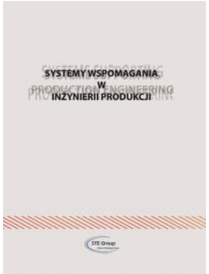
New Concept of Software for Calculation of Chain Gears

Data wpłynięcia do Redakcji: 06/2022
Data akceptacji przez Redakcję do publikacji: 09/2022

2022, volume 11, issue 2, pp. 47-56



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Abstract: At present, practically all areas of design activities are supported by computer technology, which can be effectively used in the design of gears, belts and chain transmissions, especially in the field of calculations, as well as graphics solutions. However, their use requires mastering the basic principles of computational procedures contained in the programs in question and, on that basis, critically evaluating computer-generated solutions. The presented paper deals with the design proposal and application of program for calculation and check of chain gears. Although there are currently various programs on the market that can design chain transmissions and perform strength analysis, there is still space for improvement and the creation of these programs. The computing program has been created as a spreadsheet in the working environment of the Microsoft Office program by the Excel application through defined sequences of the individual commands. The program serves for design proposal of a chain drive by means of inserted databases, graphs and tables. In the process of designing and checking the input values are entered such as performance, rotations, and number of wheels. Through calculation the software generates speed of a chain, circumferential speed, tensile force, number of chain links, axial distance, etc. At the same time the paper compares generated parameters with manual calculation of the chain gear.

Keywords: software, design, chain gears, calculation, strength

INTRODUCTION

Similar to belt transmissions, chain transmissions belong to indirect transmissions. The transmission of power and speed between the drive and driven sprocket by means of a chain takes place by means of chain gears. They are used to transmit small and medium power (up to 1000 kW) over shorter distances. The gears are supplemented as required by tensioning and guiding rollers, a suitable lubrication system, covers, guide rails and other necessary elements. Transmission of kinematic and force effects of the driving engine upon working machine is provided by the drive. The overall structure of the drive does not represent the simplest part; the entire drive consists of several segments. The segments are jointly exposed to stress and therefore the segments are overloaded and damaged. Or some of its segments get worn. All of the aforementioned reasons lead to correct specification of drive structure and to designing of its individual segments to assure reliable operation which would be safe and economical [1].

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The chain drive also consists of several segments which must work together in perfect harmony. In case of incorrect coherence of the segments the gear would be ineffective and eventually unusable. In practice the chain drive is exposed to effects of environment which influences the chain. Appropriate care and maintenance of the chain gear as well as adequate servicing can prolong its service life. Even though current market offers diverse programs which can design chain gears and carry out strength analysis still there exists platform for improvement and creation of such programs.

BASICS OF CHAIN GEARS

Chain gears are as machine parts which are used for transmission of low and average performance with circumferential speed of up to 30 or 45 $m \cdot s^{-1}$ in case of which the gear ratio reaches values of I = from 2 up to 8, from a driving shaft to a shaft or to several shafts serving for transmission of torque Mk. One of the simplest chain gears is a gear which consists of a chain and of two chain wheels [2].
Generally valid regularities of gears are applicable in case of chain gears therefore gear ratio is as follows:

$$\mathrm{i} = \frac{\omega_1}{\omega_2} = \frac{n_1}{n_2} = \frac{z_2}{z_1}\ \mathrm{i} = \frac{\omega_1}{\omega_2} = \frac{n_1}{n_2} = \frac{z_2}{z_1}, \qquad \text{or} \qquad i = \eta * \frac{M_2}{M_1} \qquad (1)$$

Alike the belt gears the chain gears are based on transmission of tensile force (Fig. 1). They perform rotary motions between two or among several shafts. The chains are mostly made of premium steel which and therefore their strength and compactness is higher contrary to belts.

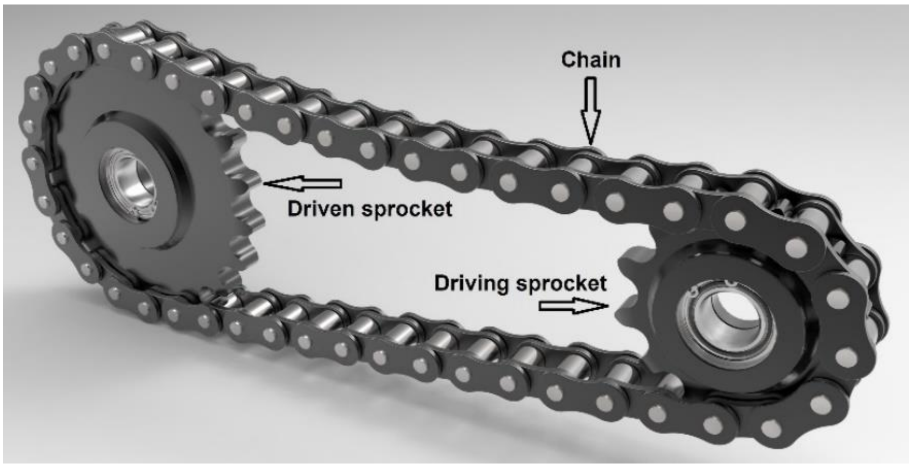

Fig. 1 Chain gear and its main parts

Source: [3]

