Smoother control using robotics

Requirements for vehicle drivetrains are constantly increasing, especially with regard to the comfortable start-up of vehicles with manual clutches. In order to efficiently analyze the clutch characteristics (clutch engagement and start-up characteristics) and to be able to reproduce these results, Porsche Engineering has developed a unique clutch robot in collaboration with the Münster University of Applied Sciences (Automation and Robotics department).

Robotic systems have been used in vehicle pedal operation testing for some time now. The existing systems present various problems, however. Because they require external sources of power and lots of space for their computer hardware, in most cases they are used only to simulate distance profiles on roller dynamometer test stands. Using these systems for vehicles actually driving outdoors is basically impossible. Furthermore, only open-loop control but not closed-loop control is possible for these systems, and the pedals cannot be positioned precisely so that conditions can be reproduced. They are therefore not very useful for the analysis of clutch engagement characteristics. For this reason,

Optimum analysis of clutch characteristics

Requirements

- Compact setup for the hardware and the power source, so that the system can also be used in vehicles without much space in the interior
- Simple assembly of the system without having to modify the seat or the driver's footwell in all vehicle classes
- Logging of variables to be measured in real time
- Logging of pedal positions independently of the dynamics of the driver's seat
- Definition of the pressure placed on the pedal independently of the position of the robot
- Operation of all three pedals by the robot
- Highly dynamic processes that can be reproduced exactly (e.g. snap starts/racing starts)

Porsche Engineering has developed a new clutch robot that solves these problems (an overview of the requirements it had to meet is shown in the information box above).

Hardware configuration

The main unit of the clutch robot consists of aluminum plates, which can be modified to fit the shape of the driver's seat and the interior of the vehicle. In the main unit, three independent, closed-loop controllable linear motors are used to operate the three pedals.

The motors are connected to the pedals via adapter plates and a coupling bar that can be adjusted in length, and the pressure on the pedals is measured by a load cell integrated into the coupling bar. The pedal position is detected by cable pull sensors, which are fixed firmly in the footwell of the driver's seat and can therefore be used for position control without influence by the seating dynamics.

After the main unit has been fitted in the vehicle, a head unit is mounted on top of it. The three motors are then connected directly to the head unit via a docking connecter, so that there is no need for extra cables when setting up the robot in the vehicle. The controllers for the motors, and the computer system with a real time operating system (RTOS) and sensor signal processing, are located in the head unit. The external sensors, such as the cable pull sensors or the vehicle CAN bus, can be connected to the system with standard connecters.

Power is provided by a separate block and is connected to the head unit via a cable. This set-up makes it possible to position the power supply anywhere in the vehicle. Because the whole system is separated into three components (see figure on page 32) – the main unit, the head unit and the power unit – it can be transported easily and installed in the vehicle quickly.

The clutch robot is linked to the user operator laptop by an Ethernet interface and is operated simply via an easy-to-use user interface.

