THE 3D MODELLING OF THE TRANSMISSION OF A GEAR BOX WITH FOUR SPEEDS

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ABSTRACT: Gear boxes must provide for the automobile with the best dynamic and economic qualities for the power and revolution of the internal combustion engine. In order to do this, it must have a simple design, light weight, reduced gauge, high reliability and easy maintenance. In this paper, based on the constructive solutions and the geometric elements that were calculated, we obtained a 3D modelling of the elements of the transmission of a gear box and the assembling of these elements in order to obtain the constructive dimensions of the gear box and in order to verify the other composing elements (shafts, bearings, synchronization mechanisms).

KEY WORDS: gear wheel, automobile, optimizing.

1. INTRODUCTION

The resistances for the automobile's advancement vary greatly, according to the moving conditions and the traction force must also be modified according to these. The great majority of existing automobiles are equipped with internal combustion engines, whose characteristic is that they allow a limited variation of the engine moment, respectively of the traction force. The graphical representation of the relation between the traction force and the automobile's speed is called an "ideal traction hyperbole" (ITH) and it represents the ideal traction characteristic of an automobile. It is obvious that the traction characteristic of a thermal engine is very remote from the ideal traction characteristic.
If we use a gear box with four gears, we obtain a traction characteristic which is close to the ideal one. From the perspective of the traction, the more gears the gear box has, the more the traction characteristic is closer to the ideal one. If we take into account the limitations of the internal combustion engine as well as the necessary traction of the car, we can say that a gear box has the following roles/functions:
- To allow the modification of the traction force depending on the variation of the forces at advancement.
- To allow the advancement of the automobile at reduced speeds that cannot be provided by the internal combustion engine, which has a relatively high minimum stable revolution .
- To allow the automobile to go backwards, without reversing the engine's rotation direction.
- To accomplish the enduring cut off of the connection between the engine and the rest of the transmission, in the case in which the automobile is not moving and its engine is functioning..

The gear boxes must rise up to the following requirements: to provide for the automobile the best dynamic and economical qualities at a given exterior characteristic of the engine; simple and comfortable operation; silenced functioning; simple construction; high rating; functioning safety; high reliability; light weight; reduced gauge and easy maintenance.
A gear box with two shafts and five gears is shown in figure 1, and has the following

components: 1 –the clutch nave; 2 – the primary shaft of the gear box; 3 –the differential's satellites; 4 – the planet wheel shafts of the differential; 5 – the differential crown; 6 – pinion for the first gear; 7 – pinion for the second gear; 8 – housing of the gear box; 9 – pinion for the third gear; 10 – pinion for the fourth gear; 11 – stopple for the axial movement of the axial-radial bearing; 12 – pinion for the fifth gear; 13 – secondary shaft; 14 – housing; 15 – engagement pinion for the fifth gear; 16 – the clutch's frame.

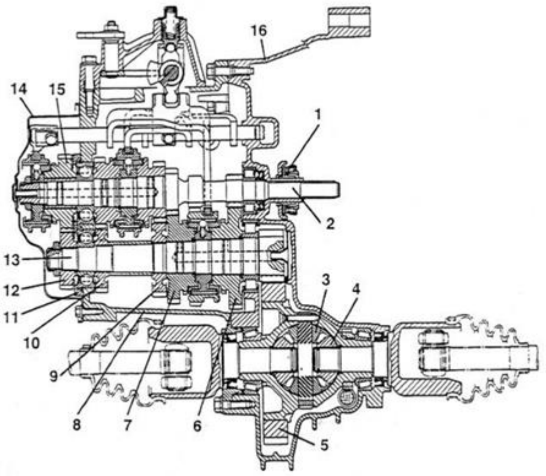

Figure 1. Gear box wuth two shafts and five gears.

2. THE CRITERIA FOR DETERMINING THE SPEEDS

The role of the gearbox is to adapt the traction characteristic of the automobile according to the movement conditions. The transmission reports in the gear box allow the automobile to meet the following criteria:

- To advance in difficult conditions (very steep road).
- To reach the maximum movement speed for which it was designed.
- To function in the domain of minimum fuel use of the internal combustion engine.

The calculation of the transmission report of the first gear (i1) is made in order to meet the first criterion, that of the maximum slope. The maximum speed of the automobile is obtained usually with the aid of the ratio of direct grip (1.00) or subunit. The minimum transmission ratio, that of the last gear, allows the engine to function in the domain of economical revolutions, which allow a reduced use of fuel when moving at relatively high speeds.

