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Modelling of Hybrid Plus Retrofit Hybrid System

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Abstract—**This paper focuses on addressing theoretical and practical considerations in developing a retrofit system for traditional internal combustion engine vehicle. Extensive simulation test results and theoretical analyses are presented and analyzed. Firstly, the basic theory of design is discussed in term of the market needs, target vehicle chosen, system components chosen, etc. A controller algorithm design is discussed in details. The performance test results are simulated later in several drive cycles. The results show that the retrofit kit can improve about 3% fuel consumption in a NEDC and 19% in a real world urban delivery drive cycle.**

Keywords: mild hybrid, HEV, CVT, matlab/Simulink

I. INTRODUCTION

Nowadays, energy consumption and CO2 emissions of road transport are the main issues amongst all impacts. CO2 emissions threaten the world with climate-change. The increasing demand and the tight supply for oil is the problem every country need to face in the next decade, many research believe that the demand for oil will exceed the production capability (Figure 1) [1] Oil reserves will run short within the near future, experts are just arguing about the time. How to maintain the energy supply to catch up with the increase demand become an on-going concern and a high priority.

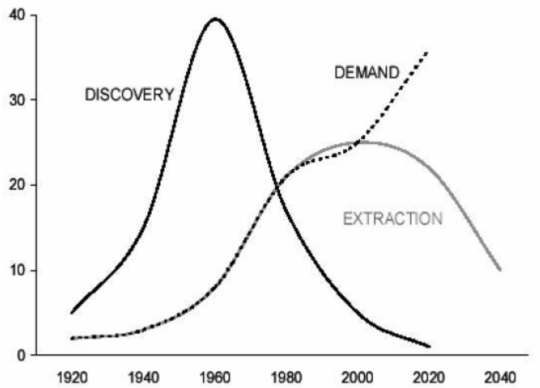


Figure.1 Actual and projected worldwide discovery, extraction and demand for conventional oil (From 1920 to 2040 in billions of barrels). [1]

The transport energy consumption takes a significant part of the oil consumption worldwide and it is continue to rise rapidly. In 2000 it was 25% higher than in 1990 and it is projected to grow by 90% between 2000 and 2030 as shown in Figure 2.[2]

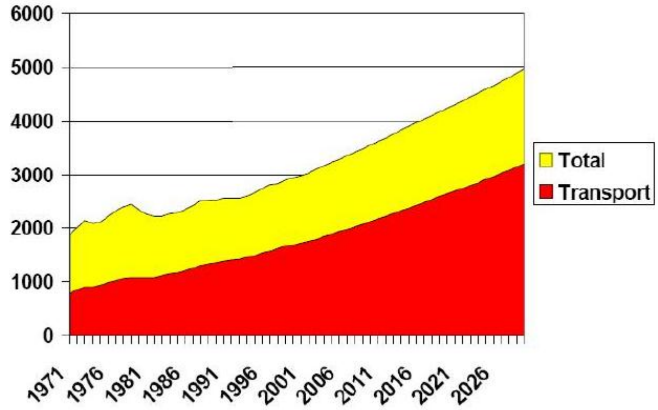


Figure. 2 Globe Oil Consumption Perspective. [2]

Some researchers indicate that Sweden and the UK are large potential markets of the HEV due to the potential energy savings and also California by the exceptionally high incentives. [3] Also the use of HEVs depends on the legislation which either increases the fuel cost or mandates high fuel economy. As a result, France and the UK are good potential markets because of the high fuel price.[4] The Daily Telegraph reported in February 2005 that "The value of home delivery has risen to £36.8bn in 2004, the story continued, with one-seventh of all spending in the retail sector now on items delivered to door". More and more big retail companies offering the online shopping and home delivery services. This door to door shopping saved a lot of time and money for customers. The accelerating growth of the new retail pattern means that a new pattern of usage needs to be checked. This new pattern of usage of delivery vehicle, door-door and start-stop all the time, is potentially highly wasteful of fuel. Vans are most commonly used in urban areas for delivery and daily commercial use. In this way, the research start from the best potential type of vehicle, diesel Vans in UK.

II. HYBRID PULS SYSTEM

The main objective of this research is modeling and validation a solution to retrofit the normal Diesel Van to mild-hybrid vehicle. Transfer the van into a vehicle which can do regenerate break and assist on start.

