Automotive Research Focus in Malaysia

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1. INTRODUCTION

The research and development (R&D) of automotive vehicle has always been influenced by fuel availability and its form. We have seen the evolution of car design from the era of horses and carriages to coal and liquid petroleum. Oil reserves are depreciating by the day. This will affect automotive designs and R&D activities, particularly in areas of alternative fuel, engine and transmission, fuel storage and vehicle body. For consumer cars, we have to seek fully-utilisable alternative fuel and/or develop new fuel. In either case, technological R&D on the engine, transmission, fuel storage and the vehicle body need to be carried out extensively. The focus areas of R&D in automotives differs from country to country, from region to region (such as EU, ASEAN) and from one economic grouping to another (such as AFTA). The choice of focus mostly depends on national interest, regional interest and also on the technical consultants and advisors of the government. For the automotive sector, international regulations related to the environment (such as EURO 3 and EURO 4) and guidelines related to passenger safety (such as NCAP) has a heavy influence on research focus. This paper intends to provide an overview of automotive research, particularly the focus areas of R&D, mechanisms and management of research activities, challenges that might be faced and issues related to procurement for the public sector automotive R&D. This paper is divided into several parts, namely; energy scenario, engine technology, focus areas of importance, research works on natural gas vehicle, and its issues and challenges. The later part of the paper will propose practical mechanisms for automotive R&D.

2. ENERGY SCENARIO

Studies on the energy demands for the 21st century have been conducted by the World Energy Council [1, 2, 3, 4] and a summary of the energy availability is shown in Figure 1 [1]. From Figure 1, it can be seen that during the period of 2005 to 2050, there will be less use of oil compared to Natural Gas (NG). Also, during this period, the use of oil is decreasing whereas for NG it remains almost constant. Therefore, it can be inferred that NG is the fuel of choice for at least the next 50 years. Malaysia, currently produces 39.8 million tonnes oil equivalent (mtoe) of NG and consumes only 19.5 mtoe [6]. Therefore, there is plenty of NG available for automotive use. However, in order to utilise the NG for automotive usage, there are a number of issues, namely, technological, economical as well as political, that need to be addressed. The author will focus on the technological aspect only. The main concern for using NG for automotive is the safety, storage and refuelling infrastructure. Table 1 shows the number of vehicle and refuelling stations for selected countries. It can be seen that NGV has been widely accepted. Argentina has the highest number of vehicles and refuelling stations. In addition to that, NGV also has less emission level as set out by the EURO 3 and EURO 4 requirements. Table 2 shows the results of test on two types of fuel compared to the standards requirement as reported by Middleton and Neumann [9]. It can be seen that NGV complies with all the requirements of these standards. Other alternative

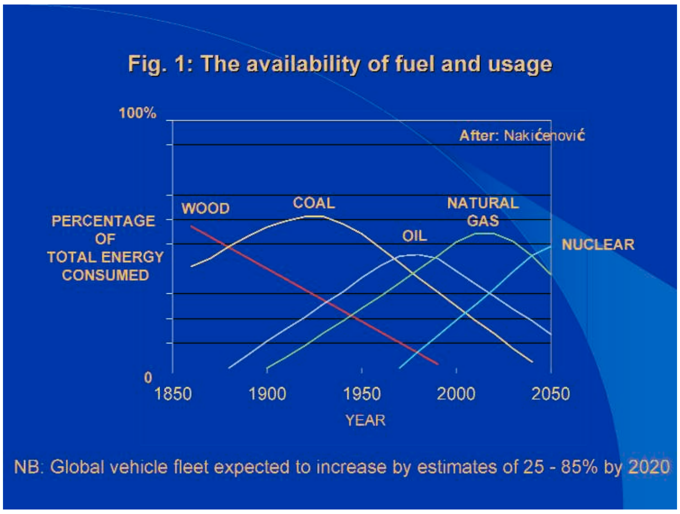

Table 1: The number of NGV and refuelling stations of selected countries (7).