Chain gear can transmit large tensile force for long distance; it is also synchronous with invariable gear ratio, i.e. without slip. The gears are immune to negative influences of environment and therefore they are used, for example, in case of shaping machines, conveyor belts, bicycles and motorcycles, construction machines and automobiles. The power transmitted by the chain, or the power transmitted by the chain transmission, is given as the product of the force in the chain and the value of its circumferential force [4]. In order for the given power to be transmitted, the necessary chain dimensions must be determined from the parameters. Such parameters are the number of pinion teeth, the method of lubrication, the length of the chain, the cleanliness of the environment and the like. Assuming these parameters are obtained, it is possible to determine how fast the chain and sprockets wear [5].

MANUAL CALCULATION OF CHAIN GEAR

To assure correct results of the designed program the program out was compared with the results of analytical calculation. The spacing together with other dimensions necessary for the design of the chain drive, such as e.g. the diameter of the pin, bushing or roller, the inner and outer width of the chain, the weight of 1m of the chain, the strength of the chain (load of the chain when it breaks), the size of the contact surface in the joint, etc., stated by the relevant standard [6]. To provide comparison the following mathematical model of design proposal and check of chain gear was proposed:

Input performance $P = 7.8\ kW$, input rotations $n_1 = 2.15\ s^{-1}$.

Proposal of chain gear

Calculation of diagram performance:

$$P_D = \frac{P}{\kappa * \mu * \varphi} = \frac{7.8}{0.82 * 1 * 0.6} = 15.85 kW \tag{2}$$

To determine the suitable chain, the diagram performance PD and rotations of output shafts are followed. Trough calculation by means of graph (Fig. 2) intended for determination of the chain drive selected is the triple-line chain 24B STN 023311 standard and selected are also $z_1=17$ and $z_2=34$.

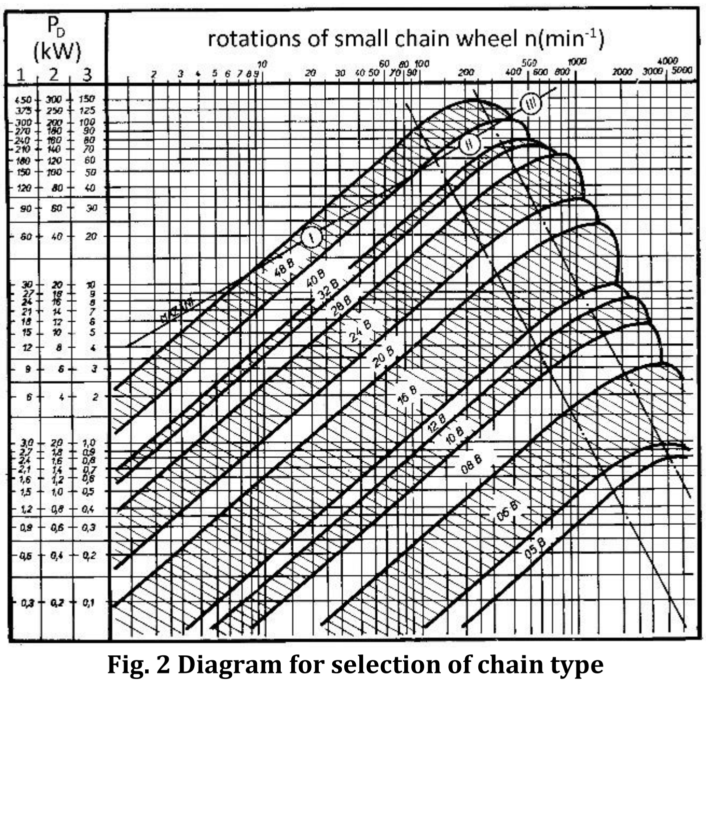

Fig. 2 Diagram for selection of chain type

Source: [4]

Calculation of Pitch Diameters:

$$D_{t1}\frac{t}{\sin\frac{180°}{z_1}} = \frac{25.4}{\sin\frac{180°}{17}} = 138.23mm \tag{3}$$

$$D_{t2} = \frac{t}{\sin\frac{180°}{z_2}} = \frac{25.4}{\sin\frac{180°}{34}} = 275.28mm \tag{4}$$

with t – chain pitch, z_1 – number of teeth of input wheel.

