SOFTWARE FOR CALCULATION AND ANALYSIS OF ISO SYSTEM OF TOLERANCES, DEVIATIONS AND FITS

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Abstract: This paper is based on the basic concept of ISO System of tolerance. We will discuss fundamental deviation, fundamental tolerance, and the calculation of tolerance according to the symbol used. The focus of the paper is software for quick calculation and analysis of ISO system of tolerances, deviations and fits. Beginning of the paper explains the basic concepts of ISO system of tolerances and fits, after that, paper describes in detail the design and implementation of above mentioned software. The software is named E-Tolerances. Except the description of design and implementation process, paper explains how to use E-Tolerance software. In the end it was said a few words about the possibilities of upgrading the software.

Keywords: ISO systems of tolerances, deviations, system of fits, software, analysis

1. INTRODUCTION

It is necessary that the dimensions, shape and mutual position of surfaces of individual parts of mechanical engineering products are kept within a certain accuracy to achieve their correct and reliable functioning [2]. Routine production processes do not allow maintenance (or measurement) of the given geometrical properties with absolute accuracy. Actual surfaces of the produced parts therefore differ from ideal surfaces prescribed in drawings. Deviations of actual surfaces are divided into four groups to enable assessment, prescription and checking of the permitted inaccuracy during production [1]:

- Dimensional deviations
- Shape deviations
- Position deviations
- Surface roughness deviations

“E – Tolerances” software includes the first group and can therefore be used to determine dimensional tolerances and deviations of machine parts.

As mentioned above, it is principally impossible to produce machine parts with absolute dimensional accuracy. In fact, it is not necessary or useful. It is quite sufficient that the actual dimension of the part is found between two limit dimensions and a permissible deviation is kept with production to ensure correct functioning of engineering products.

The required level of accuracy of production of the given part is then given by the dimensional tolerance which is prescribed in the drawing. The production accuracy is prescribed with regards to the functionality of the product and to the economy of production as well [3].

As we will see below the calculation and determination of tolerances, deviations and fits is a process that take away a lot of time from engineers. Because of that, we can see the need for this kind of software.

2. ISO SYSTEM OF TOLERANCES AND FITS

A coupling of two parts creates a fit “Fig. 1” [1].

Fig. 1. Basic terms of tolerances

where:

$d=D$ – basic size; D_{max} , D_{min} – limits of the hole size; d_{max} , d_{min} – limits of the shaft size; ES – hole upper deviation; EI – hole lower deviation; es – shaft upper deviation; ei – shaft lower deviation; T – tolerances size for hole; t – tolerances size for shaft

Basic size is the size whose limit dimensions are specified using the upper and lower deviations. In case of a fit, the basic size of both connected elements must be the same.

Fig. 2. Types of fit

Depending on the mutual position of tolerance zones of the coupled parts, three types of fit can be distinguished “Fig. 2” [3]: A - Clearance fit, B - Transition fit, C - Interference fit

The ISO system of tolerances and fits can be applied in tolerances and deviations of smooth parts and for fits created by their coupling. It is used particularly for cylindrical parts with round sections.

Tolerances and deviations in this standard can also be applied in smooth parts of other sections. Similarly, the system can be used for coupling (fits) of cylindrical parts and for fits with parts having two parallel surfaces (e.g. fits of keys in grooves). The term "shaft", used in this standard has a wide meaning and serves for specification of all outer elements of the part, including those elements which do not have cylindrical shapes. Also, the term "hole" can be used for specification of all inner elements regardless of their shape [3].

2.1 Tolerances of a basic size for specific tolerances grade

The tolerance of a size is defined as the difference between the upper and lower limit dimensions of the part. In order to meet the requirements of various production branches for accuracy of the product, the system ISO implements 20 grades of accuracy [3].

Tolerances grade	Place of use
IT01 to IT6	For production of gauges and measuring instruments
IT5 to IT12	For fits in precision and general engineering
IT11 to IT16	For production of semi-products
IT16 to IT18	For structures
IT11 to IT18	For specification of limit deviations of non-tolerated dimensions

Tab. 1. Field of use of individual tolerances of the system ISO

Each of the tolerances of this system is marked "IT" with attached grade of accuracy (IT01, IT0, IT1 ... IT18).

