ONE CONTRIBUTION TO SYNCHROMESH TYPE GEARBOX AUTOMATION

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INTRODUCTION

Synchromesh gearboxes gear shifting process is comprised out of several successive actions, such as: clutch engaging, selector levers movement, gears engaging/disengaging, gently releasing clutch pedal etc. This is only simplified display of what is actually happening during gear shifting process in a manual gearbox.

Because of the drive train configuration, command handle is almost never on a gearbox, but is actually connected to it by means of levers and joints. To engage or disengage a certain gear, this mechanism needs to move in a certain way. When divided in to simpler types of movement, lever mechanism movement is comprised out of two types of it, translatory and rotatory type.

Order in which this types of movement appear depends of a situation. All of this complicates driving process and contributes to drivers overall feeling of fatigue.

To resolve this problem, today we have automated gearbox systems, where drivers action are substituted with actions of actuators. In configuration like this small changes in drivers surroundings have been made, e.g. clutch pedal is gone, command handle, if there is one, now has only a few positions ("+", "-", N, R) and has totally different paths. Big changes have been made in gearbox surroundings. All actions between driver and gearbox are now replaced by actions of an actuators.

Main goal of this paper is to contribute further development of automated gearbox systems with one conceptual design and to present one of possible direction for future development.

GEAR SHIFTING AUTOMATION AT PRESENT

At present, solutions are based on two DC motors concept. Each of DC motors has its purpose. The first one is responsible for rotatory motion and the second one is responsible for the translatory motion.

One of the today's existing solution is presented in figure 1. System comprises out of several separate systems, all working together toward the same goal – automating the gear shifting process.

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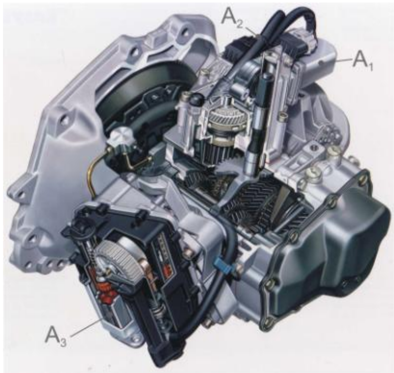


Figure 1: *Opel`s EasyTronic system*

As it can be seen in figure 1, this system is very compact and complex. All mechanical components are incorporated in gearbox housing and because of that, housing needed to be redesigned so all the parts could be easily mounted. This made the price goes up in compare to standard manual gearbox system.

Second disadvantage of this system is its complex software algorithm. Namely, system has to manages several different systems all at the same time. Among them are two DC motors which are need to be controlled sequentially and at the different speed rates and most of the times have to change rotation direction.

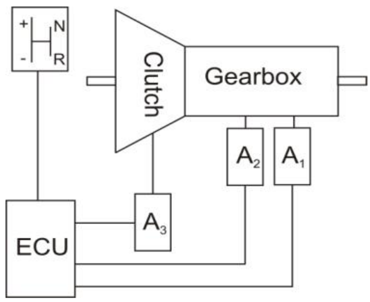


Figure 2: *Automated gearbox block scheme*

Automated gearbox system have tree actuators, marked as A_1, A_2 and A_3, in figure 1 and 2. A_1 and A_2 are DC motors and A_3 is clutch actuator. The clutch actuator unit is needed in any automated gearbox system with dry clutch system, so it can not be ignore in future constructions.

NEW DESIGN FOR GEAR SHIFTING AUTOMATION

The idea for only one DC motor for gearbox automation originates from gear shifting process in motorcycle gearboxes. Motorcycles often have a gearboxes with dog couplings, gears do not move axial and are engaged by one type of motion. Some gears are made with shaft out of one piece, while the rest of gears can freely rotate on shafts. All gears are coupled at all times, but when selector lever (fork) moves dog coupling engages particular pair of gears, see figure 3. To engage certain gear, driver moves command lever by foot or by hand and makes one type of movement, rotatory. Driver rotates cylinder which has channels on its surface, see figure 3. Selector forks are in conjunction with this cylinder by means of these channels.