The intermediary gears, the ones between the gear with maximum ratio and minimum ratio, are calculated according to different criteria (acceleration, fuel use, reliability). A gear box cannot be designed optimally regarding both the accelerations and the consumption of fuel.

Generally, automobiles have gear boxes that are designed to accomplish a compromise between the acceleration in each gear, the maximum speed reached and the consumption of fuel.

The speed range can be made using the criterion of the constant revolution interval of the engine for each gear, or the speed range using the criterion of the constant speed interval for each gear.

The transmission ratios are carefully calculated and optimizing to obtain the best compromise between the dynamic performances and the consumption performances.

3. DESIGNING THE ENGAGEMENTS FOR THE GEAR BOXES

A quality engagement must fulfill the following requirements: the elimination of interferences, an equal life span of the two wheels (bending, contact pressure and wearing); reduced noise.

High carrying capacity is obtained for engagements with straight or inclined indentations for an engagement angle higher than 20 degrees. For the life span at the breaking of the base of the indentation and at the contact solicitation to be equal for both wheels, we must use different materials, and different thermal treatments. Reduced noise can be obtained by increasing the coverage degree and by flanking the indentation. The coverage degree increases when the angle of inclination of the indentation is increased, and when the engagement angle is decreased under 20 degrees.

Whatever the engagement category, we can equalize the wearing of the two wheels in engagement by the rational choice of the ratio of the coefficients of reformation of the wheels, so that the composition between the pressure and the sliding speed of the flanks will be close to each other for the pair of gear wheels. The coefficients of reformation will be chosen so that: the wearing is uniform at both wheels; there is no undercutting; the indentation is not sharpened; the resistances to breaking at the pinion and at the wheel are close to each other.

When designing engagements for gear boxes, we begin by determining the torsion moment and the engine's revolution according to the maximum mass of the car and the maximum movement speed. The distance between the axes is connected to the diameter of the shafts, which must not have a sag higher than 0,1 ... 0,15 mm, to the diameter of the bearings and in the case of gear boxes for automobiles the size of the synchronizers.

The number of indentations must not be under 10, because of the manufacturing difficulties. For gear boxes, we accept as a minimum number 11-13 indentations. For the gear box, we indicate a slight increase of the sum of the indentations number from first gear to fourth gear.

The width of the indentation must not be under 10 mm, both because of the breaking of the indentation in case of propeller deviations and because of the small additional covering degree.

The inclination angle of the indentation must be chosen to be small, if we want to obtain small axial efforts, and must be chosen to be large to offer a large supplementary covering degree, resulting in a reduced noise of the engagement. By slightly modifying the inclination degree of the indentation, we get high modifications of the engagement angle, when β rises, α_{rf} decreases.

The defined normal module for $\alpha = 20^{\circ}$ must have a standardized value.

The coefficients of reformation must be so chosen that the life spans of the indentations of the two wheels are close and there is no undercutting at the base of the indentation or the sharpening of the head of the indentation. Coefficients of reformation are chosen differently for gear engagements and for amplifying engagements. Based on the above recommendations and on the exterior characteristics of the engine in figure 2, we made a calculus program for the transmission of the gear box with the help of the soft MathCAD.

After we determined the main transmission ratio from the condition of the transmission ratio of the gear box, we continued by determining the transmission ratios.

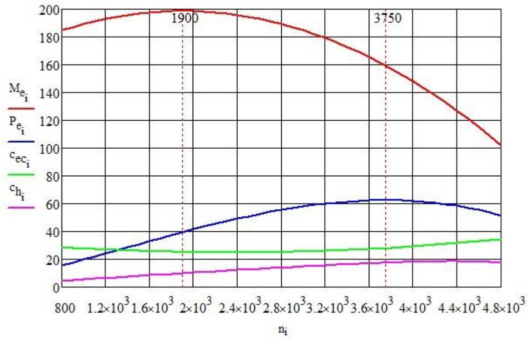

Figure 2. The exterior characteristic of the automobile's engine.

After obtaining the transmission ratios of the gear box we continued by calculating the geometric elements of the gear wheels that will equip the gear box. The calculation of the gear wheels was made for first gear.