2.2 Hole and shaft tolerances zone

The tolerance zone is defined as a spherical zone limited by the upper and lower limit dimensions of the part. The tolerance zone is therefore determined by the amount of the tolerance and its position related to the basic size.

The position of the tolerance zone, related to the basic size (zero line), is determined in the ISO system by a so-called basic deviation. The system ISO defines 28 classes of basic deviations for holes. These classes are marked by capital letters (A, B, C, ... ZC) "Fig. 3".

The tolerance zone for the specified dimensions is prescribed in the drawing by a tolerance mark, which consists of a letter marking of the basic deviation and a numerical marking of the tolerance grade (e.g. H7, H8, D5, etc.). Though the general sets of basic deviations (A ... ZC) and tolerance grades (IT1 ... IT18) can be used for prescriptions of hole tolerance zones by their mutual combinations, in practice only a limited range of tolerance zones is used [3].

2.3 Fits systems

Although there can be generally coupled parts without any tolerance zones, only two methods of coupling of holes and shafts are recommended due to constructional, technological and economic reasons [3].

- Hole basis system

The desired clearances and interferences in the fit are achieved by combinations of various shaft tolerance zones with the hole tolerance zone "H". In this system of tolerances and fits, the lower deviation of the hole is always equal to zero.

- Shaft basis system

The desired clearances and interferences in the fit are achieved by combinations of various hole tolerance zones with the shaft tolerance zone "h". In this system of tolerances and fits, the upper deviation of the hole is always equal to zero.

Fig. 3. Hole and shaft tolerances zone

3. SOFTWARE FOR CALCULATION AND ANALYSIS OF ISO SYSTEM OF TOLERANCES, DEVIATIONS AND FITS

Using E-Tolerances software the following tasks can be solved:

1. Selection of suitable fits of machine parts according to the international standard ISO 286.
2. Determination of dimensional tolerances and deviations of machine parts according to the international standard ISO 286.
3. Selection of preferred fits of machine parts and determination of their dimensional tolerances and deviations
4. Automatic design of a fit for the given clearance or fit interference respectively.

E-Tolerances software development has gone through the following phases [4]: 1-Problem identification, 2-Determination of goal, 3-Program design, 4-Implementation, 5-Testing.

3.1 Problem identification and determination of goal

As we mentioned earlier the calculation and determination of tolerances, deviations and fits is a process that take away a lot of time from engineers. This problem is even more expressed in case of young engineers who do not have much experience with the selection of tolerances and fits. To make this process easier we came to the idea of interactive software that will allow quick calculation of deviations for the selected fit. Also, E-Tolerance software can automatically select a fit for given value of maximum or minimum gap and/or overlap. In addition to the above mentioned, the goal was to create Windows application software that will work independently on other software, such as Microsoft Office Excel or Access. Most similar software from other autors is based on one of the Office software packages.

3.2 Software design

The program have two modules: Analysis of deviations and tolerances zone and Assembly dimensional string.

Module Assembly dimensional string is not enabled in this version of the software, the same module will be implemented in one of the next version. Module Analysis of deviations and tolerances zone has two submodules, submodule Deviations and submodule Tolerances. In submodule Deviations we can calculate deviations and value of gap and/or overlap for already known system of fits. In submodule Tolerances software E-Tolerances give us closest system of fit for already known value of gap and/or overlap. According with above mentioned modules, software was designed through three forms: Main form "Fig. 4", Form for module Analysis of deviations and tolerances zone "Fig. 5", Form for module Assembly dimensional string

Separate parts of the forms for submodules will be explained in the part of the paper How to use E-Tolerances software.

Fig. 4. Main form

3.3 Implementation and testing

Design and programming of E-Tolerances software is done in C# programming language with Microsoft programming environment Visual Studio 2008. Testing of the software was carried out through two hundred graphical student assignments on the course Tehnical documentation and CAD in Faculty of Mechanical Engineering in Sarajevo. During the testing of E-Tolerance software, it has shown a great accuracy.