Country	Number of Vehicles (NV)	Number of refuelling stations (NRS)
Argentina	1,459,236	1,400
Brazil	1,035,348	1,176
Pakistan	850,000	828
India	204,000	198
Iran	91,314	120
Bangladesh	44,534	106
Malaysia (8)	15,600	40
USA	130,000	1,340
Japan	25,000	289

Table 2: Comparison of emission level against standard (9) (Units: grams/kilowatt hour)

	CO	NMHC	CH4	NOX	PM
EURO 3 limit	5.45	0.78	1.6	5.0	0.16
EURO 4.1 limit	4.0	0.55	1.1	3.5	0.03
NGV test results G20 gas	0.131	0.011	0.156	3.09	0.006
NGV test results G25 gas	0.134	0.020	0.459	2.88	0.007

fuels are electric, hydrogen, propane, alcohol, bio-based, fuel cell and nuclear. However, these alternative fuels are still being researched.

3. ENGINE TECHNOLOGY

The development of the engine fuel systems technology is shown in Figure 2 [5]. From Figure 2, it can be seen that by the year 2020, the technology for most fuel systems would be direct injection (DI). It is envisaged that the DI technology will provide more efficient combustion, fuel economy and greater mileage. Hence, DI technology is the prime focus for engine research. With the recent increase of oil prices, the immediate alternative is NG. NG is readily available, does not require expensive processing technology and can be said to be direct "from earth to engine", as it were. It requires storage and transportation. Hence, it becomes necessary to accelerate the use of NG,

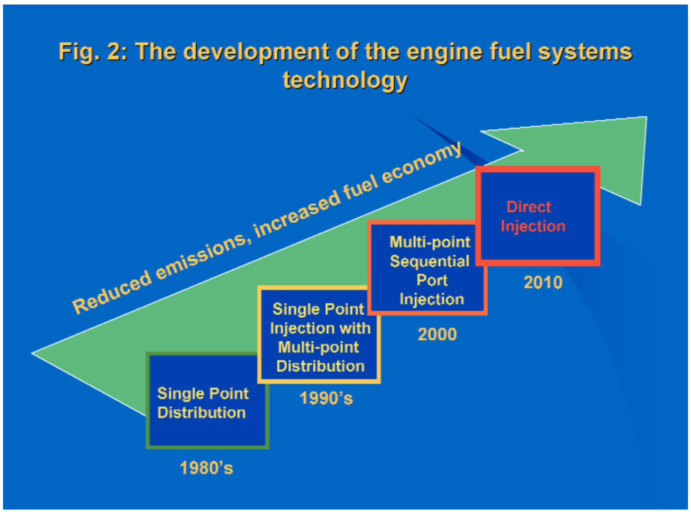

Fig. 2: The development of the engine fuel systems technology

especially for the automotive sector. New engine technologies for mono-fuel NGV, encompassing fuel systems, combustion chambers, electronic control units, vehicle body, fuel storage and refuelling infrastructure need to be further developed. Modification and/or conversion of existing petrol engine is possible as a shortcut measure at the expense of performance. Therefore, there is a need to focus on this area as well. Other engine technologies in development are bi-fuel (NG and petrol), dual fuel (NG and diesel), linear generator, hybrid vehicle, electric vehicle, fuel cell vehicle, bio-diesel, hydrogen and nuclear. Among these, the mono-fuel, bi-fuel and dual fuel are considered to be of immediate importance, whereas the others hold more promise in medium to long term plans.

4. IMPORTANT FOCUS AREAS

Given the energy scenario and engine technology trend mentioned in the previous sections, the automotive R and D work can be divided into immediate and long terms:-

a) Immediate term

For immediate term, research focuses on utilising NG as fuel for mono-fuel, bi-fuel and dual fuel vehicles. The scope includes fuel storage and fuel systems, electronic control systems, injection systems and components, transmission systems, vehicle body integration and packaging, combustion and ignition systems and emission control systems.

b) Long term research

For long term research, there are two research areas to be carried out simultaneously. The first is the development of the fuel itself. This includes the fuel composition and production, fuel characteristics, storage, delivery and conversion to mechanical and/or electrical power. Secondly, research on the engine, transmission and the vehicle that uses the fuel. Therefore, it may take longer to achieve these results compared to the immediate term. The research scope consists of linear generator, hybrid vehicle, electric vehicle, fuel cell vehicle, bio-diesel, hydrogen and nuclear.

