DESCRIPTION OF THE BEARING CHECK PROGRAM FOR COUNTERSHAFT GEARBOXES

Michal BELORIT[1], Slavomír HRČEK[2], Tomáš GAJDOŠÍK[3], Ján ŠTEININGER[4]

[1]*Department of Design and Mechanical Engineering, University of Zilina*
[2]*Department of Design and Mechanical Engineering, University of Zilina*
[3]*Department of Design and Mechanical Engineering, University of Zilina*
[4]*Department of Design and Mechanical Engineering, University of Zilina*

Abstract
The article deals with the description of countershaft gearboxes and their basic dividing. Generally explains the program created in the environment of Microsoft excel and Matlab for controlling of designated bearings in this type of transmissions.

Key words:countershaft gearbox, check program, rolling bearings.

INTRODUCTION
Transmission is important mechanical component of almost every vehicle. Especially of the ones, that are fitted with an internal combustion engine. Because in spite of great amount of these engines usage, it has disadvantages such as incapability of production torque from zero engine speed, the maximum power is reached only at the specific engine speed and the fuel consumption depends on the operating engine point. These drawbacks can be compensated by an application of a conveniently designed transmission and a clutch (Lukáč, et al., 2016).
The countershaft gearboxes fall into the category of geared transmissions. And its main functions in automobiles are to change the torque and the speed of an engine in the way a vehicle is able to move in external conditions, to allow idle running of an engine and to enable reverse motion of a vehicle (Zdeněk, Žďábský, 2012). This category is possible to divide into three more groups, depending on the count of meshing gear pairs, which the power flows through, when the speed gear is shifted. It is termed the number of the ratio stages and according to it there are those groups (Naunheimer, et al., 2011):

- Single-stage transmission
- Two-stage transmission
- Multi-stage transmission

In the Fig. 1 below are plotted schematic examples of countershaft gearboxes. Single-stage means that the power flows from an input shaft to an output shaft, which could be also a countershaft, through one geared pair. In two-stage gearboxes the power goes from input to a countershaft and then to an output shaft, so there are two geared pairs simultaneously in action. The same analogy works for multi-stage transmissions (Naunheimer, et al., 2011).
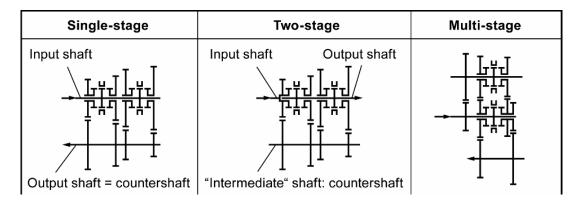

Fig. 1 Examples of countershaft gearboxes(Naunheimer, et al., 2011)

The countershaft gearboxes are also marked as gear sets with fixed axles and mainly consist of an input, output shaft and a countershaft, that are rotating in a rigid position in a gearbox. They are fitted in bearings, which are dynamically loaded throughout the transmission operating run. And they have important meaning for achieving the required durability and functionality of whole gearbox. That is why it is necessary to advisable designate rolling bearings in respect of a duty cycle and all known operating conditions (Hrček&Bucala, 2014).

MATERIALS AND METHODS

The program for control of rolling bearings was created only for the specific configuration of two-stage countershaft gearboxes. It considers that the axis of all shafts are lying in the same plane X-Z and that it is maximally twenty speed gearbox. The schematic view shown in the Fig. 2 is applicable just in the situation, when minimally two gears are mounted on the countershaft.
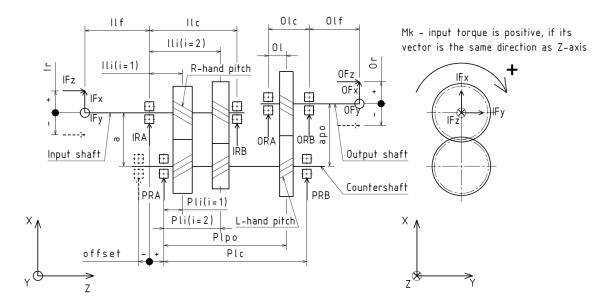

Fig. 2 The main schema of the inspected countershaft gearbox[Authors]

In the case there is mounted only one gear wheel, the countershaft becomes an output shaft and the program operates with configuration of a simple gearing plotted in Fig.3 below.
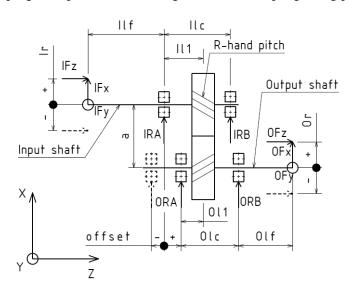

Fig. 3 The schema of a simple gearing[Authors]

RESULTS AND DISCUSSION

The program itself is compounded of two parts. One of them is created in the software Microsoft excel and the piece of it is shown in Fig. 4. The excel sheet contains the schematics mentioned above, according to which is needed to fill four tables of input data. These data includes information about relative positions of gears, bearings and shafts. Their basic geometric dimensions required for the calculation of forces distribution, duty cycle for every single speed gear and bearing characteristics. Even the database was created, that stores test array of bearings and their parameters declared by manufacturers. So the definition of each rolling bearing is executed by choosing the particular one from the dropdown list. This causes loading of all necessary specifications from the database. The list can be filtered by criterion of contact type between a rolling element and a groove of bearing rings, namely point or line contact. Next step is to set which bearings do or do not carry axial loading. It is important especially for the calculation of equivalent dynamical load (Kohár, et al., 2016).

