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Future Clutch Actuation and Control for HEV powertrains – Requirements and System Definition (a prestudy)



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Short about FFI

FFI is a partnership between the state and the automotive industry to jointly finance research, innovation and development activities focused on the areas of Climate & Environment and Security. Investment means business for approximately SEK 1 billion per year, of which the public funds constitutes 50%. Currently there are five sub-programs Energy & Environment, Vehicle and Traffic Safety, Vehicle Development, Sustainable Production and Transport Efficiency. Read more on www.vinnova.se/ffi

1. Summary

This pre-study (WP1 in application 2014-03945) was made by Kongsberg Automotive AB and Vicura AB during the period 141015-150601. With the increasing penetration of hybrid cars (HEVs), new sets of requirements for automated clutch actuation systems and their suppliers are emerging, thereby leading to a number of knowledge and technology gaps. In order to lower the barriers for hybridization of vehicles, it is necessary to address above mentioned knowledge and technology gaps. The gaps associated with automated clutch actuation are targeted for closure/reduction in the project "Future Clutch Actuation and Control for HEV Powertrains" coordinated by Kongsberg Automotive AB. This report covers opening work package within this project which is focused on requirement analysis and system definition.

An overview of clutch systems in conventional and hybrid systems is made followed by an overview of hybrid systems including examples from current production and development work. The examples are compared and it is observed that parallel hybrid systems transmissions in production in general are realized as hybridized versions of conventional transmissions by means of adding a parallel electric drive. The general features and functions of future hybrid systems are discussed. The Vicura EREV Concept is used to exemplify these features and functionalities and is presented in detail. Clutch systems functionality and requirements are described followed by a compilation of requirements for the Vicura EREV concept clutch system and a system definition. The clutch considered as reference clutch for the Vicura EREV Concept is a dry single disc clutch with inner diameter 134-146 mm, and outer diameter 205-216 mm. Maximum release load values are in the range of 1400-2000N. Typical release travel is around 10 mm. The clutch actuation is served by an electric power source which can be either from the low-voltage system or the high-voltage system. The actuation considered is primarily either electrohydraulic or electromechanical. In the latter case the motor can be located concentrically, on the housing, or in between. Other arrangements may be considered as well.

The share of hybrids solutions on the market is expected to grow rapidly within the near future and they will be important for considerable time until EV technology has penetrated all segments. One reason for the relatively low share of hybrid vehicle today is the lack of alternatives in the segments with the largest volumes, the B- and C-segment, and that the vehicle functionality is limited which prevents single-car households to replace their conventional vehicle.

With this as a background we see that an automated clutch actuation in a cost effective hybrid transmission system for mid-sized vehicles has a market potential for the future. The system shall offer similar performance and functionality as a conventional vehicle, and be integrated in an existing vehicle.

2. Background

Kongsberg Automotive AB, Vicura AB and Linköping University applied for FFI-funding Sep 2014, to do a common research project within the area of clutch actuation and control for HEV powertrains. The WP1 was approved, meaning doing a pre-study. Since Linköping University not was included in this first WP, Kongsberg Automotive AB and Vicura AB made this investigation themselves during the period of 141015-150601. This pre-study includes requirements and system definition for a future clutch actuation and control for HEV powertrain.

Increasing penetration of Hybrid Electric Vehicles (HEVs) is changing the landscape and introducing new and stricter demands on existing powertrain subsystems, as well as acting as an enabler for introduction of new technology. One powertrain subsystem subject to such change is automated clutch actuation and, as a consequence, a number of knowledge and technology gaps have been identified (cost, integration density, system integration and control theory/engineering, transduction technology and power architecture, performance and durability, safety and availability).

A key trend observed in the automotive industry over the last decades is the replacement of traditional control systems based on mechanical or basic electrical interfaces with mechatronic systems involving e.g. electromechanical transducers and sophisticated electronic control systems integrated with human machine interfaces (HMIs). The progression of this technology has, until recently, been primarily driven by increasingly advanced implementations in conventional passenger vehicles with correspondingly conventional powertrains.