After we determined the distance betweeen axes a_W = 160 mm for the average of the torsion moment and the maximum power (figure 2), we determined the module of the engagement m = 3 mm and the number of the indentations of z1 = 19 and z2 = 82. For these data, we calculated the geometric ellements of the engagements for a variation of the inclination angle angle of the indentations between 0 and 25 degrees, with the graphic represantation in figure 3.a of checking the lack of interference of the profiles of the indentations of the two wheels $\rho l < \rho f$, which is accomplished for the interval of 15-25 degrees. The condition to avoid the undercutting of the profile of the indentations at $\rho_l \geq 0$ is done for the interval of 0 – 20 degrees. We also checked for the lack of sharpening of the head of the indentations, which must be higher than 0,75 mm for bettering steels and 1,2 mm for cementing steels, this condition is not fulfilled by the pinion only for the interval 15 – 25 degrees (fig. 3.b). As a result of these onservations, we proceeded by analysing pnly the interval of the inclination angle of the indentations 15-20 degrees, which are shown in figures 3.c and 3.d, meaning that the adopted inclination

angle is β = 19º..
After we obtained these geometric elements of the gear wheels, we proceeded by checking the resistance conditions of the engagement to the solicitations of contact pressure betwen the SH flanks of the indentations and to bending wearing at the base of the indentations.
In figure 4.a we show the variation of the safety coefficients for the manufacturing of the wheels from a improvement steel, and in figure 4.b for a cementing steel.

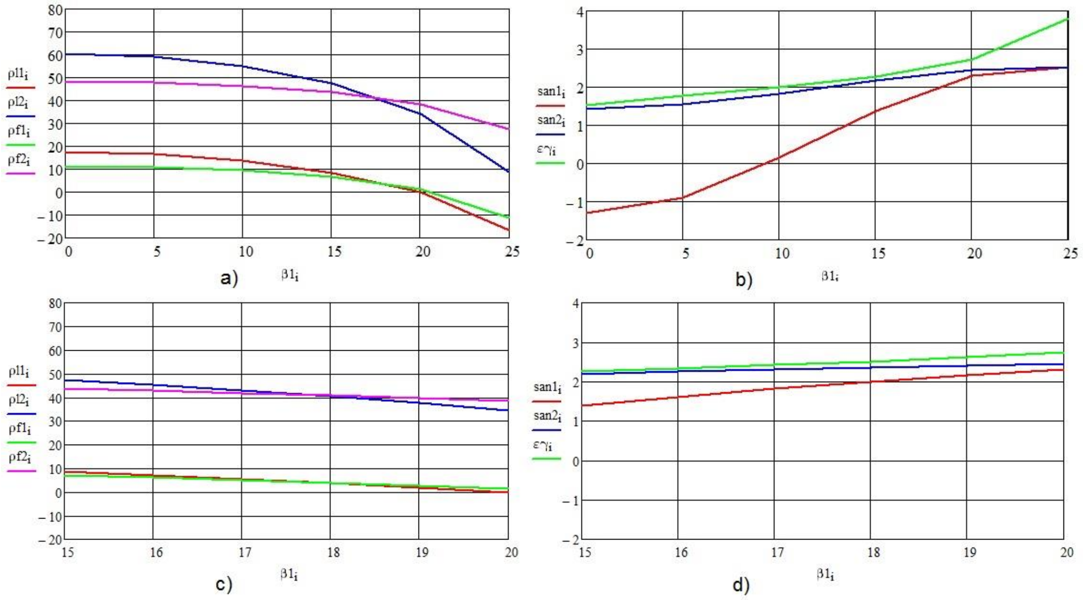

Figure 3. The variation of the radiuses that give us the condition of avoiding interference ρl < ρf and of undercutting of the teethρl<0.

The admissible coefficients for contact pressure SH3 = 1,15and of tiredness at bending SF3 = 1,25 are fulfilled only by the cementing steel..