The system is mainly designed for big delivery fleet companies, so it should match the need of the market. It is quite different between a private car customer and a commercial fleet manager. The former would like to pay for new technology and comfort features that they can afford, while the later one often resistive to new technology and more interested in a reliable, robust vehicle with the lowest cost during the ownership. In this way, the hybrid plus system should be with an affordable price, provides acceptable vehicle performance, supports versatility of the vehicle, has low impacts on the environment, consumes drastically less fuel, provides some additional value to the customer without a big cost. The lowest cost and best robust are considered mainly throughout the design. The system contains four main parts, A Supercapacitor, A CVT, A PMDC Motor and controller units. The system works as follows in Figure 3.

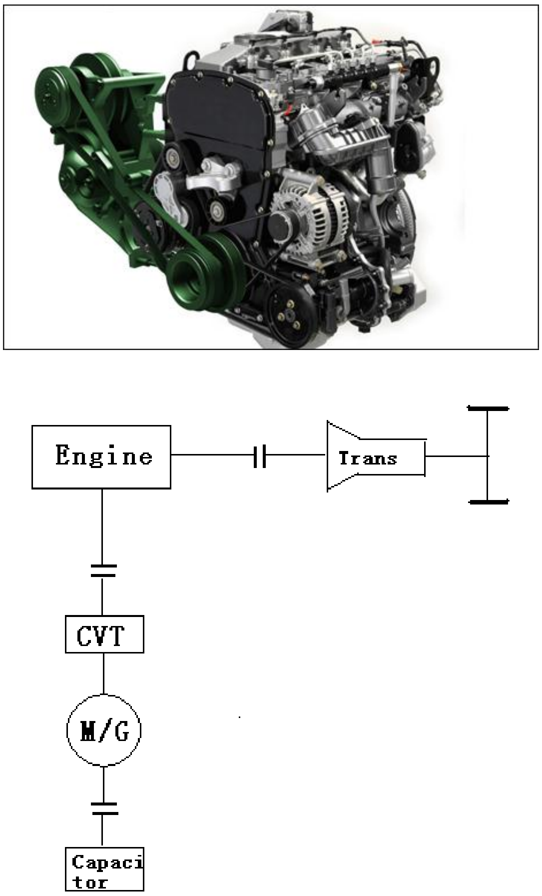


Figure.3 Hybrid plus system components

The retrofit kit will be installed in a VAN with a limit space allowed, so the size of the motor is limited. With a CVT installed between the motor and engine, the torque applied on the engine crankshaft will be increased, which means more assist and regenerate power will be provided. Normally the acceleration or brake process all finish within 3 seconds, to achieve the best assist or regenerate performance, a supercapacitor is used in this design mainly because of its quick charge/discharge performance is better than a lithium ion battery in this application

When the Engine is speed up from a very low speed, the CVT turns to a ratio which allows the motor speed same as engine speed at first. At this moment, the CVT out put the max torque and help engine accelerates. And then the engine speed is accelerating, the CVT need continuously change ratio allow the motor work at the slowest allowed speed which give a max torque on engine at every motor's speed. When the engine speed is equals to the max speed of the motor with the CVT max ratio. The clutch will off and the whole acceleration finished. This is how this system works on acceleration assist.

On the regenerate brake, it works just on the same theory. When the engine brake from a high speed to a low speed, the CVT turns to a ratio which allows the motor rotate at its max speed which will force it works as a generator. The motor generator will charge the Supercapacitor. With the engine slow down, the CVT should continuously change ratio allows the motor generator works at its max speed at every engine speed. When engine speed is decelerate to the min speed which can drive the motor as a generator, the clutch will off and the regenerate brake finish.

III. VEHICLE POWERTRAIN MODELING

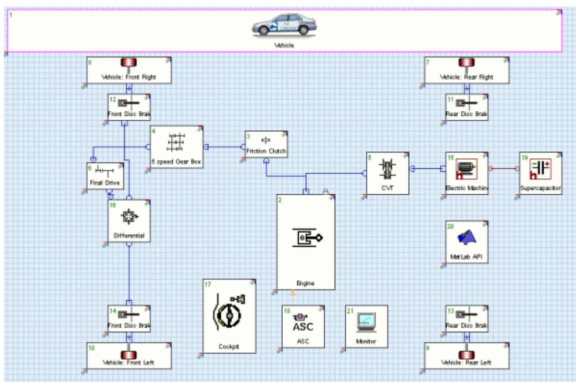


Figure.4 Hybrid plus system simulation layout

The system is basic on a typical Manual front wheel drive power-train, the system combines a CVT, a PMDC motor and a super-capacitor. With these units the system is retrofitted into a mild-hybrid vehicle. The simulation used Simulink/MATLAB run with other simulation software together build a co-simulation system.