Adjusting the position

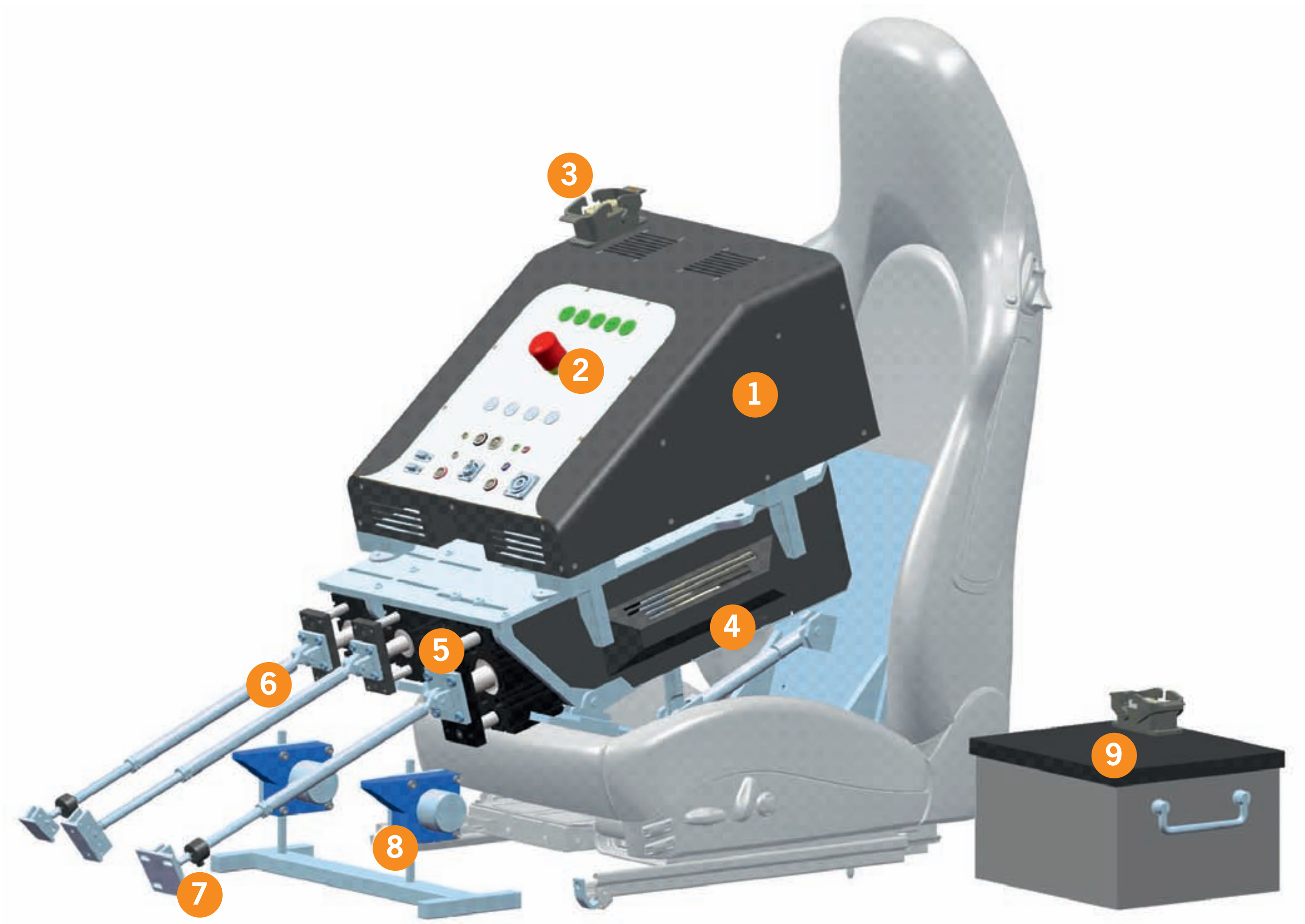
The cable pull sensor first detects the current position of the clutch pedal. Based on the current position and the target position, the controller implemented in the RTOS calculates the correcting variable for the linear motor. The implemented controller must be precise and extremely stable throughout the whole application area. Different driver's seats in particular make the setup of the controller more difficult in this regard. In sports cars the seats are generally very firm, while in small cars they are generally softer. In order to take the varying dynamics of driver's seats into account, various components have been added to the PI controller. The controller is therefore completely stable throughout the whole area of application, and there is no need for the user to modify it any further.

Areas of application

Various testing processes can be carried out with the clutch robot. The following three kinds of tests are the most important applications:

- Pedal pressure measurement
- Start-up testing
- Stall testing

With the aid of powerful analysis software, at the start of testing, the user

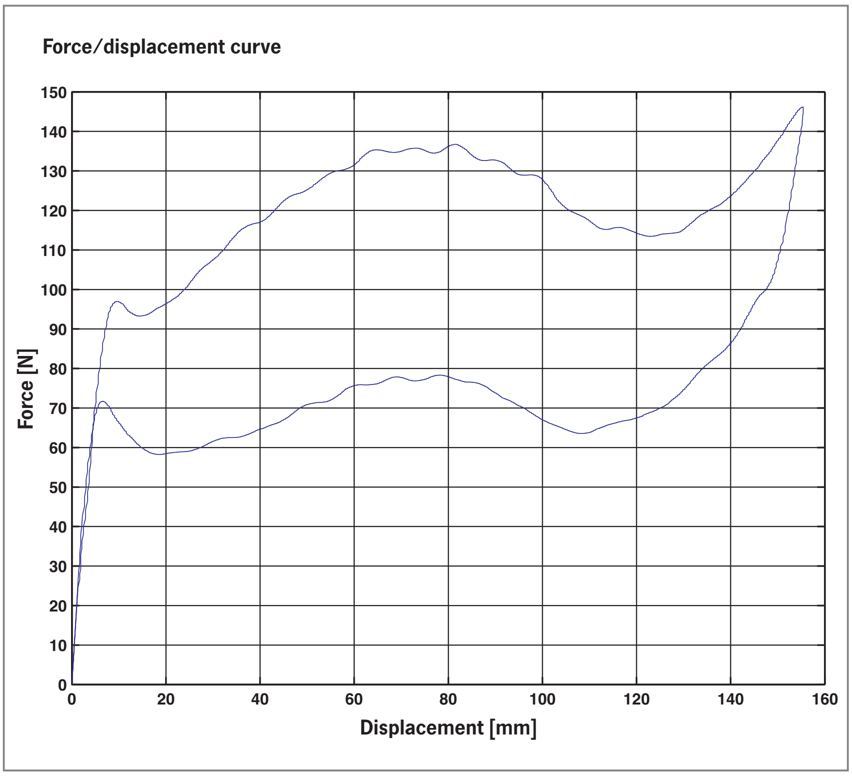


Design of the clutch robot:
1. Head unit
2. Connection panel
3. Connection to power supply
4. Main unit
5. Linear motors
6. Coupling bars
7. Load cell
8. Cable pull sensors
9. Power supply

can choose which correcting variables should be saved in a measurement file by the system with up to 1 kHz. The user also has the option to directly connect external temperature sensors to the system. There are also interfaces with the vehicle CAN bus and/or with CAN-based measurement systems. Data collection is carried out by the robotic system itself, and the recorded data can be uploaded to the user PC after the test has been carried out, in order to visually illustrate and evaluate the results. A live readout of the test enables the testing engineer to carry out an initial evaluation of the measurements while the test is still going on.

Pedal pressure measurement

During the pedal pressure measurement test, the pressure placed on the clutch pedal and the pedal travel are recorded. Before the test begins, the combustion engine speed can be set to the desired number of revolutions via the clutch robot. The clutch pedal is then pressed down fully and subsequently brought back to its starting position. The number of test repetitions



Analysis software enables a preliminary assessment during the pedal pressure test

Pedal pressure measurement

as well as the speed of pedal operation can be selected by the user. The result consists of curve graphs depicting pedal pressure in relation to combustion engine speed.

Start-up testing

The aim of the start-up test is to measure the clutch engagement limit speed. What is meant by this is the maximum speed with which the clutch pedal can be operated, and at which starting up the vehicle is still safe.

Before the test starts, the clutch pedal is pressed down completely. Then the user can set the desired combustion engine speed. The accelerator pedal is kept in a constant position by the clutch robot during the entire test. The clutch engagement speed during vehicle start-up is then varied.

The brake pedal can also be set at a desired position in order to prevent the movement of the vehicle before the test begins or to simulate vehicle start-up in relation to braking power. Depending on the set-up of the test, the brakes can be automatically released before the clutch pedal engages at a previously defined, constant speed. After the test has finished, the robot disengages and the accelerator pedal returns to the idle position. Because the tests can be reproduced in different vehicles, objective comparisons can be made between them.

Stall testing

Stall testing is similar to the vehicle start-up test, although here the vehicle is fixed in position with a tow bar. The objective of this test is to establish the drive dynamics and the stability of the engine control unit in relation to the engagement characteristics of the clutch. The tractive power is recorded by the elaborate robotic system. The behavior of the engine is recorded at variable clutch engagement speeds, all the way down to standstill.

Conclusion

With the new clutch robot, the engineers at Porsche Engineering have developed a system that intelligently meets a number of current challenges: the system has an integrated source of power, which can be fed from the vehicle power circuit or can be supplied with electricity by an independent battery pack. This makes it possible to carry out tests on vehicles driving outdoors. Measurement data collection is carried out by the robot itself. The simple setup and removal of the robot does not require the removal of any vehicle components. This enables benchmark testing in several vehicles within a very short period of time. Finally, by utilizing its own sensors and carrying out its own data collection, no additional measurement processes are required – the clutch robot therefore significantly simplifies testing the functions of manually operated clutches in vehicles.

Philipp Kamping, Johannes Aehling, Dr. Jan-Peter Müller-Kose