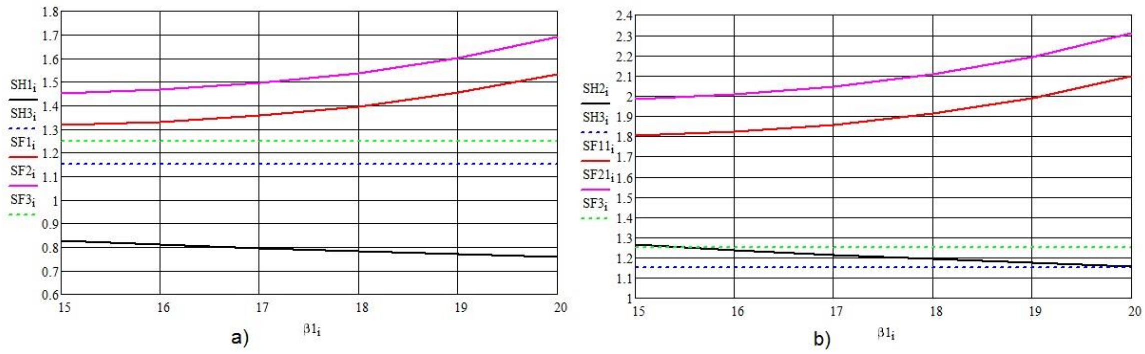

Figure 4. Modul de variaţie a coeficienţilor de siguranţă a roţilor dinţate pentru oţel de îmbunătăţire şi de cementare

4. THE CONSTRUCTION OF THE GEAR BOX

The a gear boxes contain several pairs of gear wheel mechanisms, which have the role of transforming the engine torque and the revolution with the purpose of adapting the engine at the traction requirements.
The primary pinions for all the gears are fixed on the shaft, and cannot rotate independently from the primary shaft.
On the other hand, the pinions on the secondary shaft are free on the shaft, and they rotate even if the secondary shaft does not rotate (when the vehicle is stationary).
We must remember that al gear wheels mechanisms are engaged all the time, the move in and out of a gear is done by using a coupling sheath.
Based on the constructive solutions we have

show, and based on the calculated geometrical elements we can obtain the modeling of the elements of the transmission of the gear box and their assembling in order to obtain the constructive dimensions of the gear box and to be able to verify the other composing elements (shafts, bearings, synchronization mechanisms).

5. MODELLING THE TRANSMISSION OF A GEAR BOX WITH FOUR GEARS

Based on the constructive solutions we have shown, on the established transmission ratios and on the geometric elements of the calculated engagements, we obtained the 3D modeling of the elements of transmission of

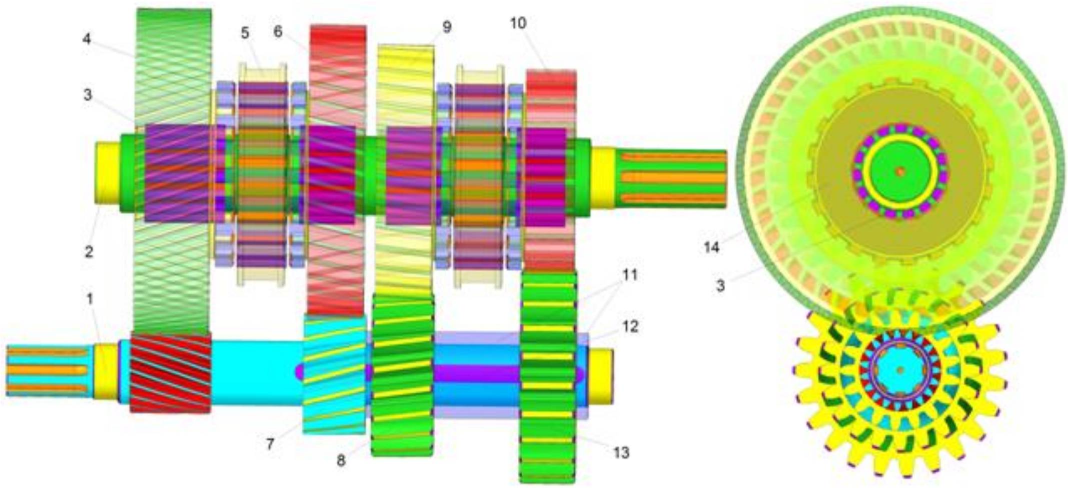

Figure 5. The transmission by gear wheels of the gear box with four gears.

the gear box shown in figure 5, where the following were noted: 1 – entry shaft; 2 – exit shaft; 3 – bearing with pins; 4 – indented wheel z = 82 m = 3; 5 – coupling sheath; 6 – indented wheel z = 82 m = 3; 7 – indented wheel z = 17 m = 5; 8 – indented wheel z = 20 m = 6; 9 – indented wheel z = 33; 10 – indented wheel z = 23 m = 7; 11 – distancing rings; 12 – parallel wedge 14x8x220; 13 – indented wheel z = 23 m = 7; 14 – coupling nave..

