When industry and academia meet: the development of a robotized semiautomatic motorcycle transmission

Lucian LOBONȚ
Lucian Blaga University of Sibiu, Sibiu, România
lucian.lobont@ulbsibiu.ro

Radu Emanuil PETRUSE
Lucian Blaga University of Sibiu, Sibiu, România
radu.petruse@ulbsibiu.ro

Paul Mihai OBRODOVICIU
Continental Automotive Systems S.R.L., Sibiu, România
paul.obrodoviciu@continental-corporation.com

Ioan BONDREA
Lucian Blaga University of Sibiu, Sibiu, România
ioan.bondrea@ulbsibiu.ro

ABSTRACT

The development of the business – industry environment is unconceivable without the involvement of academia. On one hand, the universities can provide new perspectives and know-how which can be further translated into exquisite products and services for companies. On the other hand, the business environment can raise practical problems and challenges for academia, providing in the same time material support for finding solutions to these problems. This paper presents a successful partnership between business and academia materialized in the development of a robotized semiautomatic motorcycle transmission. Since the solutions existing on the market did not meet the specific requirements of our industrial partner, we were asked to design an innovative and cost effective clutch and gearbox mechanism. The paper presents all the stages passed from establishing specific objectives and tasks for each member of the project’s team, the specific steps followed in order to develop the clutch operation mechanism and the gear mechanism, the obstacles and failures encountered during the design process and the testing procedures, the optimizations implemented, up to the final solution. The advantages of such industry-academia projects are discussed and possible obstacles that can hinder this kind of collaboration are addressed.

Keywords: semiautomatic motorcycle transmission development, business and academia

INTRODUCTION

While the academia may be perceived as solely focused on education and research and the industry as interested only with productivity and financial efficiency, their interaction is an obvious desideratum in the nowadays global competitive environment. The interaction between academia and industry represents one of the key modalities to maximize the value of research data and turn them into superior quality products and technologies (Appleyard, 2017).}

Sosnowski (2014) presents the cooperation between academia and industry as a flow of knowledge and skills, technical and human resources, ideas, finances etc. This cooperation model is
characterized by a positive feedback: the industry benefits of new ideas to be implemented, of specific answers for the real problems it encounters, while the academic institutions get to have a better knowledge of industry’s expectations and to adapt their educational programs so as to keep the pace with the technological development and to deliver high skilled graduates.

In Lucian Blaga University of Sibiu (LBUS) and especially in the Faculty of Engineering there is a constant preoccupation for strengthening the cooperation with major actors from industry. This is proved by numerous partnerships in research projects that LBUS has with companies like Continental Automotive Systems, Marquardt, NTN - SNR, Compa and by the increasing number of services contracts that are signed between members of LBUS and various organizations. The members of LBUS are encouraged and stimulated to develop research activities, these activities being a factor in the assessment of their annual performance.

Most often, the cooperation between universities and industrial organizations takes the form of research projects, funded by the industry, where the aim is to develop solutions for specific technical and logistical problems. These projects are usually carried out by teams formed of professors and students, which perform activities focused on providing optimized answers to the specific requests of the industrial organization. The present paper describes such a research project, namely one that aims at developing a robotized semiautomatic motorcycle transmission. Due to the high quantity of information, the paper will present only the development of the clutch and gearbox mechanism. The development of the electric system is presented in another paper (Neghină et al., 2017). The system was implemented on a second hand motorcycle Suzuki SV650.

**METHODOLOGY**

The project was developed between Lucian Blaga University of Sibiu - Faculty of Engineering and Continental Automotive Systems S.R.L. The specific requirements of the industrial partner were presented during several formal and informal meetings and, after all the necessary information were established, a partnership contract was prepared and signed by all the involved parties. The basis of the development was a project map (fig. 1)
The project map was further developed in the following steps:

- Developing of an automated clutch operation mechanism;
- Testing the automated clutch operation mechanism;
- Developing of an automated gear shifter operation mechanism;
- Testing the automated gear shifter operation mechanism;
- Developing the clutch operation mechanism software;
- Testing the software for controlling the clutch operation mechanism;
- Developing the gear shifter operation mechanism software;
- Testing the software for controlling the gear shifter operation mechanism;
- Developing electronic control (PCB development);
- PCB tests;
- Integrating all the components into a single assembly;
- Testing the final system.

Establishing the team

When we established the project team our focus was to involve both members from academia, as well as students. The final team was composed of 3 teachers and 3 students. For every member of the team there were established clear objectives and tasks.