5. RESEARCH WORK ON COMPRESSED NATURAL GAS (CNG)/DIRECT INJECTION (DI) ENGINE AND TRANSMISSION

With regards to the mono-fuel direct injection passenger vehicle; UPM, UM, UKM, PRSS, UTM, UiTM, UTP and PROTON came together as a group to carry out a research program in developing the Compressed Natural Gas (CNG) Direct Injection (DI) (CNG/DI) vehicle sponsored by the Ministry of Science, Technology and Innovation (MOSTI) under the Intensification of Research Priority Areas (IRPA) mechanism [10]. A prototype vehicle is due to be completed in June 2006. The program comprises 7 projects covering natural gas storage (UPM), development of fuel system and injectors (UKM, UM), combustion and ignition studies (UKM, UPM, UTP), development of an electronic control unit and its diagnostic kit (UPM), performance and emission studies of a new direct injection compressed natural gas engine (UM, UiTM), vehicle architecture and integration (UPM) and NGV refuelling facilities and equipment (PRSS, UTM, UTP). PROTON is involved in every project. It is a collaborative effort between the Universities, Research Institutes and Industries and these efforts are supported by solid funding.

The program uses the 1.6 liter CAMPRO as a base engine, as shown in Figure 3 and the Proton Waja vehicle platform as the base platform (Figure 4). The program road map is shown in Figure 5. The development includes the vehicle platform,

