

# Integrated CAE/CAD system for designing a jack-screw with rotating nut

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**Abstract.** Efficient and prompt assembly design, tailored for implementation in the industrial setting, is a key objective within the realm of economic considerations. This paper presents a user interface that forms the basis of the CAE/CAD system used for designing a jack-screw with rotating nut. The user interface makes the calculation process much more efficient by automating it. Therefore the designer saves a lot of time when modifying one of the parameters, because there is no need to redo the calculations manually. Another important aspect is that the system leaves no room for human errors as the user is guided when choosing the input data, which is then transformed into output data, that being the dimensions of the jack's components.

## 1. Introduction

In today's fast-paced and ever-evolving world, the engineering industry stands at the forefront of innovation and progress. Engineers are tasked with designing, developing, and optimizing systems that drive modern society, from manufacturing to energy production, transportation and communication. The challenges faced by the engineering industry today are multifaceted. With global demand for products and services on the rise, engineers must meet higher production levels while adhering to strict quality and safety standards. Additionally, there's a growing need for sustainable practices, as society grapples with climate change and resource conservation. With the constant demand for higher efficiency, safety, and sustainability, the engineering field faces a critical imperative: embracing automation.

This paper presents the creation of a screw-nut assembly, in this particular case, a jack-screw with rotating nut. To facilitate the technical calculation report, a MS Excel spreadsheet was implemented. This serves both to keep the data in a digital format that is easily accessible and intuitive, and to allow real-time data modification, and, consequently, result updates, eliminating the need for repeated calculations. As a result, the designer saves time and is not required to redo the calculations when errors occur or when one of the parameters is modified.

The project exhibits the attributes of an integrated CAE/CAD system. The system created is dedicated to designing a jack assembly. The assembly was 3D modeled using SolidEdge software, based on the dimensions obtained through the calculation process.

## 2. The calculation algorithm

### 2.1. The flowchart of the calculation algorithm

The flowchart presented in figure 1, summarizes the logical thread of the algorithm used for sizing and verifying the assembly's components. Following this algorithm, a modular calculation form was created.