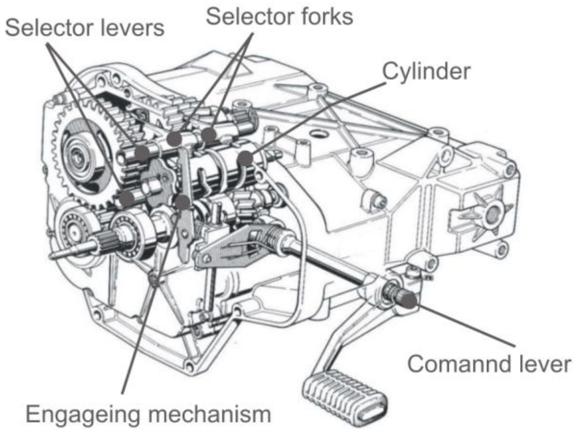


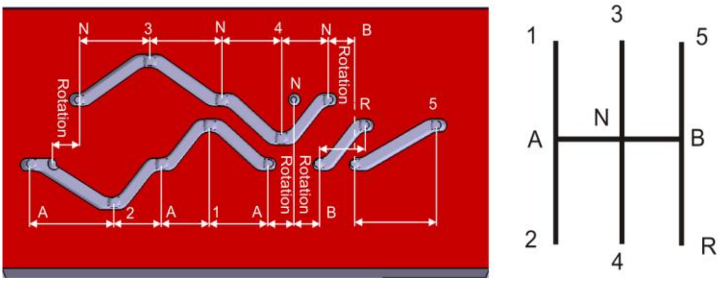
Figure 3: *Motorcycle gearbox*

If channel path is straight then there are no selector lever movement, therefore no change in gears. But if the path of the channel on the surface of the cylinder has a slope then one out of two things will happen, either gear will engage or it will disengage. So if a driver moves command lever, he is actually making rotatory movement by which he is moving, firstly, engaging mechanism, then cylinder and at the end dog couplings. Most important part of this system is cylinder with his channels, because it leads selector levers so they can engage gears.

DESIGN PRESENTATION

This one DC motor gearbox shifting mechanism is comprise from mechanical and electrical parts and in this paper only most important one’s will be presented. Mechanical parts are: profiled plate, gear pair, cylinder with prongs, housing and flange. Electrical parts are: DC motor, DC motor controller, sensors, cables, command joystick, supporting electronics. The focus of this paper is at the mechanical part, because, choosing the DC motor and after that everything else is conditioned by hardware dimensions and construction.

Profiled plate is a key part of the system, because profiled plate is converting movement type. It is cuboid, dimensions varied by type of specific model of a gearbox. Main requirement for profiled plate dimensioning are stroke length and turning angle of the command lever. Beside dimensions of the profiled plate, more important thing is depth of its channels which are on the surface of the profiled plate, see figure 4.



a) b)

Figure 4: *a) Profile plate with gears displacement: 1…5 - number of a gear, N –neutral, A, B - neutral positions of a gearbox between two specific gears, b) H scheme of gearbox gear shifting process*

Layout of these channels is displayed on figure 4, as well as gear displacement. At the same figure, ordinary H scheme of gearbox gear shifting process is presented. In figure 4 rotation represents rotation of the cylinder with prongs i.e. moving gearbox command lever from neutral to neutral between two gears.

Length between two gears on the profiled plate directly proportional to stroke length of gearbox lever and is different for every gearbox model. Channels end positions are completely arbitrary but still very much depending of the type of a gearbox and they are also directly influencing DC motor speed change during gear shifting process. So it is better that this distances are equal in length, so that we could have constant DC motor speed at all time and at the end DC motor controller of a lower cost. End points span, between end points that are not jointed by the channel, is directly coupled with gearbox lever turning angle.

Cylinder with prongs is part of this mechanism that transform profiled plate translatory movement into command lever rotatory and translatory movement. There are three prongs, see figure 5. Prongs are joined together by a supporting cylinder. Supporting cylinder have two bases on which two shafts are welded, one on each base.. These shafts are supported by slide bearings in the way represented in figure 5, and bearing are embedded in the housing, later on. Slide bearings allow rotatory and translatory movement through them as well.

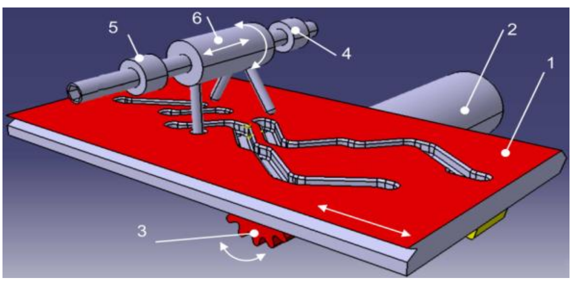


Figure 5: *Gear box shifting mechanism with single DC motor: 1 – profiled plate, 2 – DC motor, 3 – sprung gear on DC motor, 4, 5 – sliding bearings, 6 – cylinder with prongs*

When profiled plate moves translatory (left or right), cylinder is rotating and moving back and forward because one prong is always coupled with profile plate and is following path of the channel. In figure 6, cross section of the mechanism is presented.

