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Developments in Automated Clutch Management Systems

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ABSTRACT

Since the very beginning of the automotive era the industry has tried to automate control of the clutch. Until very recently such control was impossible. Intensive use of new system simulation tools combined with the latest developments in electronics now allow the realisation of comfortable and reliable automated clutch systems at an affordable price. This paper describes clutch system requirements, their realisation through a close co-operation between system, hardware and software engineering, as well as field test results.

1. INTRODUCTION

The vast majority of European cars are equipped with manually operated gearboxes. When asked, customers indicate they prefer manual shifting to automatic gearbox control because of the lower cost of manuals and also because of the feeling of having complete control of the car in the dense and nervous European traffic. On the other hand most people also admit that in traffic jams operating the clutch requires an important effort and may divert their attention from the traffic.

From the opinions above and from the car industry's tendency to continuously enhance the driver's comfort, we can conclude that automatic Clutch Management Systems (CMS) will have a bright future provided such systems combine reliability and low cost with control strategies that insure very comfortable and safe shifting. Since the invention of gearboxes various systems have been invented and even been produced, yet the existing technology did not allow to satisfy the above conditions for success.

operated directly by the driver where in the last ten years most other car functions have seen the introduction of electronic control in replacement of either driver operation or mechanical control. Electronic control in general enhances comfort (e.g. remote access control), safety (e.g. ABS) or increases performance (e.g. electronic engine management or automatic gearbox control) and should therefore naturally be applied to the cumbersome clutches. Absence of electronic control until now is mainly due to the fact that, although the replacement of the driver's left foot seems fairly straightforward, automatic clutch control requires rather sophisticated control strategies and therefore high end electronics. Only recently has the evolution of technology allowed an automatic clutch control to be offered at a reasonable cost. This paper describes an automatic clutch management system (CMS) which is the result of the combination of more than ten years of control strategy development and up to date electronic technology.

2. ADVANTAGES OF CMS

CMS offers advantages to both the driver as well as to the car manufacturer.

From the driver's point of view the first and most obvious advantage is the increase of comfort due to 2 pedal operation. CMS takes away the stress of continuous clutch operation (clutches require forces up to 250 N) in city start-stop traffic; it facilitates hill starts as well as parking in tight spaces and it improves handling of the car at low speeds. In addition high end CMS offer the possibility of limited yet tightly controlled slip to reduce low speed driveline noise and vibration. Both easier operation as well as a quieter environment favorably impact safety.

in many fields such as price, fuel economy, quick response and engine braking. CMS also offers the absence of creeping and the satisfaction of the driver to be in control by determining himself his gear switch points.

To the car manufacturer CMS offers first of all a competitive advantage due to customer satisfaction. In addition CMS eliminates drive train stress due to rather frequent mishandling of the clutch by the average driver. Reduced drive train stress translates into both a potential down sizing of the gearbox and drive train as well as a reduction in warranty costs. In normal driving conditions the precision and the speed of electronic control leads to lower clutch wear than with the average human driver. For this reason CMS can use controlled slip to reduce noise and still comply with clutch wear standards. This has been proven by tests on cars as well as on durability benches.

3. PREVENTION OF NOISE AND VIBRATION

As already indicated, in addition to its main function, CMS can be used to improve noise and vibration levels. Various types of noise can be distinguished :

1. jerk :
when driving in 1st or 2nd gear at very low speed at very low throttle and an engine operating close to idle, the car may jerk ahead on light tip-ins and eventually oscillate close to 1 Hz.
The introduction of limited controlled slip prevents this very uncomfortable situation.

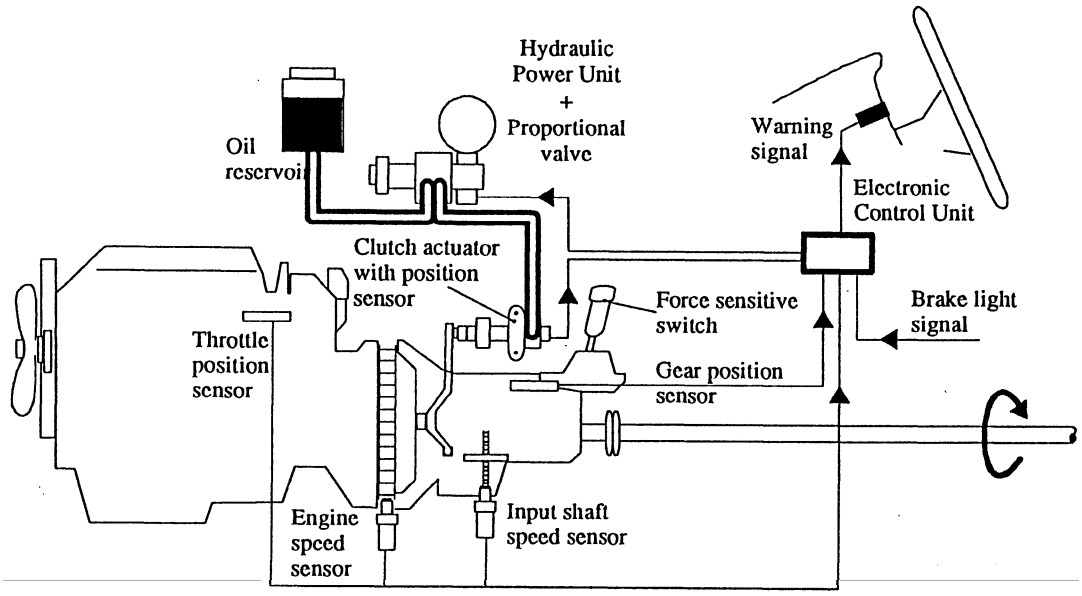
2. shunt (tip in -tip out clunk) :
Due to backlash in the driveline, a sharp bang or clunk is heard and felt when the driver lifts his foot off the gas pedal and then presses it down again while the clutch is fully engaged thus causing drive line torque to change directions.
A responsive Clutch Management System can eliminate shunt through quick disengagement of the clutch at the moment the torque direction inverts.

