DIN - DEPARTMENT OF INDUSTRIAL ENGINEERING

PhD Course in Mechanics and Advanced Engineering Sciences (DIMSAI)

PHD STUDENT POSTER - AY *2016/2017* Curriculum number *2* Cycle *XXXI*

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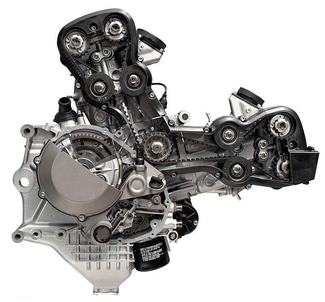
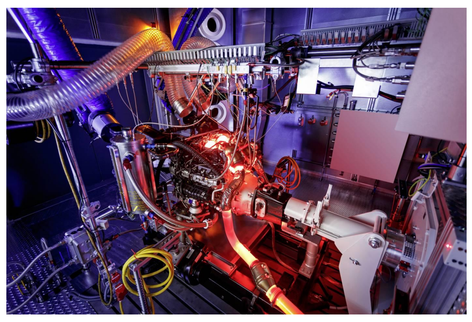
Development of systems for automated engine testing



Ducati two cylinders engine



Engine test bench

Nowadays complex mechanical solutions coupled with a massive use of electronic components are used to realize smart engines, capable of adapting to any operating condition to meet the requirements of the driver, offering the best performance and the most comfortable driving experience. Such a complexity of engineering and on board electronic parts involves a relevant phase of test and calibration activity. The test bench plays a key role during this process, offering the opportunity to collect a large amount of data carrying out several types of tests. Many factors can affect results in terms of performance, emissions and component reliability. So, to achieve the best accuracy and repeatability during tests, the test bed management system considers a high level of automation:

- To manage several conditioning systems of the test bench (such as oil, water and intake air temperature, air humidity, etc.) in order to maintain controlled variables on target during tests.
- To provide the ECU with all the signals necessary to make the engine work properly in the desidered operating condition.

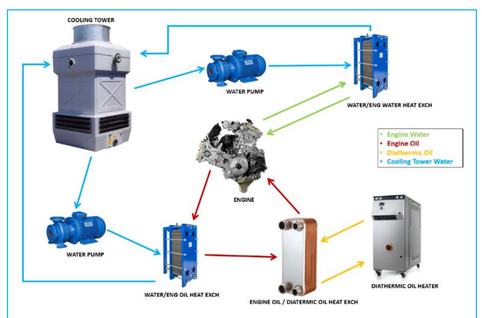
This work presents the development of the automation system of a test bench, implemented on an open software Real-Time compatible platform, allowing the integration of the conditioning systems control with all other functionalities concerning the test management.

Centralized Model-Based Test Bench Conditioning Systems Control

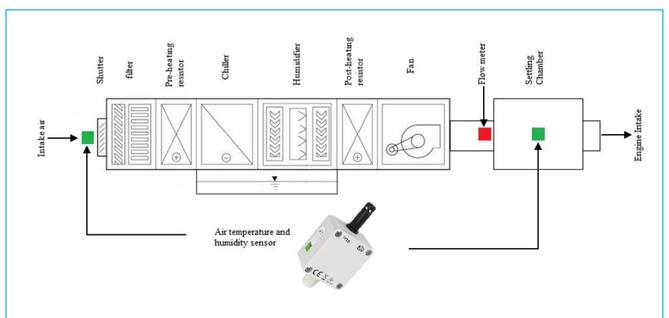
Implementation of NI Labview models, integrated in the test bench management software, to control:

- *Intake air temperature and humidity,* managing a HVAC (Heating Ventilating and Air Conditioning) System, equipped with a chiller, resistors and a steam generator.
- *Engine oil temperature*, managing, through a pump, the cooling tower water flow rate that perform an heat removal from the motor oil inside a plate heat exchanger; moreover, managing an heater that control the temperature of diathermic oil, it is possible to transfer heat to or from the motor oil into a second heat exchanger.
- *Engine water temperature*, managing, through a pump, the cooling tower water flow rate that perform an heat removal from the engine coolant water inside a plate heat exchanger.