Analysis of existing systems

One of the development steps was to analyze the existing projects and solutions and also the costs of the commercial solutions. We identified many commercial solutions, such as:

- Kliktronic - semiautomatic gearshift solutions for people with disabilities [http://www.kliktronic.co.uk/technical] Price 680$ + VTA. Kliktronic system is composed by: the Kliktronic Electric Shifter which is constructed with a bidirectional solenoid with 2 poles and a command on the handlebar and double lever for break and clutch, both hydraulic;
- ShiftFX Electronic Shift Transmission – Modular system that allows semi-automatic (button) or automatic gear shifting [http://www.shiftfx.com/electronic-shift-transmission]. This kit is designed for all types of motorcycles. Inside is an ECU system, so the kit is very flexible and can be exploited in any environment, from adventure, which facilitates the gear shifting to reduce fatigue, to sports, which allows automatic gear shifting at optimal RPMs. Starting price 439$ for the kit unidirectional (only upshifting) without clutch operation.
- Pingel Electric Speed Shifter – Operation system for gear shifting using a bidirectional solenoid. This system also allows its user to shift gears manually. The Pingel kit does not modify the clutch; the gear shifting operation is “forced”. Price starts from 1,076$ [http://www.pingelonline.com/prodcat/electric-speed-shifters.asp]
- Translogic – Similar with ShiftFX, it is a concept for track motorcycles. Price from 670 to 825£ [http://www.translogicuk.com/powershifters.php]

All these commercial solutions presented above do not automatically operate the clutch.

There are also some DIY projects, one of them is aSsemi-automatic Motorcycle Gear Shifter created by Patrick Kowalski and Caspar Baczynski. https://www.youtube.com/watch?v=4BJWqNCN1bk, using a Pingle Electric Speed Shifter system improved with a controller which automatically shifts gears depending on the engine’s RPMs.

The development of the clutch and gearbox mechanism

For the development of the two mechanisms we followed the next steps:
- drive forces have been determined;
- brainstorming sessions were conducted to identify the optimal drive solution;
- components design and CAD representation in CATIA;
- finite element analysis was performed to identify areas with breakage potential for the main parts;
- prototypes were printed on the 3D printer;
prototypes were tested;
- results-based improvements have been achieved;
- the final shape of the drive and fastening system has been established;
- performance tests and endurance tests have been carried out.

RESULTS

Clutch operation mechanism development

To determine the necessary force to operate the clutch we used a digital dynamometer. In order to determine the maximum force required to operate the clutch, seven measurements were performed (fig.2). Maximum linear force calculated was 450N. For safety, we chose a mechanism for 550-600N.

![Figure 2: Required force to operate the clutch](image)

After determining the necessary force, several brainstorming sessions were organised in order to identify ideas for the clutch operation mechanism. We identified the following three possible solutions:

- Operating the clutch using an actuator
- Operating the clutch using a solenoid
- Operating the clutch using a hydraulic kit specially developed for motorcycles to reduce the force needed to operate the clutch lever.

After the analysis of pro and cons for each proposal, we have decided for the solution of operating the clutch using a hydraulic kit available on the market that reduces the force needed to operate the clutch lever.

Starting from the hydraulic kit solution, different clutch actuating mechanisms were designed. To operate the clutch, an electric motor and a steel cable actuation were used. The solution was first 3D modelled in Catia v5 in order to verify the kinematics (fig.3). After the digital mock-up validation, some of the parts required to be 3D printed. For the first prototype all the fixtures and the cable winder were 3D printed using FDM (Fused Deposition Modeling) 3D printing method (fig.4).

![Figure 3: 3D Catia model design](image)
During the clutch operation mechanism tests, the first encountered problem was related to the handlebar fixture parts, which were under dimensioned and cracked under pressure. Also we had to modify the cable winder in order to support the forces. The black fixing part seen in figure 14 was redesigned to handle the required tensions. After remodelling these two parts, the clutch operating mechanism (fig.5) was successfully tested.

The prototype was further developed and the result was the optimized concept (fig.6). To operate the clutch, the final actuation solution was to use an electric motor and a steel cable. In this case, the engine fastener was comprised of four metal clamps with rubber clothing, two of them were fixed on the handlebar and two on the motor. The mount allows adjustment of an axis of rotation around the handlebar and straight to the handlebar profile. The steel cable that actuates the clutch lever was wound onto a roller with 55 mm diameter made of plastic printed at 3D printer.
Gearshift mechanism development

For the development of the gearshift mechanism we organised several brainstorming sessions in order to identify specific mechanism ideas for gear shifter operation. After the brainstorming meetings, we have come up with the next concepts:

- operation using a hydraulic/pneumatic piston and electro valves;
- operation using a linear solenoid;
- operation using an actuator;
- operation using a DC motor which engages a rack mounted on the gear shifter’s shaft.

After determining the forces necessary to actuate the gearshift lever we had to eliminate the mechanical incompatible solutions as follows:

- Operation using a hydraulic piston actioned by electro valves. Solution unfeasible due to the complexity of the operating mechanism and the high costs that it implies;
- Operation using a DC motor which engages a gear mounted on the gear shifter’s shaft. Solution unfeasible because of the high rotation speed necessary to change gears. For this speed is difficult to obtain the required torque of 30Nm from our DC motor. At the same time, this solution requires a fabricated cogwheel compatible with the gear shifter’s shaft which has a very fine groove. Another disadvantage is the DC motor control;
- Operation using an actuator. Solution unfeasible due to the low speed that the actuator can generate. Although we performed a market research, we have not found any linear actuators to provide the necessary speed for changing gears;
- Operation using a linear solenoid. This solution is also present in most of the commercial systems presented previously in the paper. To find a bidirectional solenoid to fit our requirements, we contacted some providers and we encountered the following problems: prices too high, solenoid not sold separately, being already a part of commercial kits or we could not find any compatible solenoids on the market.