Type of chain 24B was selected on the basis of the calculated value of diagram performance and input rotations by means of the following diagram (Fig.2).

Strength check of a chain

Chain Speed:

$$v = \frac{\pi * D_{t1} * n_1}{1000} = \frac{\pi * 138.23 * 2.15}{1000} = 0.933\ m.s^{-1} \tag{5}$$

Circumferential speed of a chain wheel:

$$F_o = \frac{P * 1000}{v} = \frac{7.8 * 1000}{0.933} = 8360.12\ N \tag{6}$$

Circumferential force caused by the effect of centrifugal force:

$$F_{oc} = m' * v^2 = 8 * 0.933^2 = 6.96\ N \tag{7}$$

Overall tensile force of a chain:

$$F_t = F_o + F_{oc} = 8360.12 + 6.96 = 8367.08\ N \tag{8}$$

Calculation pressure in a joint of a chain:

$$P_P = \frac{F_t}{S} = \frac{8367.08}{631} = 13.26\ MPa \tag{9}$$

Permitted pressure in the joint of a chain:

$$P_D = p * \lambda \geq P_P \tag{10}$$

$$P_D = 26.6 * 0.6 = 15.96MPa$$

λ – coefficient of friction

$$15.96\ MPa \geq 13.26\ MPa \implies \text{ satisfactory}$$

Safety coefficient against rupture in case of static load:

$$k_s = \frac{F_{pt}}{F_t} \geq 7 \implies \frac{181500}{8367.08} = 21.69 \geq 7 \implies \text{ satisfactory} \tag{11}$$

Safety coefficient against rupture in case of dynamic load:

$$k_s = \frac{F_{pt}}{F_t * Y} \geq 5 \implies \frac{181500}{8367.08 * 1} = 21.69 \geq 5 \implies \text{ satisfactory} \tag{12}$$

Number of chain elements: a = 300 mm is selected

$$X = 2 * \frac{a}{t} + \frac{Z_1 + Z_2}{2} + \left[\frac{Z_2 - Z_1}{2 * \pi}\right]^2 * \frac{t}{a} = 2 * \frac{300}{25.4} + \frac{17 + 34}{2} + \left[\frac{34 - 17}{2 * \pi}\right]^2 * \frac{25.4}{300} = 54.69 \implies$$

54 elements are selected. (13)

Actual axial distance

$$a = \frac{t}{8} * \left[2 * X - (Z_1 + Z_2) + \sqrt{(2 * X - Z_1 - Z_2)^2 - F(Z_2 - Z_1)^2}\right]$$

$$a = \frac{25.4}{8} * \left[2 * 54 - (17 + 34) + \sqrt{(2 * 54 - 17 - 34)^2 - F * 0.8130(34 - 17)^2}\right] = 355.28mm\text{a} = \frac{25.4}{8} * \left[2 * 48 - 15 - 30 + \sqrt{(2 * 48 - 15 - 30)^2} - \text{F}(30 - 15)^2\right] = 247.65\text{mm} \tag{14}$$

DESIGN OF A CALCULATION SOFTWARE

The program itself is designed as a spreadsheet in the Microsoft Excel workspace. Designing of the program starts in the Excel environment through getting acquainted with the program environment and trough consequent implementation of descriptions and of cells, which are intended for entering the numerical values into program. Selection of suitable descriptions assures transparency during calculations and unnecessary mistakes in recording are thus avoided [7].

Implementation of all descriptions inevitable for the user, to be able to get oriented in the program easily, is followed by a part in case of which formulae must be entered into predetermined cells. Entering of the formulae represents rather significant part in program creation from the point of view of correct functioning of the program. As the figure shows, the formula consists of entered values which are needed for the calculation [8]. When inserting formulas, it is necessary to pay attention to the correct writing of the formula in the cell, because incorrect insertion leads to an error and consequently incorrect calculation, which further leads to incorrect substitution into the next formula and thus a total calculation error and the program is not working properly.

Basic and design part of the program

The main program contains a series of calculations which are inevitable for calculation of the chain gear (Fig. 3).