IV. MODELING AND SIMULATION RESULT OF THE VEHICLE

The basic theory of all hybrid vehicles is to regenerate the “free energy” from vehicle braking and use this energy to help a vehicle accelerate when it need more power. In this system the vehicle has four different states: assist mode, regenerate mode, curise mode and idle mode. The controller read CAN signal identify the vehicle mode and give the right command to motor and CVT.

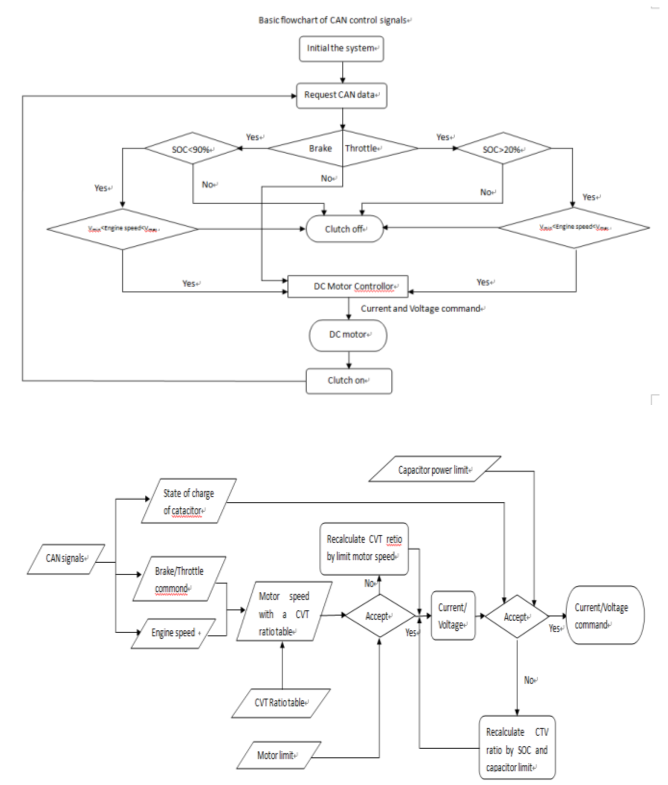


Figure.5 Hybrid plus system controller calculation piority chart

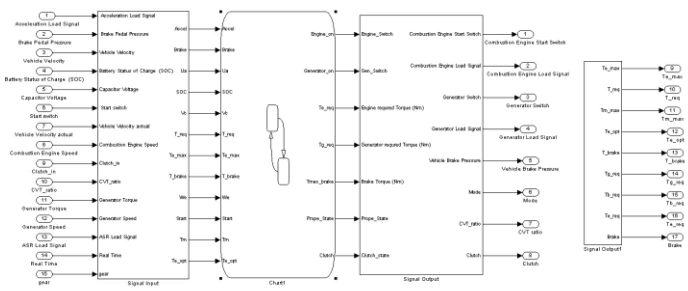


Figure.6 Hybrid plus system controller block in Matlab/SImulink

The simulation system is based on Simulink/MATLAB, the main inputs and outputs are shows in the following tables. There are three main calculation block in the model. The main part of the model is a stateflow chart. The main function of this chart is used the signals to identify the system states and gives out different commands to CVT and motor.

	Name of inputs	unit
1	Acceleration Load Signal	%
2	Brake Pedal Pressure	bar
3	Vehicle Velocity Require	km/h
4	Battery Status of Charge (SOC)	%
5	Capacitor Voltage	V
6	Start switch	-
7	Vehicle Velocity actual	km/h
8	Combustion Engine Speed	1/min
9	Combustion Engine Torque	Nm
10	CVT_ratio	-
11	Generator Torque	Nm
12	Generator Speed	rad/s
13	ASR Load Signal	%
14	Real Time	s
15	gear	-

	Name of outputs	unit
1	Combustion Engine Start Switch	-
2	Combustion Engine Load Signal	%
3	Generator Switch	-
4	Generator Load Torque	Nm
5	Vehicle Brake Pressure	Bar
6	Mode	
7	CVT Ratio	
8	CLutch	-

Table.1 Veriables used in the controller

The stateflow chart shows as follows. There are 5 main states: start, stop, normal drive, acceleration and brake. The states are changed when the inputs changed.

