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DESIGN AUTOMATION OF SET SCREW CONNECTION

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Abstract: This paper will be given the dimensioning and check calculation of set screw connections with the design automation process. The introductory part of the paper shows the papers which deal with set screw connection problems. A critical overview of this field is given, along with the possibilities of design automation. A practice example of design was chosen for this investigation. Before the design model is made, the design is translated to mathematics parameters for dimensions and check calculations of set screw connection. Special attention is paid to the user communication interface to minimize errors that can happen due to human mistakes and make the automation process successful. The paper concludes with the integration of set screw connection into CAD software with testing of practice usage. Also, further research directions are pointed out.

Key words: Design automation, Set screw connection, Dimensioning, Check calculation

1 INTRODUCTION

Today, industry is growing rapidly, which leading to a new era of fully digitalized production. The rise of automation processes and the Internet of Things has further accelerated this growth. This evolution has given birth to Industry 4.0 or even 5.0, where digitization and automation are key to staying competitive. A crritical aspect of this transformation is the communication between customers and manufacturers,

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between manufacture, facilitated by product developers and designers. Now, many products, especially product families, can be designed and manufactured automatically through these systems. Developers make a bridge over the gap between customers and production, particularly for standardized products like furniture, transportation systems, process equipment, standardized parts and parts connections, and tools.

This paper deals with set screw connetcions design automation. There are a lot of investigations aobout the set screw connections. Zhao et al. [1] defined forces and stresses in a bolted connection in their research, based on which sizing of the threaded connection is possible. Qingmin Yu and 2 others [2] developed a detailed three-dimensional finite element model of bolted conncetion that depends on various parameters. Hawam [3] analyzed the maximum diameter deviation at which the bolt holes are arranged, taking into account the characteristics of the workpiece and cutting tools. Lujan [4] extensively researched the application of geometric tolerances in designing various accelerator components. John Ross Aitken [5] analyzes methods for easier determination of tolerances, enabling improvements in tolerance usage. Yiran Jiang [6] conducts a comparative analysis of tolerances in screw holes made using three different tools in his book.

Other part which is fused into this research is about how to integrate those investigations into design automation. Matejic et al. dealt with documetation wokflow [7] and design automation with product configurations [8] in their research. Heikkinen [9] gave the good investigation in design automation systems using visual programming. Machchhar et al. [10] did the data-driven design automation for product-service systems design based on real products. Because this field is very attractive nowadays, researchers are dealing with design automation both in theoretical reseach and practise.

An automated design with dimensioning and check calcuclation with CAD integration of set screw connection is shown in this paper. The aim of the paper is to show advantages of design automation trought calculations and CAD integrations in order to shorten the timenecessary to get parts and its connections readz for production.

2 THEORETIC MODEL OF SET SCREW CONNECTION

The set screw connection is dimensioned by shear critera, and checked by allowable pressure criteria. The example of set screw connection is given in Fig. 1.

Figure 1. *Set screw connection example*

The main parts of this screw connection is the: hub or housing, working element and set screws. In most cases set screws are inserted by workers or engineer experience which can lead to the subassemblies or assemblies malfuinction or even a failure. That problem can be avoided by conducting calculation of this screw connection.

2.1 Dimensioning by shear criteria

The main parameter for calculating the socket set screw connection according to the shear criteria is the safety factor. For the connection to be robust and to prevent failure under shear, the safety factor needs to be greater than the minimum value, typically ranging from 1.5 to 2. The safety factor against shear failure is determined using Equation 1.

$$S = \frac{\tau_{doz}}{\tau} \tag{1}$$

where are

- τ_{doz} allowed shear stress N/mm^2,
- τ working shear stress N/mm^2.

Shear stress, which occurs as a result of the transverse force F_s and acts on the support-ing surface of the screw A_s, which is given by Equation 2.

$$\tau = \frac{F_S}{A_s} \tag{2}$$

Transverse force F_s is transmitted from one part of the screw to another, and is calculated using Equation 3.

$$F_S = \frac{F_R}{z}\xi_R \tag{3}$$

where are:

- z number of socket set screws,
- ξ_r factor of uneven load distribution.

2.2 Checking calculation by surface pressure criteria

During the contact of the screw and the parts to be joined, a surface pressure occurs, which can lead to the appearance of plastic deformations. Therefore, when calculating socket set screw connections, it is necessary to check the safety factor against surface pressure, using Equation 4.

$$S_T = \frac{p_T}{p} \tag{4}$$

where are:

- p_T=1,2·R_e – allowable surface pressure in contact and
- p – working surface pressure, calculated by Equation 5.

$$p = \frac{F_S}{0,5 d_2 l_k} \tag{5}$$

In the conducted calculation in accordance with presumed diameter D_z tolerance the supporting surface, loaded with surface pressure, of the socket set screw $l_k \cdot d_2/2$ had a variable area.

