Use of automatic control techniques for internal combustion engines

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Fig. source: http://www.global-hydrogen-bus-platform.com/

The need for reducing the emissions and improving the efficiency in the internal combustion engines has led to research on new types of engines and new methods to control the development of the combustion. Automatic Control takes a very important role in order to achieve these objectives.

Internal combustion engines are widely used nowadays. One of the most common uses is the propulsion of vehicles. The vast number of cars that are being used these days make the emissions and the consumption of these engines to have a great impact on the environment. For this reason, research on new types of engines and on new ways to control the combustion is under development.

An internal combustion engine produces mechanical power from the chemical energy stored in the fuel and this energy is released by burning the fuel in a combustion chamber. Internal combustion engines can be classified by the ignition method. This classification leads to gasoline engines (where the mixture of fuel and air is ignited by spark) or diesel engines (where the mixture is self ignited by compression when the pressures in the cylinder are high enough). Gasoline engines have lower efficiency than diesel engines which leads to a higher consumption, but diesel engines have higher emissions, which leads to more contamination.

But, would it be possible to put the advantages of both engines together? New types of engines are under research to solve this question. HCCI (Homogeneous Charge Compression Ignition) engines join the best of each engine to get both, high efficiency and low emissions. Nevertheless, these types of engines are difficult to control, which makes them difficult to use. Another type of engine which is under research tries to solve this problem. PPC (Partially Premixed Combustion) engine lets an easier control while keeping good levels of efficiency and emissions. However, using automatic control techniques is required to control these new types of engines.

The controller used to control these types of engines is called MPC (Model Predictive Control). This controller can be tuned in several ways which let the user to give more importance to have higher efficiency or lower emissions. The controller also lets to keep the emissions level under a certain value. Nevertheless, to design an MPC controller, it is necessary to create a mathematical model of the engine. In order to obtain a model that behaves like the reality, system identification of the engine must be done.

One way to identify an engine is to use physical equations that describe the theoretical behavior of the engine. Among such equations are thermodynamic and geometric equations. Once the model has all the necessary equations, it is possible to simulate the engine and obtain data that can be compared with data extracted of the real engine to improve the mathematical model. When the model behaves close enough to the reality, the design of the MPC can begin.

Another way to create a mathematical model is to use data extracted from a real engine. With enough data, it is possible to deal with the engine as a black box where only the input and output data are known. Afterwards, it is possible to fit these data to some mathematical equations using different techniques. When the result is reasonable, the model obtained can be used to design the MPC. This method is simpler to use than the previous one, but the main disadvantage is that the quality of the obtained model is directly related with the quality of the data.

Once the most suitable model has been found, the MPC controller must be designed. One should define previously the desired behavior of the engine that must be accomplished. For example, the efficiency will be maximized and the emissions will be minimized. Nevertheless, the controller will have to trade-off these aspects. For this reason, many simulations should be done before application to the real engine.

The simulations that have been carried out show lots of conclusions that must be taken into account when working with the real engine. First of all, it has been demonstrated that these types of engines can be controlled by MPC controllers. The possibility of customizing the controller lets a wide variety of behaviors for each condition.

MPC is highly dependent on the mathematical model, which is also dependent on the data from which has been obtained. For this reason, special attention must be paid when obtaining the data that will be used.

An optimal working point that has been obtained from the simulations is a trade-off between high efficiency and low emissions. It has been found that it is easier to reduce the emissions without sacrificing engine power than to increase the efficiency. It is also possible to add an upper bound to emissions in order to keep those emissions below a certain level. Besides, with the MPC it is also possible to reduce the engine noise, if there is a mathematical model that describes it.

MPC controllers are complex controllers that need a considerable amount of time to compute the control signals that must be sent to the engine. In addition, the time available for the controller to compute the control signal depends on the speed of the engine. If the engine is running at higher speeds, the controller will have less time to perform calculations. For this reason, the time that the controller needs must be taken into consideration and the quality of the processor and the complexity of the controller must be chosen accordingly to these limitations.

In conclusion, new technologies let to increase efficiency and to decrease emissions by using automatic control techniques applied to internal combustion engines. Although these engines of tomorrow still are under research, great strides are being made and will be available in a near future.

References

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