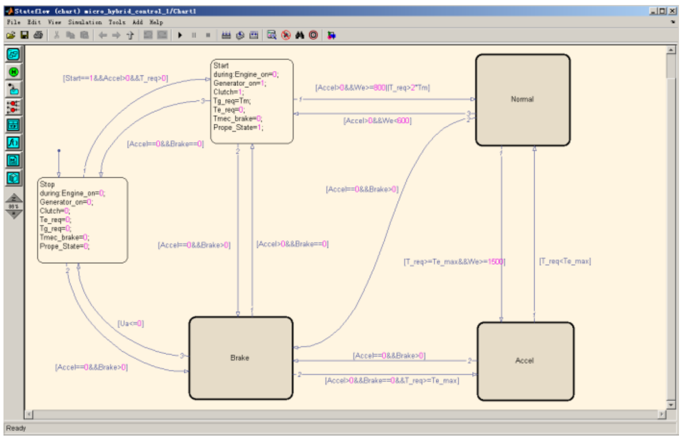


Figure.7 Figure.3 Hybrid plus system controller all modes in Stateflow

In the stop mode, the Acceleration signal is 0, Brake signal is 0, torque required is 0 and vehicle speed is 0, an engine off signal will be given.

In the start mode, the engine is on, clutch signal is on and car is about to move.

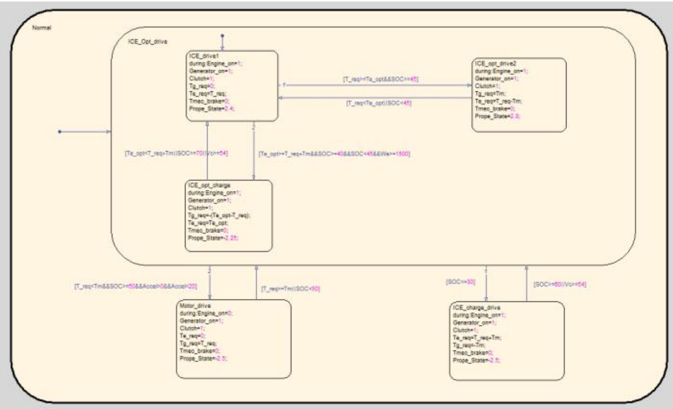


Figure.8 Hybrid plus system normal drive mode in Stateflow

In the normal drive mode there are 3 different drive sub-modes. The motor drives only state, combine drive state and engine drive only state. When the vehicle get a start signal, the motor will spin up first drives the engine crankshaft and helps the engine to start. This state mode will be less than 1 second and then both of the engine and motor will working together or engine only. This depends on the SOC (state of charge) of the supercapacitor. When the SOC is lower than the minimum limit, the motor will work only as a generator to charge the battery.

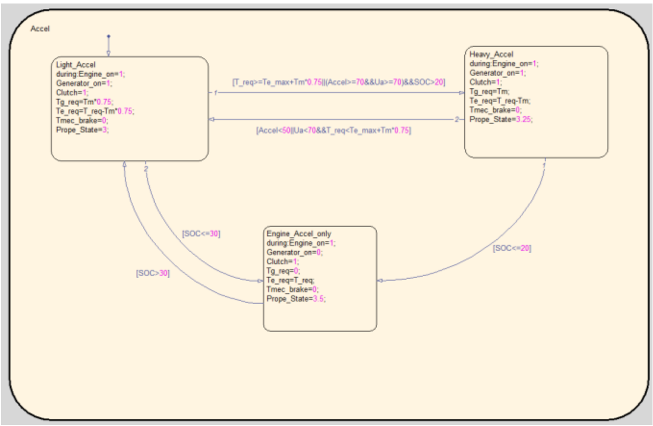


Figure.9 Hybrid plus system acceleration mode in Stateflow

In the acceleration mode, there are 3 states. Engine accelerates only, light accelerate demand and heavy accelerate demand. When the SOC is lower than the minimum limit, the motor will stop working. In the heavy acceleration state, the motor will work in full load, in light acceleration mode the motor will work with a calculated load signal from the controller.