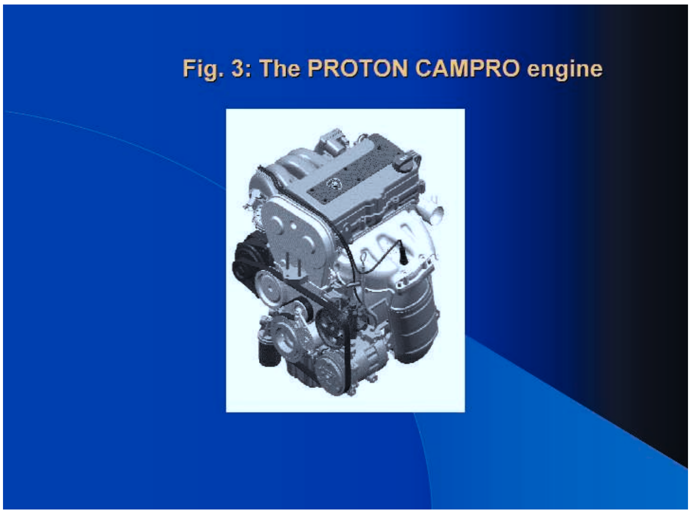
Fig. 3: The PROTON CAMPRO engine

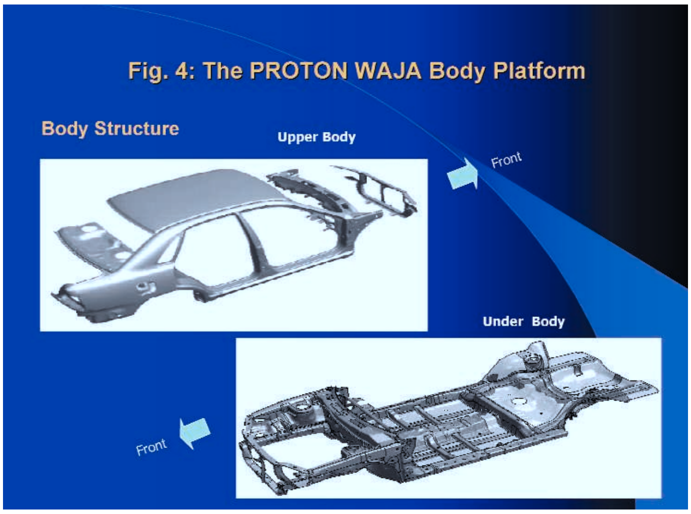

Fig. 4: The PROTON WAJA Body Platform

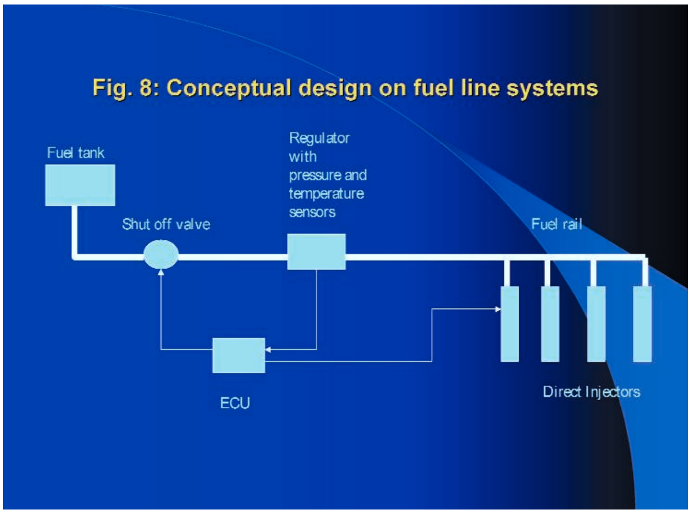

Fig. 8: Conceptual design on fuel line systems

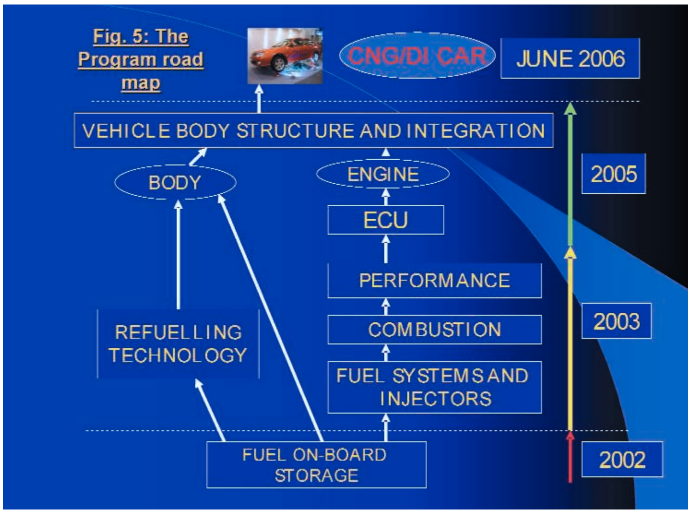

Fig. 5: The Program road map

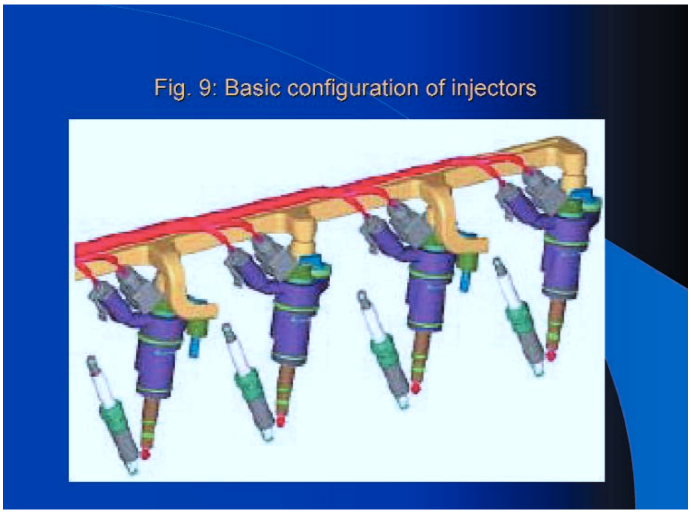

Fig. 9: Basic configuration of injectors

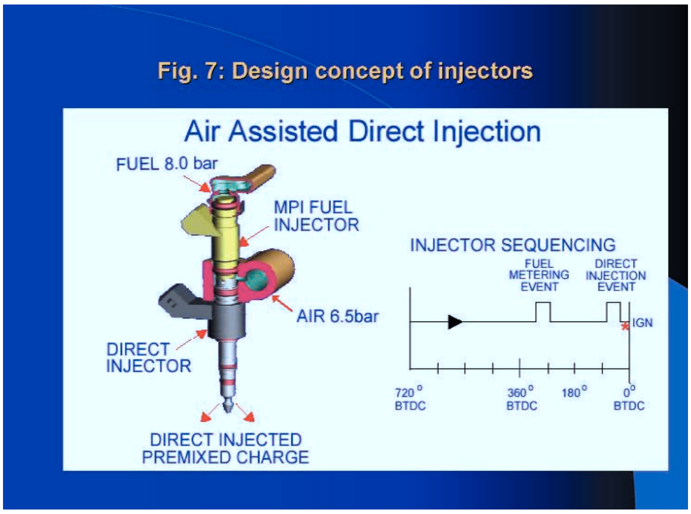

Fig. 7: Design concept of injectors

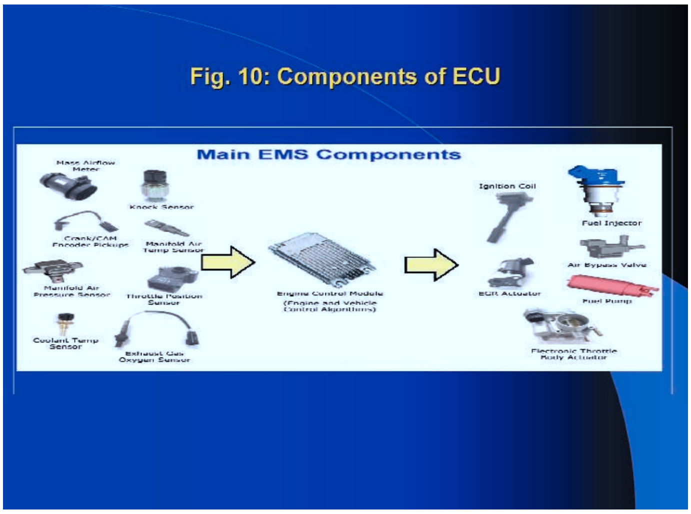

Fig. 10: Components of ECU

fuel storage tank, fuel system, ignition system, cylinder head, exhaust, electronic control unit, fuel injectors and the refueling equipment; compressor and dispenser.

For CNG/DI vehicles developed in this program, the fuel storage is a cylindrical tank with an aluminium liner wound with carbon fibre. The pressure capacity is 200.0 bar. The design concept is shown in Figure 6. Three tanks are fitted to provide a predicted range of 300.0 km. A new cylinder head was designed to fit the injectors and fuel rail to the CAMPRO engine block with an increased compression ratio. To achieve desired combustion characteristics, a longer spark plug is used. Figures 7, 8 and 9 show the design of the injector and fuel systems configurations. A new Electronic Control Unit (ECU), which includes the hardware, software and diagnostic kit, was designed and calibrated. The main components used are shown in Figure 10. The program also takes into account the exhaust