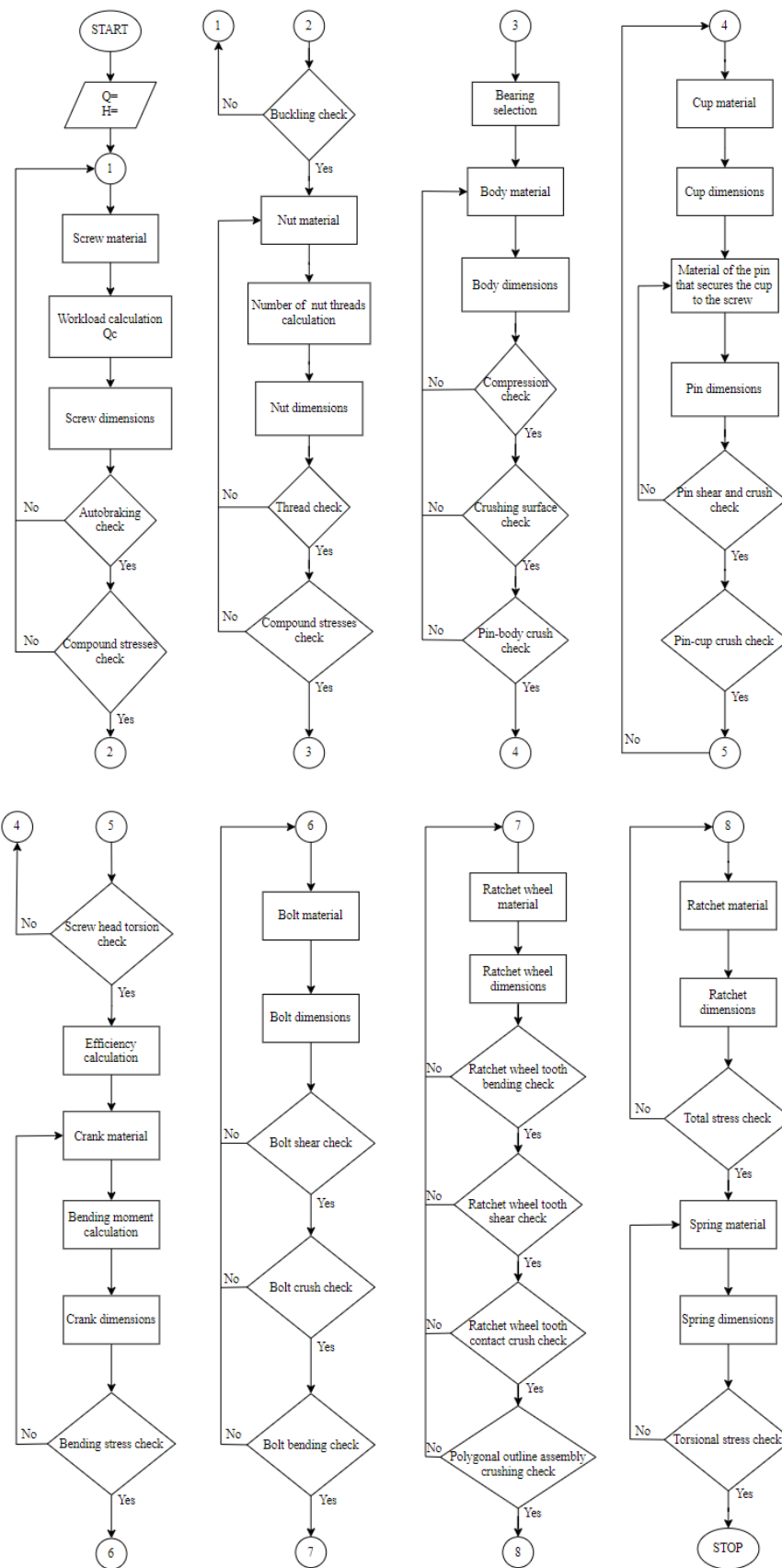


Figure 1. Calculation algorithm flowchart

## 2.2. The transformation of mathematical formulas in MS Excel formulas (CAE)

Once all the steps presented in the flowchart were established, the next stage required introducing the mathematical formulas in MS Excel. That way, the designer would be spared from going through all the steps manually, because all the data would be processed by the software. Table 1 depicts the transformation of some of the formulas. For space considerations, only the formulas for the screw and the nut are presented.

**Table 1.** The transformation of mathematical formulas in MS Excel formulas

No.	Mathematical formula	MS Excel formula
<b>SCREW</b>		
<b>Screw inner diameter <math>d_3</math></b>		
1.	$d_3 = \sqrt{\frac{4Q}{\pi\sigma_{ac}}}$	$d_3 = \text{SQRT}((4*B10)/(PI()*C6))$
<b>Pitch angle of the thread spiral <math>\beta_2</math></b>		
2.	$\beta_2 = \text{arctg} \frac{P}{\pi d_2}$	$\beta_2 = \text{DEGREES}(\text{ATAN}(B22/(PI()*B20)))$
<b>Apparent friction angle <math>\varphi'</math></b>		
3.	$\varphi' = \text{arctg} \frac{\mu}{\cos \frac{\alpha}{2}}$	$\varphi' = \text{DEGREES}(\text{ATAN}(B25/(\text{COS}(PI()/12))))$
<b>Effective compression stress <math>\sigma_c</math></b>		
4.	$\sigma_c = \frac{4Q}{\pi d_3^2}$	$\sigma_c = 4*B8/(PI()*(B21^2))$
<b>Effective torsion stress <math>\tau_t</math></b>		
5.	$\tau_t = \frac{16M_t}{\pi d_3^3}$	$\tau_t = 8*F11/(PI()*(B21^3))$
<b>Equivalent stress <math>\sigma_e</math></b>		
6.	$\sigma_e = \sqrt{\sigma_c^2 + 4\tau_t^2}$	$\sigma_e = \text{SQRT}(F15^2+4*(F13^2))$
<b>NUT</b>		
<b>Number of threads <math>z</math></b>		
7.	$z = \frac{4Q}{\pi(d^2 - D_1^2)p_a}$	$z = \text{INT}((4*\$Surub!J2)/(PI()*(\$Surub!B16^2-\$Surub!B17^2)*B9))+1$
<b>Thread bending check <math>\sigma_i</math></b>		
8.	$\sigma_i = \frac{3Q(d_2 - d_3)}{\pi d_3 h^2 z}$	$\sigma_i = (3*\$Surub!J2*(\$Surub!B20-\$Surub!B21))/(PI()*\$Surub!B21*B18^2*B10)$
<b>Thread shearing check <math>\tau_f</math></b>		
9.	$\tau_f = \frac{Q}{\pi d_3 h z}$	$\tau_f = \$Surub!J2/(PI()*\$Surub!B21*B18*B10)$
<b>Effective compression stress</b>		
10.	$\sigma_c = \frac{4Q}{\pi(d_{ci}^2 - D_4^2)}$	$\sigma_c = 4*\$Surub!J2/(PI()*(B13^2-\$Surub!B19^2))$