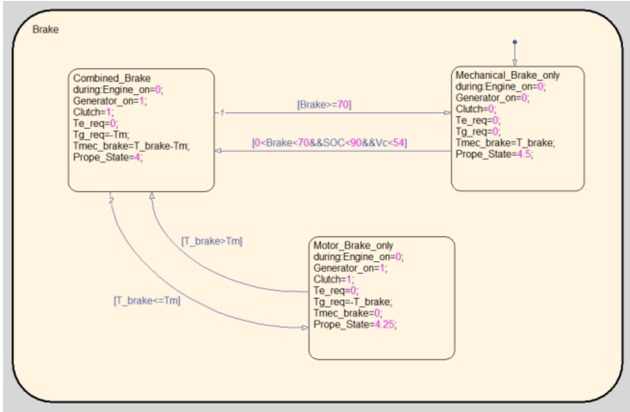
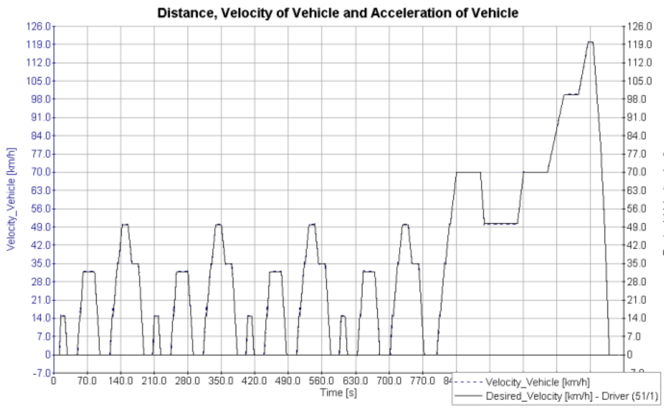


Figure.10 Hybrid plus system brake mode in Stateflow

In the brake mode, there are 3 modes. Motor brake only, combined brake and mechanical brake only. This is depends on the brake signal from the CAN bus.

The vehicle been tested with several drive cycles. One simulation running under NEDC-manual (New European Driving Cycle), the simulation result shows as follows, the vehicle follows the drive cycle quite good. It follows other ones quite good as well.



V. SUMMARY AND CONCLUSIONS

The focus on this study is the feasibility analysis and evaluation of the retrofit set, and the improvement of the fuel economy of the Van after the kit installed. This study utilized a combination of simulation and some on-road test. This paper presents the results of modeling and simulation of the mild hybrid vehicle after the kit installed.

In the NECD drive cycle the test results show that the hybrid plug in system will increase about 3% fuel consumption.

But in the door-door start stop Urban Delivery Drive Circle (UDDC) the conventional ICE vehicle test results are

Overall Fuel Consumption:	*0.6229*	*[kg]*
Idle Fuel Consumption:	*0.0310*	*[kg]*
Acceleration Fuel Consumption:	*0.2858*	*[kg]*
Constant Drive Fuel Consumption:	*0.2457*	*[kg]*
Deceleration Fuel Consumption:	*0.0603*	*[kg]*
Fuel Consumption:	*7.56*	*[l/100km]*
CO2 Emission:	*178.23*	*[g/km]*

The Hybrid Plus system one is

Overall Fuel Consumption:	*0.5016*	*[kg]*
Idle Fuel Consumption:	*0.0009*	*[kg]*
Acceleration Fuel Consumption:	*0.3093*	*[kg]*
Constant Drive Fuel Consumption:	*0.1846*	*[kg]*
Deceleration Fuel Consumption:	*0.0068*	*[kg]*
Fuel Consumption:	*6.09*	*[l/100km]*
CO2 Emission:	*143.59*	*[g/km]*

The fuel consumption has reduced 19.4% and CO2 emission has reduced 19.4% as well. Based on the result, this system has a great potential on energy saving and reduce CO2 emission in urban delivery vans. This retrofit gear could also be applied on the HGVs, with a proper size of motor and capacitor. The system still could be improved with the engine start/stop function while idling.

References

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