In figures 6, 7, 8 and 9 we show the

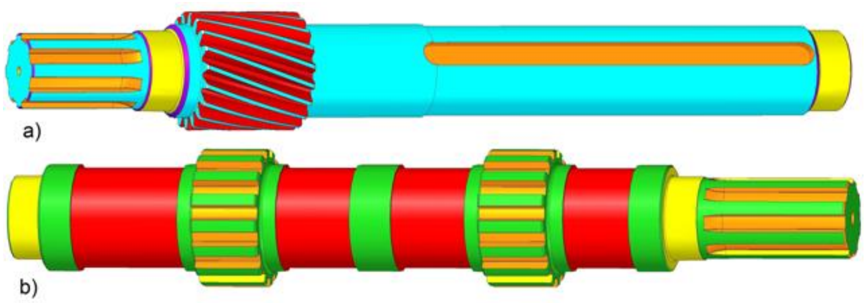

Figure 6. The shafts of the gear box.

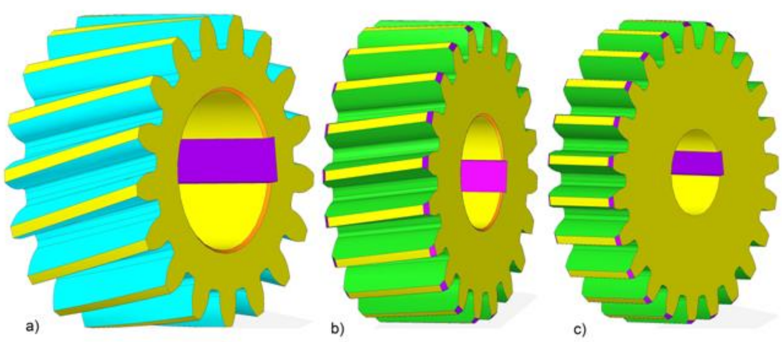

Figure 7. The indented gear wheels from the entry shaft.

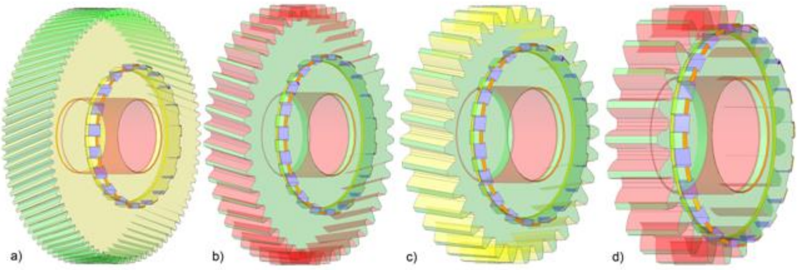

Figure 8. The indented wheels from the exit shaft.

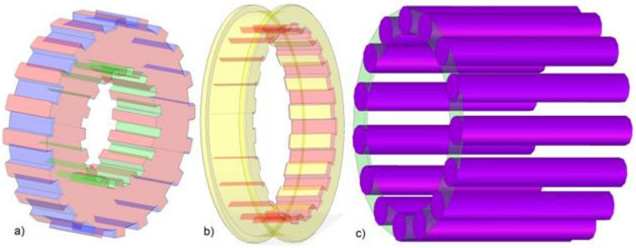

Figure 9. Coupling parts for the indented wheels at the shaft and bearing with pulleys.

constructive solutions for the shafts, indented wheels, the elements of coupling of the gear wheels at the exit shaft and at the bearing with pins/pulleys.

We must remember that all gear wheels mechanisms are engaged all the time, the coupling and the uncoupling of a gear can be made using coupling sheaths.

6. CONCLUSION

When designing engagements for gear boxes, we begin by determining the torsion moment and the revolution of the engine according to maximum mass of the car and the maximum movement speed.

The gear box, by sequencing the speed ratios, has an essential role regarding the adaptation of the engine's characteristics at the traffic and road conditions.A gear box that is badly sequenced, and is not adapted to the engine of the car, can have important negative effects on the performances of an automobile.

Usually, constructors opt for a compromise, good acceleration in the first gears and reduced consumption in the superior gears, Δv = constant.

In order to design engagements with cylindrical gear wheels for automobiles, and to meet the requirement of optimization power-gauge an ample analysis is necessary, which can be somewhat done with the help of calculus software in which certain stages must be achieved.

Based on the constructive solutions and on the geometric elements calculated we can make a 3D modeling of the elements of the gear box and its assembling in order to fulfill the constructive dimensions of the gear box and to be able to verify the other component elements (shafts, bearings, synchronization mechanisms)..

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