No.	Mathematical formula	MS Excel formula
<b>Effective torsion stress <math>\tau_t</math></b>		
11.	$\tau_t = \frac{0.5M_{ins}}{16d_{ci}} (d_{ci}^4 - D_4^4)$	$\tau_t = (0.5 * \text{Şurub!F11}) / (\text{PI}()) / (16 * \text{B13}) * (\text{B13}^4 - \text{Şurub!B19}^4)$
<b>Equivalent stress <math>\sigma_e</math></b>		
12.	$\sigma_e = \sqrt{\sigma_i^2 + 4\tau_t^2}$	$\sigma_e = \text{SQRT}(\text{F18}^2 + 4 * (\text{F19}^2))$

### 3. Case study

To better understand how the algorithm works, a case study will be presented. The input data for the case study will be:

- Load Q = 12000 N
- Travel H = 150 mm

After entering the input data, the spreadsheet will return the dimensions of the components and check if they verify the conditions. The algorithm does this process for all the components of the assembly, but for space considerations, the given examples will be for the screw and for the nut. Figure 2 shows the output data returned by the algorithm, regarding the screw checks and dimensions.

Screw										
Screw material	with stress raisers				Load	12000 N				
OL 60	TT quality class	Stress [MPa]				Travel	150 mm			
		Traction	Bending	Twisting	Shearing	$h_{cup}$	30 mm			
		$\sigma_{al} = \sigma_{as}$	$\sigma_{al}$	$\tau_{al}$	$\tau_{al}$					
	1	58	67	36	46					
F	12000 N	Compound stresses check				Buckling check				
$\beta$	1.115									
$F_c$	13380 N	H	3858.98 N	$l_{min}$	4.63 mm					
$d_{3min}$	17.14 mm	$l_{torque\ wrench}$	10.75 mm	$l_{min}$	5749.85 mm					
		$M_{torque\_wr}$	41484.04 N*mm	A	268.80 mm <sup>2</sup>					
		$\tau_t$	16.684223 MPa	$l_{buckling}$	360 mm					
STAS screw dimensions		$\sigma_c$	44.642438 MPa	$\lambda$	77.83784					
Screw size	Tr24x5	$\sigma_b$	55.735092 MPa	$\lambda_0$	89					
d	24 mm	$\sigma_e \leq \sigma_{ac}$	OK	$\lambda_0 > \lambda$	PLASTIC					
D <sub>1</sub>	19 mm					C	4.94			
D <sub>2</sub>	21.5 mm					$3 \leq C \leq 5$	OK			
D <sub>4</sub>	24.5 mm									
d <sub>2</sub>	21.5 mm									
d <sub>3</sub>	18.5 mm									
pas	10									
Autobraking check										
$\mu$	0.16									
		degrees	radians							
$\beta_2$	8.422	0.147								
$\phi'$	9.405	0.164								
$\beta_2 < \phi'$	OK									

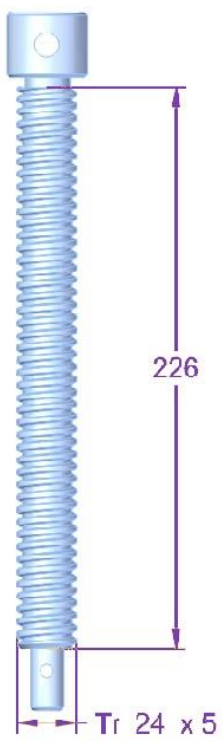


Figure 2. Screw spreadsheet

Once the screw is designed and checked, the algorithm proceeds with the next steps in the flowchart and does the same thing with the nut. Figure 3 represents the output data returned by the algorithm, regarding the nut checks and dimensions. Going further, the algorithm follows all the steps in the flowchart until it reaches the end, when all the components of the assembly are dimensioned and checked.

Nut					
Nut material	TT quality class	With stress raisers			
		Stress [MPa]			
		Traction	Bending	Twisting	Shearing
OL 42	1	$\sigma_{at} = \sigma_{ac}$	$\sigma_{ai}$	$\tau_{at}$	$\tau_{af}$
		45	52	28	36
Nut dimensions					
$P_a$	10	MPa			
$z$	8				
$H_p$	40	mm			
$D_e$	44	mm			
$d_{ci}$	32	mm			
$H_{pc}$	60	mm			
$H_1$	36	mm			
Thread check			Compound stresses check		
$h$	3.17	mm	$\sigma_c$	36.056341	MPa
			$\tau_t$	4.911437	MPa
$\sigma_i$	23.114986	MPa	$\sigma_e$	37.370424	MPa
$\sigma_i \leq \sigma_{ai}$	OK				
$\tau_f$	8.141612	MPa	$\sigma_e \leq \sigma_{ac}$	OK	
$\tau_f \leq \tau_{af}$	OK				