In particular, one technology subject to changing demands due to this paradigm shift is automated clutch actuation. Originally, development of automated clutch actuation was driven primarily by the introduction of transmissions complementing traditional manual and automatic transmissions (MT and AT), primarily the Automated Manual Transmission (AMT) and Dual Clutch Transmission (DCT). However, with the increasing penetration of HEVs, new sets of requirements for clutch actuation systems

and their suppliers are emerging, thereby leading to a number of knowledge and technology gaps.

In order to lower the barriers for hybridization of vehicles, it is necessary to address above mentioned knowledge and technology gaps in automated clutch actuation; gaps which are targeted for closure/reduction in the project "Future Clutch Actuation and Control for HEV Powertrains" coordinated by Kongsberg Automotive AB.

3. Purpose

The main purposes with the project "Future clutch actuation and control for HEV powertrain" were to close knowledge and technology gaps related to the new demands with the increasing penetration of Hybrid Electrical Vehicles at the market, and to act as an enabler for introducing new technology.

The purpose with this pre-study (WP1) was to investigate and analyze future requirements for a clutch actuation, and perform a system definition.

4. Implementation

Since this is only a pre-study, the implementation is mainly related to go further with the findings and go into a concept development phase.

The pre-study was made by Kongsberg Automotive and Vicura. The first part was to go through literature and available information from competitors within the field, and look into how they have done. Also a comparison and a gap analysis were done. With the Vicura EREV concept as a reference we also went through the clutch control functions and requirements, also including a small part with the shift and control functions and requirements. Finally we made a system definition for a future clutch actuator, and lined up some conclusions and the potential for the future.

5. Results

5.1 Contribution to the FFI-goals

This pre-study supports the goals to introduce new technology to reduce emissions and to close these knowledge and technology gaps related to an increasing market penetration of hybrid cars and such technology. It also supports to strengthen the Swedish automotive industry and the collaboration between academy, tier 1 and SME.

6. Dissemination and publicaiton

6.1 Transfer of knowledge and dissemination of results

This is still a pre-study, and the results can be used for further development of a concept. The increasing penetration of EV and HEV/PHEV cars may make this even more urgent to find cost effective solutions for midsize hybrid cars.

6.2 Publications

Nothing is published yet within this pre-study project.

However, even if we didn't got any funding for the other WP's yet where Linköping University should attend and contribute, we have a thesis work on-going in parallel to this pre-study. This thesis work is still on-going while I write this. The thesis work name is "Modeling and control of a parallel HEV powertrain with focus on the clutch", and the thesis worker is Mahdi Morsali.

7. Conclusions and future research

One of the keys to reach an increased penetration for hybrid solutions in the automotive market is to be able to offer efficient, affordable, and capable hybrid systems. For future hybrids these are also benchmarking criteria. To be able to provide efficient and inexpensive solutions all sub-systems and components must be adapted and optimized for their particular functions.

A strategy to achieve affordable hybrids with significant emission reduction could be formulated as follows:

1. Start out from a powertrain concept that has the potential to be less expensive and that already has reasonably low emissions.
2. Choose a hybrid transmission concept that has the potential to be less expensive by exploiting the potential of the combination of ICE and EM to and reduce redundant functions.
3. Exploit the potential with fewer parts, less weight, and automation to reduce the weight and cost for the clutch and actuation hardware. Add functionality by means of controls rather than by adding components



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This calls for research and development activities to support development within this area and for point three above in particular. For clutch systems both hardware and controls are areas where the dimensioning criteria and functional requirements are changed. This opens up possibilities for downsizing and for new actuation concepts. There is also a potential to exploit the clutch and its actuation for new functions since automated actuation is an integral part of the hybrid transmission concept. Further down the line, as these systems are implemented in demonstrator vehicles and test vehicles new integration phenomena will most probably also be uncovered.

To conclude, the requirements and functions for future clutch actuation in parallel HEV powertrains differ from those of conventional powertrains. This is valid for thermal properties, strength, durability, size, actuation performance, and also for the electronic control. Considerable work is therefore required to develop and obtain clutches and clutch actuation systems that are optimal with respect to function, weight, cost, and efficiency.

8. Participating parties and contact persons

Participating parties in this pre-study have been Kongsberg Automotive AB and Vicura AB.

Contactpersons from Kongsberg Automotive are Henrik Nilsson and Bengt Cyrén

And the contactpersons from Vicura are Martin Johansson and Mikael Mohlin