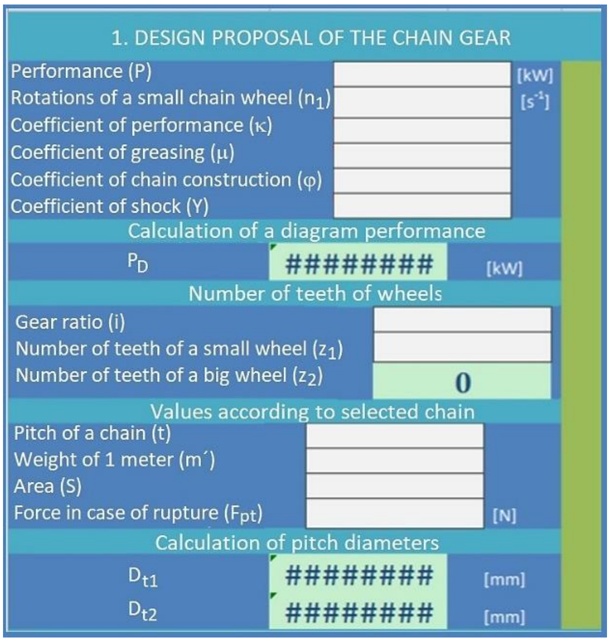

Fig. 3 Design part of the program

The entire program is divided into two parts in the first one of which the chain gear is designed and in the second one of which the calculations related to strength checks of the chain are carried out.

In case of design part, the entered values are filled into the cells such as performance, rotations of a small chain wheel, coefficient of performance, coefficient of greasing, coefficient of chain construction, coefficient of shock, gear ratio and number of teeth of a small wheel. According to the entered values the values of diagram performance are calculated, number of teeth of a big wheel and calculations of pitch diameters for both wheels [9].
The design part also contains a section for determination of values of the selected chain the values of which are necessary for the chain check.

Checking part of the program
The second part of the program is focused on strength check of the selected chain which must meet particular conditions to be put into practice (Fig. 4). From this point of view, the chain is tested under diverse types of loads. In the checking part the chain is tested. In the second part calculated is speed of chain, number of elements of the respective chain as well as its actual axial distance.

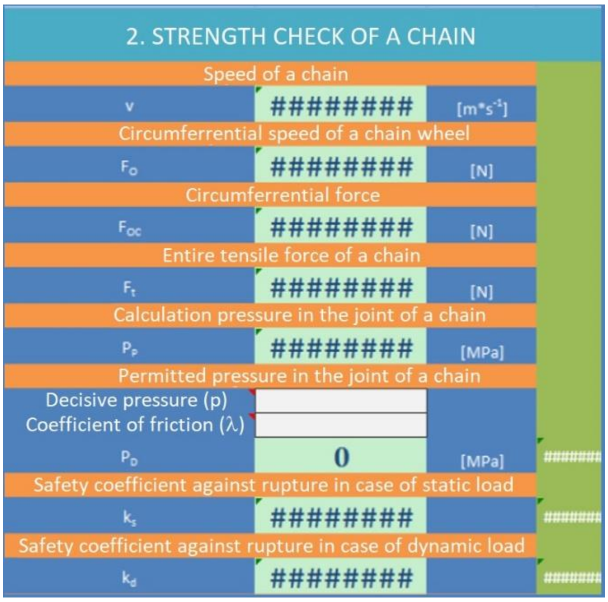

Fig. 4 Strength check of the chain

According to the entered and calculated values the program determines the values of circumferential force, of overall tensile force in the chain, calculation pressure in the joint of the chain, safety coefficient against rupture in case of static and dynamic loads. Permitted pressure in the joint is the value calculated out of the table values for decisive pressure and coefficient of friction [10].
For correct check of the chain it is inevitable to detect if the chain is suitable (Fig. 5). The program also works with the comparison of the values which are consequently assessed. In case of unsuitable values, it immediately detects and assesses the value as being the suitable or unsuitable.
The program compares calculation pressure with the permitted one. The permitted pressure should be higher than the calculation one.

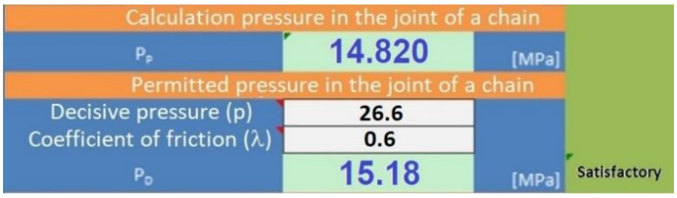

Fig. 5 Suitable pressure

In case of unsuitable pressure, the program colours the cell red and assesses the pressure as the unsuitable one (Fig. 6).

Fig. 6 Unsuitable pressure

The same applies to the safety factors against breakage under static and dynamic loads, where the chain breaks at lower values than allowed. The program also evaluates these values and, when falling below the required value, warns that the chain does not meet safety requirements and is therefore not suitable.