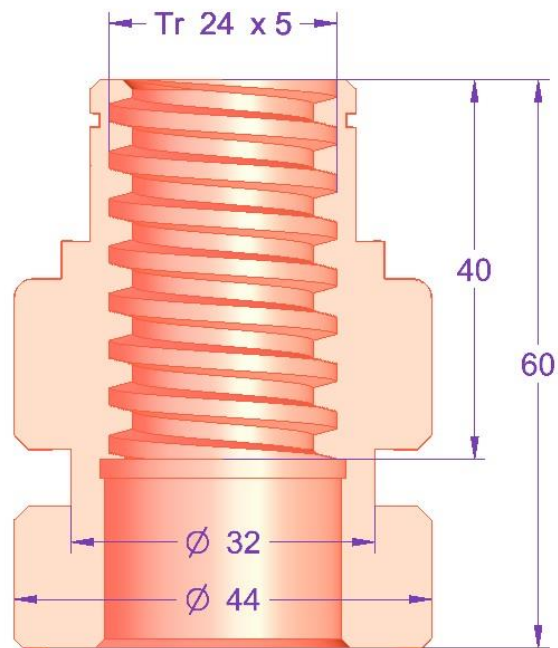


Figure 3. Nut spreadsheet

#### 4. The user interface

The MS Excel spreadsheet proves to be very useful when it comes to the calculation algorithms. But they have a very big problem: they are easily corruptible. The designer could modify data in the spreadsheet without realising it, and therefore, corrupting the whole document. Unnoticed problems during the design process can lead to very big problems once an assembly is manufactured.

One solution to this problem is a user interface. The designer provides the input data, but he can only visualize the output data, without being able to modify it. This is very useful, because the results of the calculation algorithm cannot be altered. That means that the user interface leaves no room for unintentional errors. The case study presented in section 3 will be described in this section, showing the benefits the user interface brings over the spreadsheet. Figure 4 presents the starting window of the software, where the designer is supposed to provide the input data.

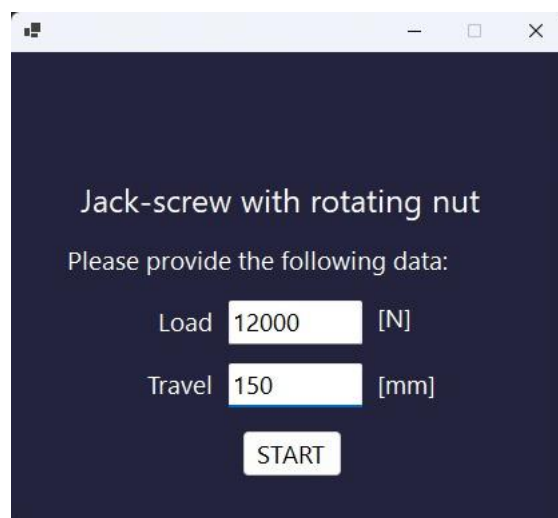


Figure 4. Starting window of the user interface

After the input data is entered, the software proceeds with the calculation. The results regarding the screws are presented in figure 5.