3. booming :
When driving at high power in a high gear at low engine RPM, torque spikes from the engine generate audible resonances in the passenger compartment.
A precise Clutch Management System can prevent booming by precisely controlling a relative slip between 50 and 100 RPM.

4. idle rattle :
When the clutch is engaged in idle with the gearbox in neutral, torque spikes from the engine may generate resonance frequencies in the gearbox.
CMS easily prevents this by opening the clutch.

5. gearbox rattle :
At high loads at 1200-2500 RPM in 2nd or 3rd gear, the gearbox may generate a rattling noise when the oil is hot.
Gearbox rattle can be eliminated by a relative slip between 50 and 100 RPM provided the Clutch Management System is precise enough to control this slip accurately.

Responsiveness and precision are key to noise prevention; these parameters require high processing power, and therefore directly determine the system architecture of a high end Clutch Management System.



4. CLUTCH MANAGEMENT SYSTEM SET-UP

All CMS systems basically consist of (see synoptic diagram in figure 1) :

- sensors reading both driver intention and the current status of clutch and gearbox
- a clutch actuator
- an electronic control unit (ECU)

One of the main difficulties of CMS is that the system cannot anticipate driver intention; it only detects the driver wants to shift gears, when he starts operating the shift lever or releasing the gas pedal. The detection strategies must therefore be very fast, yet they must also avoid unintentional opening of the clutch for instance when the driver plays with the lever while driving normally. As soon as the intention to shift gears has been recognised the system must open the clutch as fast as possible to avoid the driver feeling resistance when he starts moving the lever. On the other hand, it must not open so fast that the sudden release of tension in the drive line will cause a shock. Once the gearshift has taken place, CMS must close the clutch again in a controlled manner. Especially at low speeds operating comfort is dramatically enhanced when the Clutch Management System is set-up to offer the possibility of precisely controlled slip in this phase of operation.

Speed and precision are thus the key parameters for the clutch actuator. Hydraulic systems outperform electric actuators because they allow slow building of pressure in an accumulator that will instantly deliver the power required for fast shifting. Opposite to electric actuators, hydraulic systems also offer an inherent safety feature since the accumulator load can deliver the energy for several clutch activations independent of the power source. To be noted that the hydraulic power source can eventually be shared with ABS or power steering reducing the CMS system cost.

The objective of our development being a clutch management system with a high performance / cost ratio, a hydraulic actuator was an obvious choice. This choice implied also the need for high performance wide bandwidth electronics and therefore an in depth analysis and simulation of the system to insure optimum performance and stability. More details on all these items will be presented in the next sections.

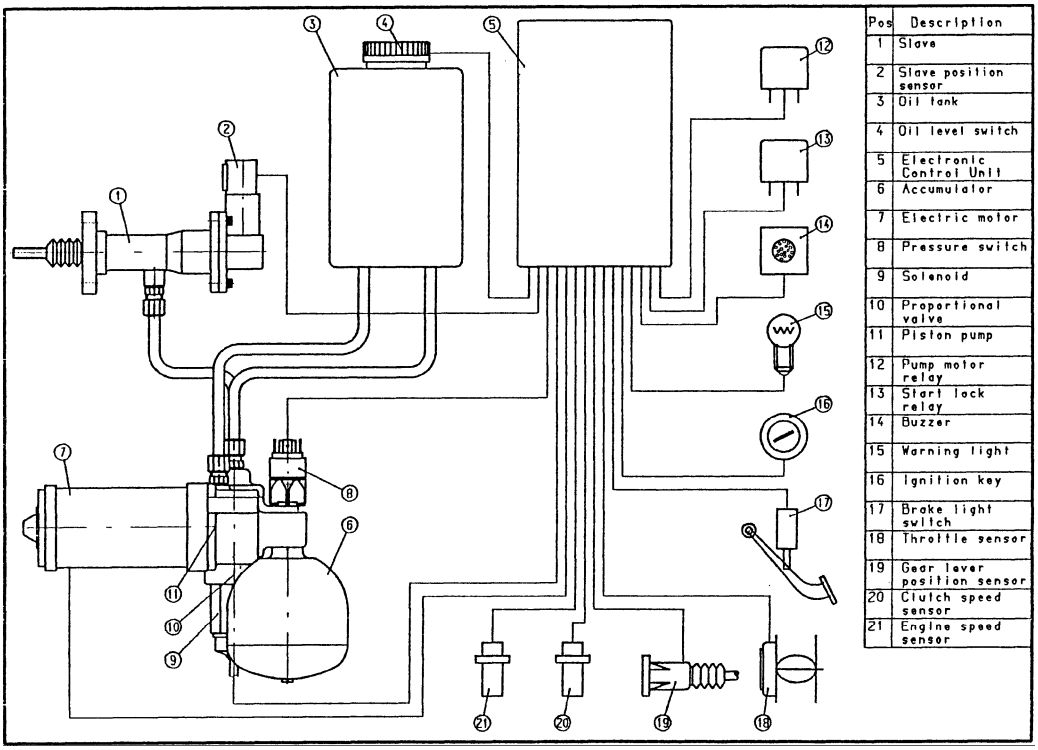


figure 2 : CMS SYSTEM LAYOUT

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