3 CAD INTEGRATION ON PRACTISE EXAMPLE

The integration of calculation is conducted in CAD software Autodesk Inventor. The calculation integration and connecting with implementation on CAD model is performed by using a Visual Basic programming language which has a wide range of command integrated into Audesk iLogic enviorment. The accesing of those commands is given in Figure 2.

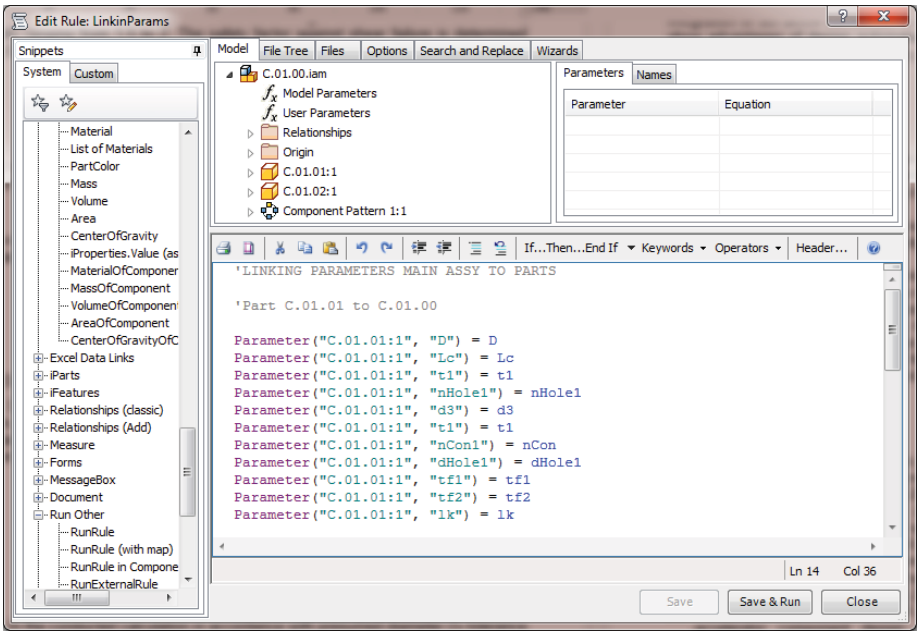

Figure 2. *Accesing to programming mode in iLogic*

It is very important that in case of implementation calculation in assembly file the top-down strategy for both modeling and programming must be used. The integration of set screw connection requres the following:

- example of CAD model where this conection is used,
- dimensioning calculation which will update the model permanently,
- checking calculation for preventing set screw connection failures and
- optionally connection with workshop drawing generation.

Al of those requirement had to be enabled to work as one part and enable user the easy comunication with all required elements. The communication with user is done by User Forms, which are shown in Figure 3.

In the user form permamanent update based of the dimensioning results is enabled.

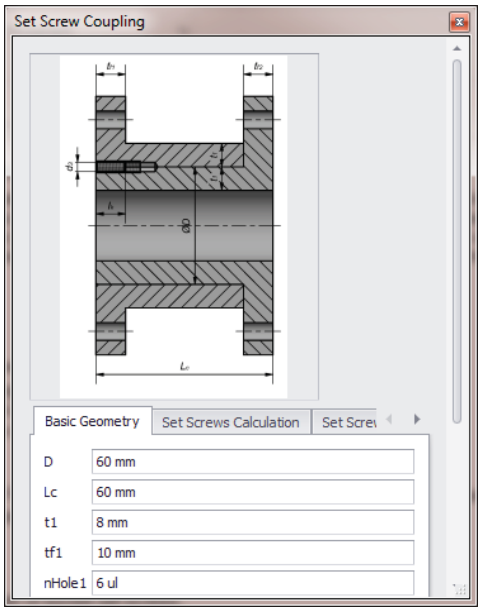

Figure 3. *User Form of sec screw connection calculation*

4 OUTPUT RESULTS

As a result a fully defined and calculated model of coupling is obtained. The CAD model with user interface is shown in Figure 4.