28	inputs		
29	a	95,00	mm
30		R	Hand of pitch (input shaft)
31	IFx	0,00	N
32	IFy	0,00	N
33	IFz	0,00	N
34	Ir	0,00	mm
35	Ilc	177,50	mm
36	Ilf	0,00	mm
37	Offset	0,00	mm
38	OFx	0,00	N
39	OFy	0,00	N
40	OFz	0,00	N
41	Or	0,00	mm
42	Olc	60,00	mm
43	Ol	10,00	mm
44	Olf	0,00	mm
45	apo	95,00	mm
46	Pdpo	84,76	mm
47	Plpo	70,00	mm
48	Plc	80,00	mm
49	alfapo	21,35	°
50	betapo	27,83	°
51		L	Hand of pitch (co –ou shaft)

Parameters of each geared pair (i=<1,2,…,20>)

	1	2	3	4	5	6	7
Effective transverse pressure angle αi [°]	19,871	20,468	22,831	22,460			
Effective helix angle βi [°]	30,855	29,984	30,204	27,040			
Effective pitch radius Di [mm]	129,460	115,280	92,200	61,380			
Distance from center of 1. bearing IA to the cenetr of gear Ili [mm]	22,5	72,5	93,5	152			

Duty cykle of geared pair i

		1			2		
	Mk1 [Nm]	n1 [ot/min]	t1 [h]	Mk2 [Nm]	n2 [ot/min]	t2 [h]	Mk3 [Nm]
1	5,00	100,00	14,22	2,00	100,00	20,21	5,00
2	2,00	200,00	50,00	3,00	20,00	100,00	
3	3,00	200,00	60,00				
4							
5							
6							
7							
8							
9							
10							

Rolling bearing selection

			radial and axial factor:	X	Y	
Ball bearing d=25 D=47 B=12 Cr=10,07 Cor=5,806	IA	Point	contact	radial	1,00	0,00	yes
Ball bearing d=70 D=110 B=20 Cr=37,96 Cor=30,959	IB	Point	contact	axial - radial	0,56	1,00	yes
Ball bearing d=30 D=55 B=13 Cr=13,243 Cor=8,25	PA	Point	contact	radial	0,56	1,00	no
Cylindrical bearing d=20 D=47 B=14 Cr=13,9 Cor=10,2	PB	Line	contact	axial - radial	1,00	0,00	yes
Ball bearing d=45 D=75 B=16 Cr=21,1 Cor=15,3	OA	Point	contact	radial	0,56	2,00	yes
Ball bearing d=35 D=62 B=14 Cr=15,956 Cor=10,328	OB	Point	contact	axial - radial	0,56	2,0	yes

Fig. 4 Excel file with input data [Authors]

After filling of all needed inputs comes the second part of the program. It was created in the environment of software Matlab of company Mathworks. Here is written a function whose code includes conditions and all essential equations. Running of the function executes the code and starts loading the data from the excel file and calculating. It calculates forces in gearings, speed of shafts, reactions in supports (only of statically determinate beams), medium radial and axial load, equivalent dynamic bearing load, calculated dynamic load rating and so on. There is the connection between the Matlab function and the Excel file, so the results are written back into this file. The most important output is the calculated dynamic load rating of each bearing. Because according to the criterion (1)

$$C \le C_r \tag{1}$$

where C is the calculated dynamic load rating (kN), C_r is the basic dynamic load rating (kN), is evaluated if the chosen bearing is suitable for required conditions. In the excel file is the column, emphasised in Fig. 4, that gives information whether the criterion for each one bearing is met or not. This way the bearing check program works (Kohár, 2015).

It is also possible to use the program for the designation of bearings. But in this state it is too complicated because it requires to stepwise select bearings and after each selection to run the program, until the program says the bearings are satisfying.

CONCLUSION

The program, that is able to calculate a countershaft gearbox of any configuration and then evaluate the applicability of the assigned bearings or designate convenient bearings from the list on its own, would be really useful and desirable. It could save the time of this operation and eliminate an aberration. So the next developing of the program will be focused on the designation process and augmentation of the gearbox variants.

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REFERENCES

1. Hrček, S., Bucala, J. (2014). Thermalsimulationsofplasmabitelectronicsystemprotectivehousings. In *Modernmethodsofconstruction design* (pp. 71-76). Cham: Springer.

2. Kohár, R., Brumerčík, F., Lukáč, M., Nieoczym, A. (2016). Numericalanalysisofrollerbearing. In *Appliedcomputer science* (pp. 5-16).

3. Kohár, R. (2015). Úvod do štrukturálnejoptimalizácie. In *Wspomaganekomputerovomodelowanie, analiza i projektowanieelementówmaszyn i mechanizmów* (pp. 95-103). Lublin: PolitechnikaLubelska.

4. Lukáč, M., Brumerčík, F., Krzywonos, L. (2016). Driveabilitysimulationofvehiclewith variant tireproperties. In *Communications : scientificlettersofthe University of Žilina* (pp. 34-37).

5. Naunheimer, H., Bertsche, B., Ryborz, J., Novak, W. (2011). Automotivetransmissions. *Springer Heidelberg Dordrecht London New York*.

6. Tropp, M., Lukáč, M., Nieoczym, A., Brumerčík, F. (2106) Hydrauliccircuits in transport and mechatronicsystems. In *Logi : scientificjournal on transport and logistics* (pp. 143-149)

7. Zdeněk. J., Žďábský, B. (2012). Automobily (2) – Převody. *Avid.*

Corresponding author:
Ing. Michal BELORIT, Department of Design and Mechanical Engineering, Faculty of Mechanical Engineering, University of Zilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic, e-mail: michal.belorit@fstroj.uniza.sk