To solve this problem we decided to use a DC motor for operating the gear shifter’s shaft using a fork shaped rod with a keyhole profile. The fork part is fixed on the gear shifter’s lever and the other end on the output shaft of the reducer attached to the DC motor (fig. 7).
The development of the parts for the gear shift mechanism started with the gear shift rod which suffered several changes in design due to the problems that have been signalised during the tests. The first rod model snapped (its fork broke) after successive tests in which we tried to suddenly change the gears, because we exceeded the maximum tension limit of the material we used to make the rod and because of its design.

We improved the rod’s design by adding material in the tensioned zones. We have also performed a FEA (finite element analysis) on the 3D model of this rod in order to verify if the fork withstands the required force (fig. 8).

Due to a delamination in the additive manufacturing process, the second rod prototype had also failed, but in a different place. The breaking point of the second prototype confirmed the FEA which indicated that the maximum tension in this rod was around the keyhole profile (fig. 9).
The third prototype for the gear shifting rod passed the FEA (fig.10) and had also behaved well during the physical tests. The improvements brought to this prototype were: increase radius for the fork section, rotate the keyhole profile and an increase in the wall thickness.

During the next stages we developed the DC motor fixture which was also 3D printed and the first prototype passed the physical tests. The issue with this fixture was that it didn’t offer enough rigidity for the mechanism and the gear change became imprecise. The solution was to add an extra part to the mechanism which was fixed to the motorcycle’s frame. Another fixing part was designed to prevent the motor from spinning in the fixture (fig.11).

The next step for improving this prototype was to change the fixtures from the 3D printed plastic to metal ones. For the optimized concept (fig.12), we kept the original lever control of the motorcycle. The most stressed element from the fastener system is the electric motor support, which must carry a relative big weight. The electric motor support is also strained by the torsional forces that are generated when the shift lever is actuated. For these reasons, in the final version we developed and
implemented a fastening system comprised of a L-shaped piece of metal having a thickness of 2.5 mm with stiffening rib. For fixing the electric motor we used metal clamps with rubber clothing. We connected the metal clamps with the L-shaped support through 2 screws M8x85. The screws fixing were carried out so as to be possible to adjust the position of the motor to the rotation axis by moving on the vertical axis. The method of clamps fixing also allowed the adjustment along the horizontal axis. The fastening was performed on the motorcycle in available positions using three screws (1 screw M8x50 (and two screws M4x40. Because the shift lever control withstood the tests, it wasn’t replaced.

![Figure 12: Gearshift actuator and fastener system – optimized concept](image)

**DISCUSSION**

None of the advanced solutions received validation from the first trial. Each of them needed to pass repeated tests and received various optimizations, as far as the design and the materials used were concerned. The fact that the motorcycle subjected to our actions was a second hand one posed additional challenges since the functionality of its systems was not comparable to those of a new motorcycle.

Each stage of the project was supervised and approved by the beneficiary (Continental Automotive Systems), our team being in a permanent constructive and reciprocally fair collaboration with this company.

**CONCLUSIONS**

This paper presents a solid example of good practices for the collaboration between academia and industry. This partnership comes with benefits and advantages for all the involved parties. For the industrial environment the main benefit it the possibility of using the results of research activities aimed at developing new products and services at low costs. For the academia the benefits come from the opportunity of connecting the theory with practice and of providing its staff and students with experiences useful for their personal and professional development.

During the realization of this project we have encountered some administrative obstacles concerning the acquisition process of the components necessary for the activities within the project. These obstacles resulted in certain delays in the achievement of the established objectives. We appreciate that this kind of obstacles are solvable and it is in the interest of every involved party to find the proper solutions so as further collaborations would function in a more efficient and faster manner.
Following the finalization of the above described project, we have received propositions for more future collaborations in this area, which represents for us a strong signal that these kind of joined activities are beneficial and appreciated and should be considered more in the future.

ACKNOWLEDGEMENT
The research leading to these results has been supported by a research contract from Continental Automotive Systems Sibiu, Contract no. C-1028 from 17.10.2016.

REFERENCES

Appleyard, D., (2017). Mind the gap: A bridge between industry and academia. *Renewable Energy Focus*, 18, 36-38.

Neghină, M., Petruse, R. E., Olteanu, S., Bondrea, I., Lobonț L., and Stanciu, G. (2017). Robotized semiautomatic motorcycle transmission development. Electronic and software design, *MATEC Web Conf.*, 121 (2017) 06007 (https://doi.org/10.1051/matecconf/201712106007)

Sosnowski, J., (2014). Precipitating innovations by academia and industry feedback. *Procedia–Social and Behavioral Sciences*, 109, pp. 113-119.