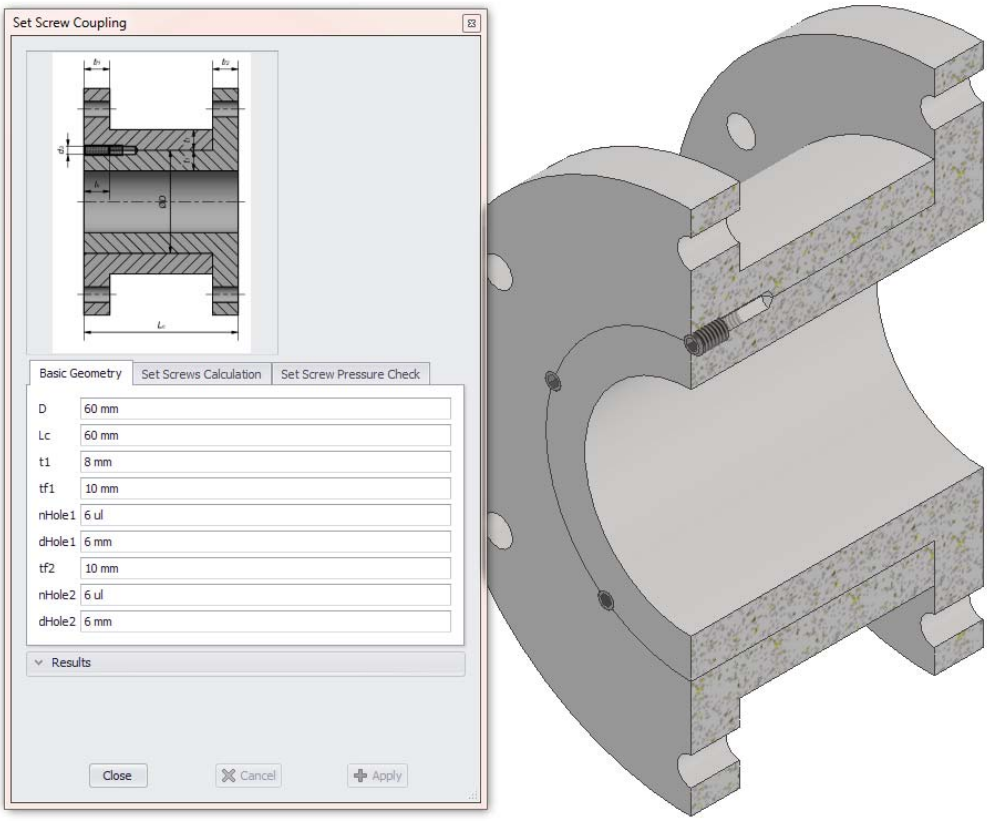

Figure 4. *CAD model of the coupling with set screw connection*

The final result is technical drawing of both copling isdes all along with tolerances which is automatically generated. The code for automatic drawing generation is given in Figure 5.

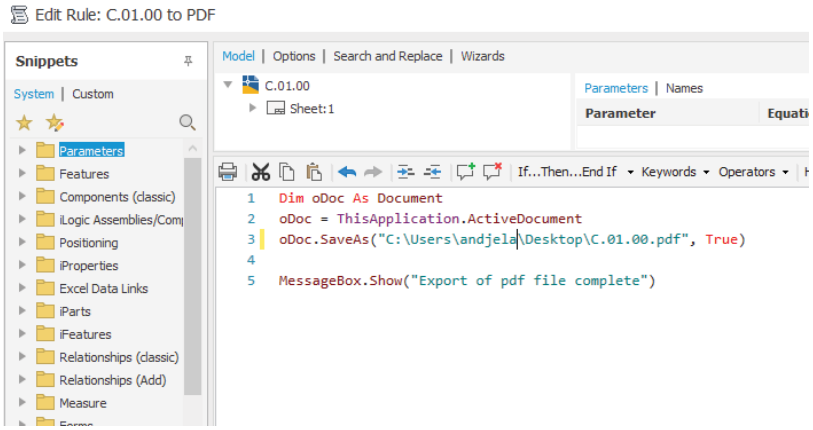

Figure 5. *Code for automatic drawing genereation*

In depenance what is nceseary for the users code can be made to generate drawings in various extensions such as PDF, DWG, IDW etc.

5 CONSLUSIONS

The presented example of the automated design of set screw connection has some advantages and they are:

- the presented model of calculation integration in CAD is very good for products which are manufactured as product families;
- when the system is built, the amount of necessary administrative and engineering staff can be significantly decreased, which is very positive for big companies;
- the mistakes in product design and documentation is fully avoided;
- the user has a full control on the offered product options;
- the deals between engineer and calculation process has a much easier flow etc.

The usage of these systems of calculation inegration, as this paper shows for set screw connection, is very good choice. The future authors work in this field will be related to implementation of these tools into advanced CAD courses at their Institutions as a very perspective and attractive tool, which can be very successfully used in practice.

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