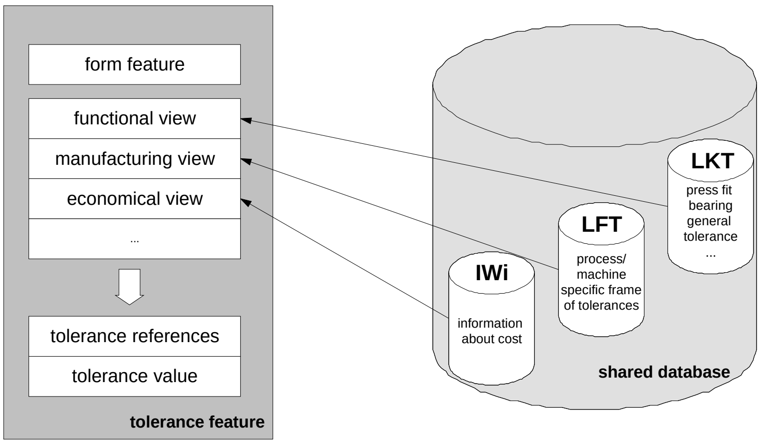

Figure 4. Tolerance feature

There are several views to be explained in detail:

First of all, the functional view (LKT, Department of Engineering Design/CAD) of the tolerance feature has to be mentioned. The result of the feature-based approach from the designer's point of view is the appropriately toleranced design feature which fulfils the design specification. The concepts of FbMDT and FbDT as described above are strategies belonging to this functional view.

The manufacturing view (LFT) of the tolerance feature gives the designer information about the manufacturing processes which are both necessary and possible in the own workshop.

After the designer's decision for a (functional necessary) tolerance combination the manufacturing division scrutinises the tolerances concerning the manufacturing processes. First the question has to be answered if there are any tolerances which cannot be manufactured with the machines available in general. During this evaluation step indispensable information are retrieved out of a database. The

database comprises the manufacturing division’s specific tolerance frame and represents the division's tolerance experience. If it is not possible to manufacture a part with the required tolerance specification this result is fed back to the designer. He might change the dimensions, the tolerance scheme or even the solution principle to avoid cost driving problems as early as possible.
Secondly, a first choice of machines to manufacture the part can take place. Additionally a first reflection on machine utilisation can be done. Hereby conclusions about the period of time for manufacturing and the date of completion can be drawn. Especially the time schedule for the manufacturing process is another important information which has to be taken into account. If it seems to be impossible to meet the given deadline, the designer can alter his solution.
The third view to implement is the economical view (IWi). The aim of this view is to give information about the cost of different tolerances at the designer’s fingertips.
Especially tolerances which are too tight and in consequence too expensive should be recognised and eventually be overworked by the designer. In order to make this type of information available, a calculation during the design process and a calculation of the expected process cost have to be realised. Too expensive tolerances can lead to a step backwards in the design process, too.
The co-operation between the functional, the manufacturing and the economical division during the design process is depicted in figure 5. Different information included in the tolerance feature can effect a change of solutions, principles or even sub-functions in the design process.

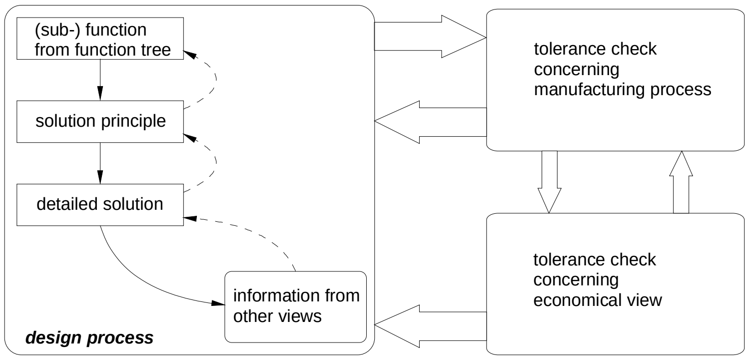

Figure 5. Co-operation during the design process

3. Present State and Perspective

The presented approach of feature-based tolerancing will be implemented in combination with „VecTol“ [Thome97] which is a prototype for vectorial tolerancing [Stark94] in the 3D-CAD-System CoCreate/PE SolidDesigner. „VecTol“ is divided into three components: attachment of vectorial tolerances, simulation and calculation.
After several parts are toleranced vectorially the designer has the possibility to check the tolerances by displaying the maximum and minimum deviations of parts, see figure 6. This can be realised by a visual collision check or by pre-defined calculations between deviated parts. As the vectorial approach is really predestinated for handling in CAx-systems it is complicated for the designer to use. To guarantee the ease of use a translation is in work to bring vectorial tolerancing in line with ISO-tolerancing.
Among lots of other feature „views“ particularly the inspection view is worthwhile to implement. Similar to the manufacturing view it is of special interest which kind of inspection methods are necessary and available to check the part’s dimensions [Ciesla97]. It would be pointless to specify tolerances with small values which cannot be measured by the inspection equipment available. Hence, the implementation of feature-based tolerancing will be as flexible as possible to ensure easy extensions of the feature concerning other views.

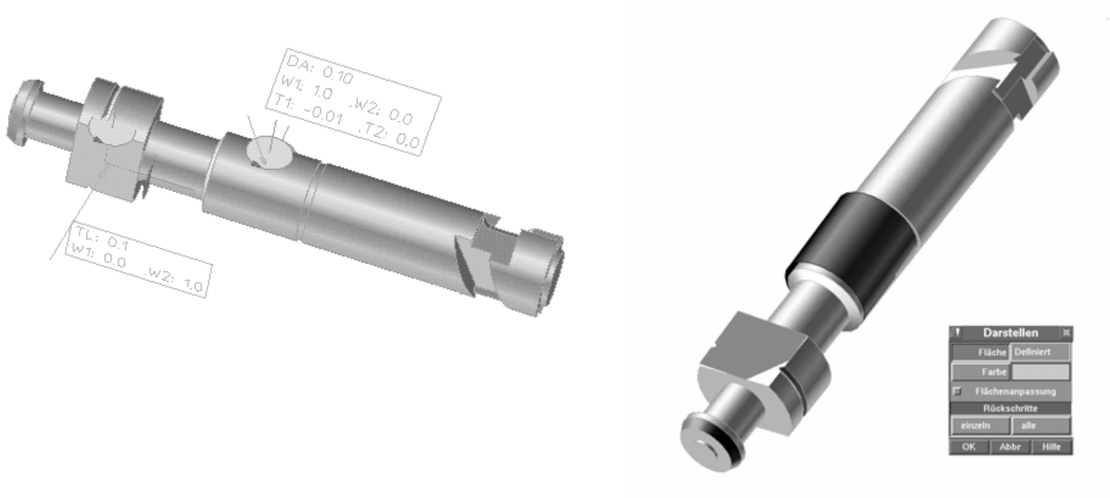

Figure 6. VecTol: Displaying of deviation

4. Conclusion

The currently predominating method of tolerancing by personal experience will be improved by the synthetical approach of functional tolerancing as shown. Besides functional correct and unambiguous tolerance information, the use of CAD-technology helps to save time during the design phase by generating geometry and tolerance information (semi-) automatically.

Furthermore, the approach of feature-based tolerancing enhances simultaneous engineering. During the design process various views can be considered. First steps of later stages in the product life-cycle can start earlier during the design process. Because of feature technology other divisions can start with more comprising information. A very flexible feature implementation supports an easy enlargement of the currently available feature views.

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