Fig. 5. Form Analysis of deviations and tolerances zone – submodule Deviations (left), submodule Tolerances (right)

4. HOW TO USE E-Tolerance SOFTWARE

Before we can use the E-Tolerances software, it must be installed in a standard way as other Windows software. Since the software is freeware, the setup file can be obtained by sending request to the e-mail: adis.muminoivc@mef.unsa.ba. After installation, the software will have shortcut on desktop and in start menu. After starting the software, the main form will appear, in which we have only one ribbon with following buttons: New File, Help and Credits. Clicking the button New File we will get the dropdown menu where we can choose one of the above mentioned modules “Fig. 6”,

Fig. 6. Dropdown menu New File

keeping in mind that in this version of the software, we can work only in the module Analysis of deviations and tolerances zone.

Help button opens PDF file with instruction for software use. If you click the Credits button you will get information about authors of the E-Tolerances software.

After we select module Analysis of deviations and tolerances zone, his form will open, at the beginning this form only have main reabon with buttons Deviations, Tolerances and with dropdown menu File. Throug this dropdown menu we can access to Open and Save file options. Save option allows us to save data on which we are currently working. By saving data E-Tolerance create txt file which we can open later through Open option. By clicking on the button Deviations or button Tolerances form changes look depending on the selected submodule “Fig. 5”.

4.1 Submodule Deviations

In submodule Deviations we can calculate deviations and value for gap and/or overlap for already known system of fit, without manual calculating or extracting data for any table. Also, this submodule automatically tells us the type of fit. It has several parts “Fig. 5”:

- *Chose tolerance fit system* – In this section we need to input basic size, choose basic system “h” or “H”, choose “IT” tolerance grade of accuracy for hole and saft and choose tolerance zone. For example 153H9/f4, where is basic size $D = 153$ mm, basic system H, tolerances zone for saft f, tolerance grade for hole IT9 and tolerance grade for shaft IT4. To calculate above entered system of fit it is necessary to click on the button Draw and Calculate. If we want to calculate new system of fit, without restarting the software, we can click on the button “>>New”.
- *Deviations* – In this section E-Tolerance software display value of deviations and value of gap and/or overlap. Also software automatically tell us the type of fit for 153H9/f4.
- *Draw section* – In this section of the software we can see position of tolerances zone for hole and saft in relation to the zero line.

We can see that engineer, in this submodule, can very quickly and easy try out a variety of fits and get data for

them. And what is more important he can get data without manual calculation or using tables.

4.2 Submodule Tolerances

Submodule Tolerances allows engineers to obtain an appropriate system of fit for already known value of gap and/or overlap. In practice it may happen that assembly must be made to the defined value of gap and/or overlap, in that case, engineer must known to define appropriate system of fit to achieve given value of gap and/or overlap. This submodule has several parts “Fig. 5”:

- *Enter gap or/and overlap* – In this section the user enters values for minimum and maximum gap and/or overlap depending on the type of fit. Also, user must enter basic size and chose basic system “h” or “H”. For example, if we have minimum and maximum value for gap $G_{\min} = 12 \mu\text{m}$ and $G_{\max} = 50 \mu\text{m}$, it is necessary to check the first check box, enter given value for gap, enter basic size $D = 63$ mm and chose basic system “h”, after that it is necessary to click on the button Draw and Calculate.
- *Closest fit system* – This section displays the closest system of fit, which was adopted from table using basic deviations. Also, this section displays all relevant data (ES, EI, es, ei, T, t) for adopted system and give us the value of deviations for adopted values in relation to the calculate values. For the above entered data, based on the basic deviations for hole, the following system was adopted 63h5/G6 with value of deviations $2 \mu\text{m}$.
- *Draw section* - In this section of the software we can see position of tolerances zone for hole and saft in relation to the zero line for adopted system of fit.

5. CONCLUSION

The paper is briefly presented E-Tolerance software. The software, which can assist engineers while placing tolerances for fit system according to the standard ISO 286. We have seen that the software enables quick calculation of data for a given system of fit and quick selection of a fit for given value of gap and/or overlap. The paper was elaborated basic terms related to ISO system of tolerances and fits, explained the implementation phase of the software and introduce us how to use E-Tolerance software. This software offers lot of space for upgrade, this upgrade can be additional modules related to other ISO standards, such us assembly dimensional string

6. REFERENCES

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