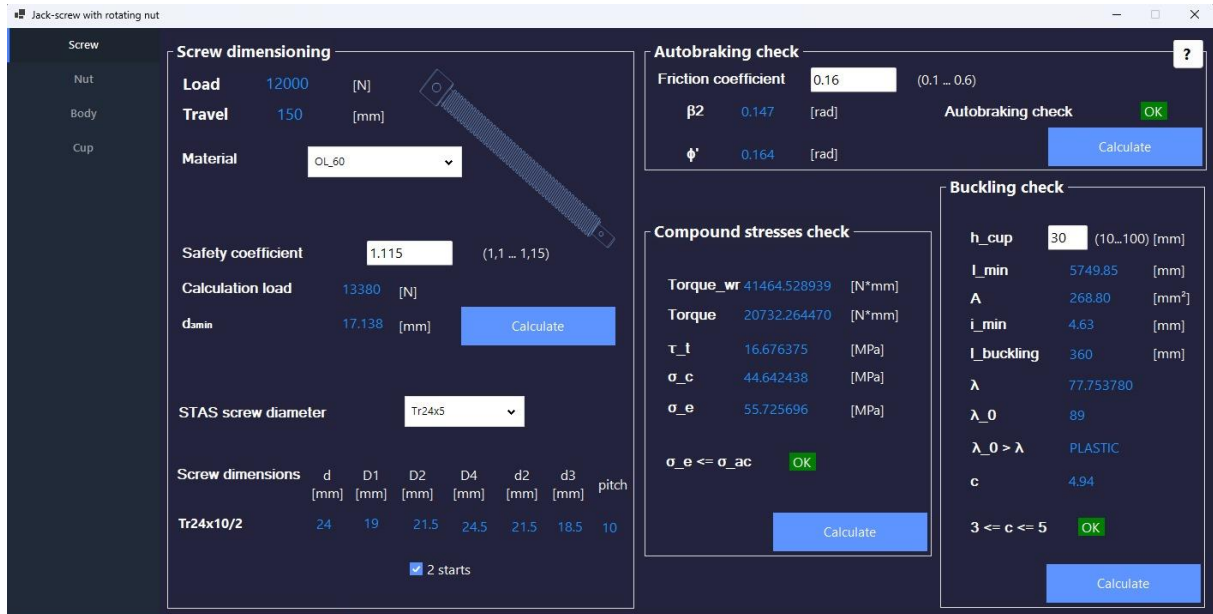


Figure 5. Screw output data

Figure 6 shows the results for the calculations regarding the nut.

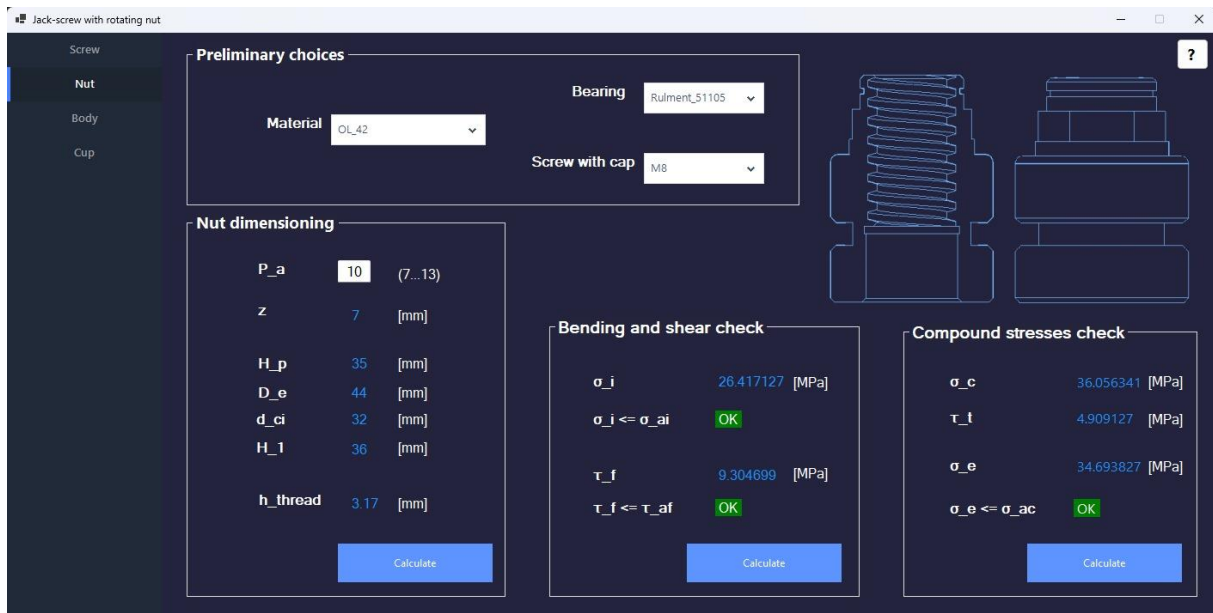


Figure 6. Nut output data

## 5. Conclusion

Taking into consideration the current state of the engineering industry, automation is an essential thing to do. The purpose of this CAE/CAD system is to streamline the calculation process. It helps the designer save a lot of time and it leaves no room for errors.

The implementation of this system to a jack-screw with rotating nut is a proof of concept. Future prospects involve creating a parameterized 3D model of the jack and linking the CAD software to the

user interface. That way, when the input data is changed, the whole assembly modifies according to the data. Once that goal is accomplished, the system could be implemented to other assemblies like plastic injection molds. The system would prove to be very efficient when it comes to plastic injection molds for ski boots making. In that case, the input data could be the shoe number and when the designer changes the shoe number, the whole mold assembly could change according to that shoe number.

## References

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