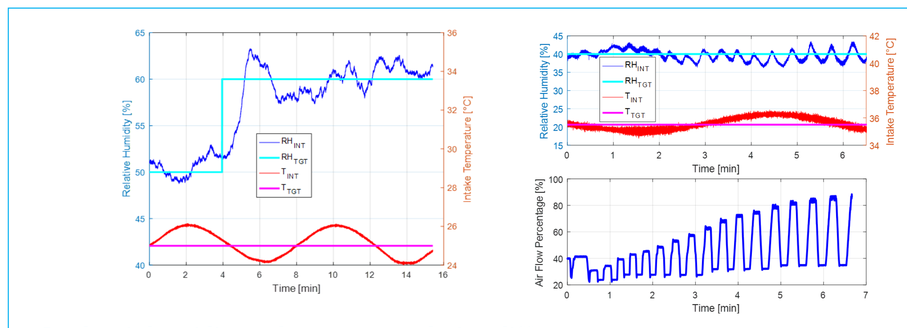
Each actuator control setting is determined coupling model-based open loop contribution, and a closed loop PID contribution.
The open loop control is based on a physical heat e.xchange model between the fluid in exam and the specific plant element to be controlled, while the closed loop part is based on the difference between target and measured conditions of the specific fluid.
The advantage of a centralized control of several actuators is that the control actions can be coordinated, avoiding conflicts between component actions.
Developed control models have been integrated into a test bed management software, running on a Real-Time platform. In this way, it has been possible to validate conditioning systems control methodology on a test bed, by performing intake air, engine oil and engine water conditioning tests, both making the engine work in steady conditions and in very unsteady conditions, feeding the model inputs with the test bench sensors outputs



Oil and water plants layout



Scheme of the HVAC system and sensors layout



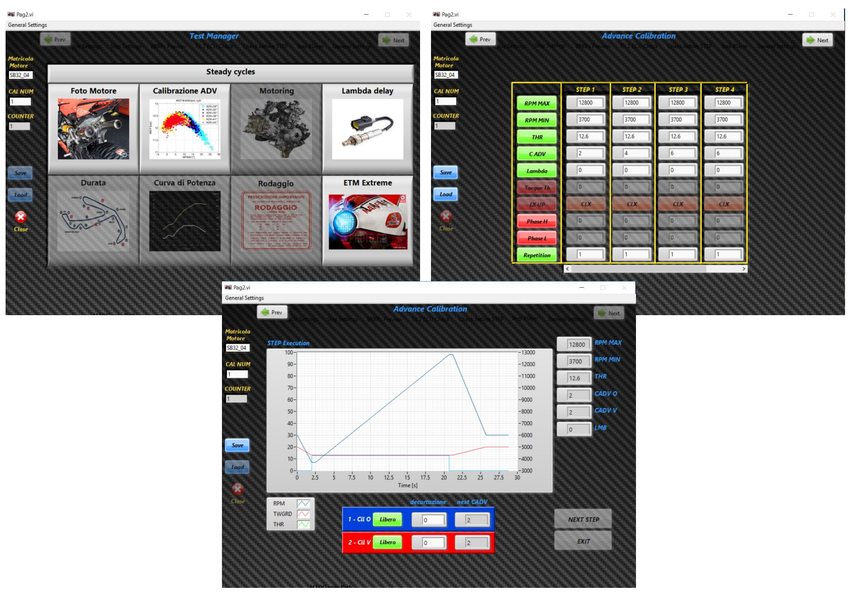
Intake air humidity and temperature during different tests:
- Target humidity transient with fixed temperature and air flow rate (left figure)
- Temperature and humidity target maintenance with higly variable flow rate (right figure)

Custom automation manager tool

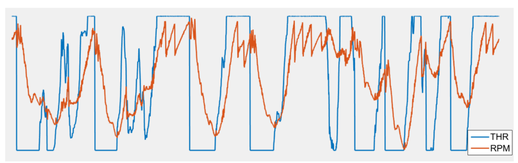
Development of an automation management tool, that helps test bed operator to perform quikly, in safe conditions and, most of all several type of tests, quikly
Possible purpose of the tool:

- *Perform data telemetry replay to carry out racing condition simulation on the test bench.* The purpose is check components reliability and test control engine strategies implemented on the ECU.
- *Perform power curve* to detect engine performance in different operating conditions once a calibration of the engine management system has been established.
- *Perform calibration cycles*, that are simple sequences of ramp and steady of engine speed, managing the throttle and overwriting specific ECU signals, like spark advance, injection phase, air fuel ratio and all the other engine actuations overwritable via CAN protocol. These tests aim to highlight how the engine's behavior changes, playing with ECU's parameters, in order to establish for example the calibration that maximizes the performance but not only. Other possible purpose of these kind of tests could concern the study of strategic engine sensors dynamic response, such as lambda sensors.

The tool is developed in NI Labview and actually is a stand alone application that communicate run time with the test bench management software, developed in NI Veristand. However the application could be easily integrated into the test bed management software.



Automation management tool user interface



Data telemetry replay example

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