Auxiliary tables of the program

Since the chain program calculation requires several values being determined on the basis of the tables the program itself contains the parts in which the values can be sought for. The tables allow faster and easier calculation as should that be not the case the dictionary of engineering terms must be used.

To facilitate the work, the following data and values were entered into the program:

- *Coefficients of shock* – in the program "selectable" in case of the offered option which can be opened and out of which the needed value can be selected. To determine the coefficient of shock correctly the program contains the table with descriptions referring to type of shock. Thus correct determination of its value is possible.
- *Coefficients of performance* – other table of values refers to coefficient of performance which is selected according to number of teeth of the small chain wheel, gear ratio and coefficient of shocks.
- *Coefficients of greasing* – alike the coefficient of shock the coefficient of greasing can be selected out of the given values. To select correct value of the coefficient of greasing the program also contains the table with descriptions referring to its correct determination.
- *Decisive pressure of the joint* – it refers to a table value which is selected according to operation time of the chain, coefficient of shock, coefficient of greasing, coefficient of axial distance and gear ratio. When the values have

been detected, the decisive pressure can be read off the attached table of the program.

- *Coefficients of friction* – have been included into the table part of the program. To determine the value of coefficient of friction correctly, it is inevitable to determine coefficient of shock correctly, gear ratio, chain according to the standard, etc [11].

CALCULATION EXAMPLE BY MEANS OF THE NEWLY PROGRAM

Figure 7-9 shows an example of a calculation with the new program.

1. DESIGN PROPOSAL OF THE CHAIN GEAR		
Performance (P)	7.8	[kW]
Rotations of a small chain wheel (n_1)	2.15	[s^{-1}]
Coefficient of performance (κ)	0.82	
Coefficient of greasing (μ)	1	
Coefficient of chain construction (φ)	0.6	
Coefficient of shock (Y)	1	
Calculation of a diagram performance		
P_D	15.6235	[kW]
Number of teeth of wheels		
Gear ratio (i)	2	
Number of teeth of a small wheel (z_1)	17	
Number of teeth of a big wheel (z_2)	34	
Values according to selected chain		
Pitch of a chain (t)	25.4	
Weight of 1 meter (m´)	8	
Area (S)	631	
Force in case of rupture (F_{pt})	181500	[N]
Calculation of pitch diameters		
D_{t1}	138.23	[mm]
D_{t2}	275.28	[mm]

Fig. 7 Designed Chain Gear

2. STRENGTH CHECK OF A CHAIN			
Speed of a chain			
v	0.933	[m*s^{-1}]	
Circumferrential speed of a chain wheel			
F_o	8357.15	[N]	
Circumferrential force			
F_{oc}	6.78	[N]	
Entire tensile force of a chain			
F_t	8363.64	[N]	
Calculation pressure in the joint of a chain			
P_p	13.247	[MPa]	
Permitted pressure in the joint of a chain			
Decisive pressure (p)	26.6		
Coefficient of friction (λ)	0.6		
P_D	15.96	[MPa]	Satisfactory
Safety coefficient against rupture in case of static load			
k_s	21.67		Satisfactory
Safety coefficient against rupture in case of dynamic load			
k_d	21.67		Satisfactory

Fig. 8 Strength check of chain gear 1/2

Number of chain elements		
Axial distance (a)	300	[mm]
X	54.42	elements
Selected number	54	elements
Actual axis distance		
K	0.8	
a	355.28	[mm]

Fig. 9 Strength check of chain gear 2/2

CONCLUSION

When all inevitable values have been calculated by analytical calculation and by consequent calculation with the designed program the program might be considered as correctly designed since it generates results comparable with the design of chain gear and strength check of the selected chain. The chain must be lubricated to reduce friction losses when the chain comes into contact with the teeth. The choice of lubricant type and lubrication method depends primarily on the peripheral speed and operating conditions. Contrary to analytical calculation the program appears to be rather advantageous and in case of inevitable calculations no calculators are needed which prevents incorrect entering of values. To simplify the calculation, the attached tables were used which shortened the period of searching for table values. Although everything is working as it should be, there is still room for future improvements that could improve the program and take it to the next level in the field of computing programs, which make it easier for us to work on creating complex operations. By adding more complex operations to the program, the calculation work can be made even easier.

Ultimately, the program thus facilitates work during calculations and assures their accuracy. Newly designed program can be applied in education process as well as in practice in development and production sphere.

ACKNOWLEDGEMENT

This article has been prepared within the project KEGA 017TUKE-4/2021. This work was also supported by the Slovak Research and Development Agency under contract No. APVV-18-0316.

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