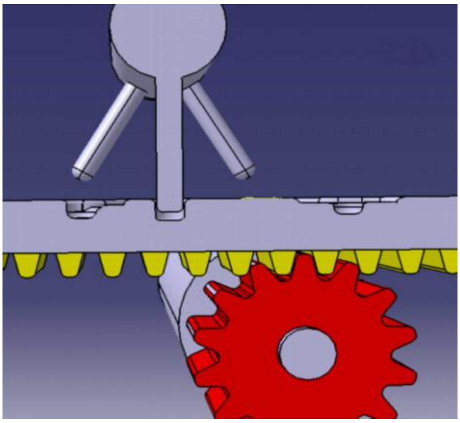


Figure 6: *Gearbox shifting mechanism cross section*

DESIGN ANALISYS

Profiled plate is a single metal piece that not necessary needs to be a plate. Older solutions similar to the profile plate tend to be round in shape. So now we have cylinder and disks with similar cannel displacement on surface of them. As presented in figure 6, prongs are always in contact with profile plate and are following channels paths, but there is a moment of time when switching in which prong is currently coupled with the plate. At this moment two prongs are coupled with the plate at the same time. Because of the cylinder rotatory movement one prong is exiting the channel while the other is entering it at the same time. At this point it is out of most importance the profile of top end of the channels, end on which prongs are sliding while entering or exiting the channel. This radius depends out of many factors, from which most importants are length of the prongs, rotatory angle of gearbox (synchromesh engaging stoke length, etc). These radiuses need to follow exiting/entering trajectory of the prong, so the resistance would be as less as possible. Channels path can vary from model to model of a certain gearbox, because of their difference in construction, so it is very important as well to plan carefully the paths when designing new profile plate.

Number of gears determents number of prongs on cylinder. Maximal number, which one prong can cover is two if shifting pattern is H type. So if there are five gears plus reverse that means that there are six gears to be covered with prongs, so that means tree prongs. If a vehicle would have six gears plus reverse, that would mean four prongs on the cylinder, etc. DC motor for this kind of application has to have big momentum and relatively low speed (speed is depending of the length of the profiled plate). Therefore the DC motor must have one suitable reducer, that reduce the motor speed and increases its torque. Needed ratio for suitable DC motor is around 200 or 300, because, DC motors with brushes usually runs at speeds of 2000 or 3000 rpm, and we need speed of 10 to 20 rpm.

There are many complete solutions for this type of application on market. Most important characteristics for choosing the right DC motor are nominal speed [min^{-1}], nominal torque [Nm], nominal output power [W], nominal current [A], starting torque [Nm] and mass [kg].

When completed, new system have less moving parts and less electrical ones. Block scheme is presented in figure 7. A_1 and A_2 are the two only actuators on the system. The A_1 is clutch engaging/disengaging actuator, and the A_2 is DC motor which moves profile plate.

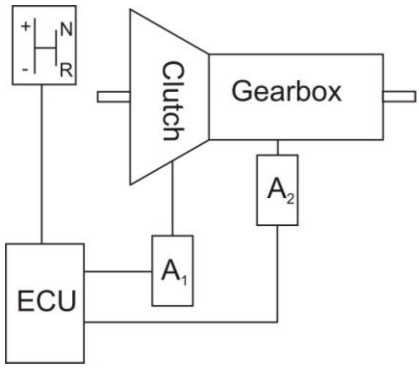


Figure 7: *Block scheme of the single DC motor gearbox shifting system*

The most important improvement of this system is that, that in comparing to the other solutions, this one is detachable from the gearbox. This system is only attached to the already existing system of transmission and it is not necessary to make any kind of changes to the gearbox housing, Another interesting feature of this single motor gearbox shifting mechanism is that it can be mounted under any angle as long as the command lever of gearbox and output shaft, of cylinder with prongs, stays coaxial.

Possible spots for embedding this system are vast, because this system is not limited with points of its connection with gearbox, except of command lever. This means that this system can be built in under any given angle as long as his cylinder shafts and command lever stays coaxial. Empty spots left after building in system like this on can be used to put a new command handle in a drivers cabin or it can even be pushed away from the gearbox if there is a straight corridor between them.

CONCLUSION

This paper presents actuator for gearbox shifting automation in automobiles with synchromesh gearboxes, that operates with one DC motor. This actuator represents upturn in comparison to today's two DC motors solution, because the system is simplifying. Mechanical part of a system comprises out of a profiled plate, cylinder with prongs, gear pair, DC motor and housing. Because of a small number of parts and simplicity, this mechanism is suitable for production and maintenance. Modular installation is possible on different types of manual gearboxes, with small necessary modifications such as changes in the channels paths, gear pair ratio, prongs lengths etc.

At present, described actuator does not exists in automobile production, but it seems worth researching it's potentials.

In course of future development, kinematics and dynamics of the system should be investigate as well as the possibility to replace profiled plate with profiled cylinder, which will simplify the presented system even more.

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