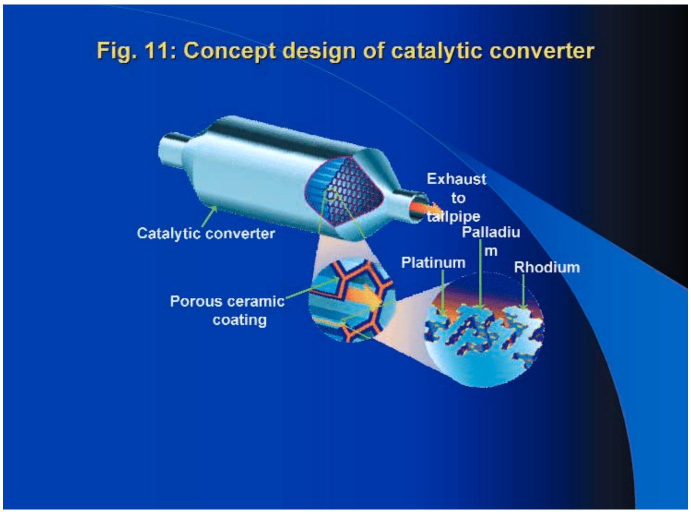

Fig. 11: Concept design of catalytic converter

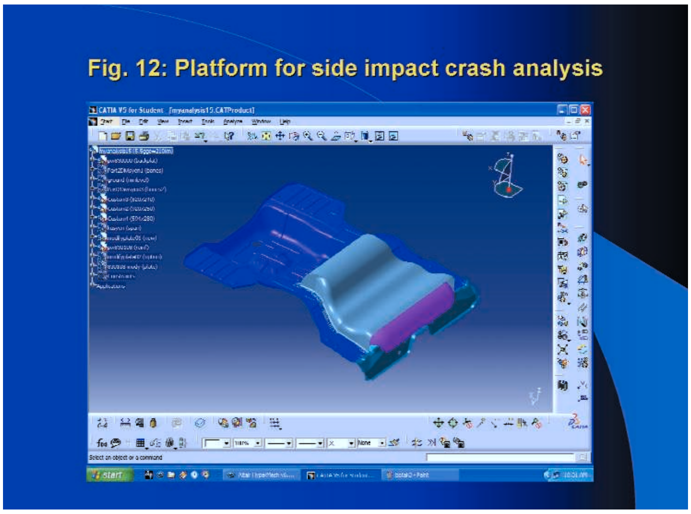
Fig. 12: Platform for side impact crash analysis

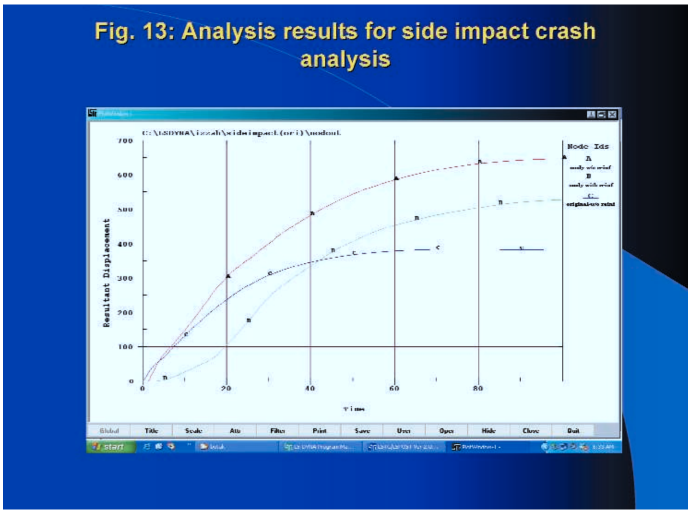

Fig. 13: Analysis results for side impact crash analysis

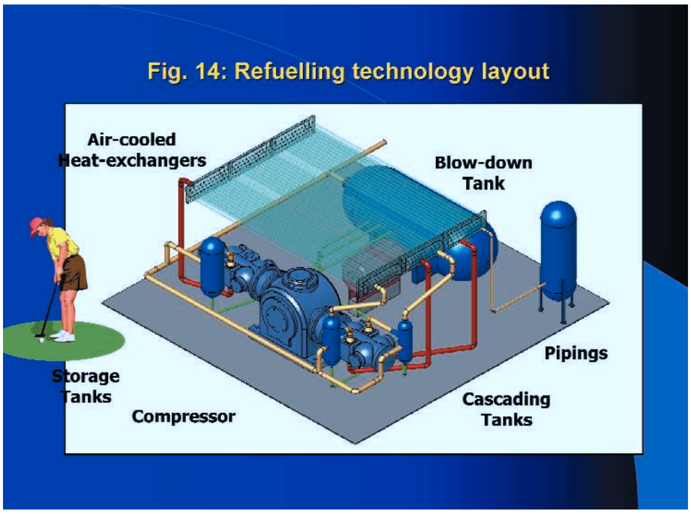

Fig. 14: Refuelling technology layout

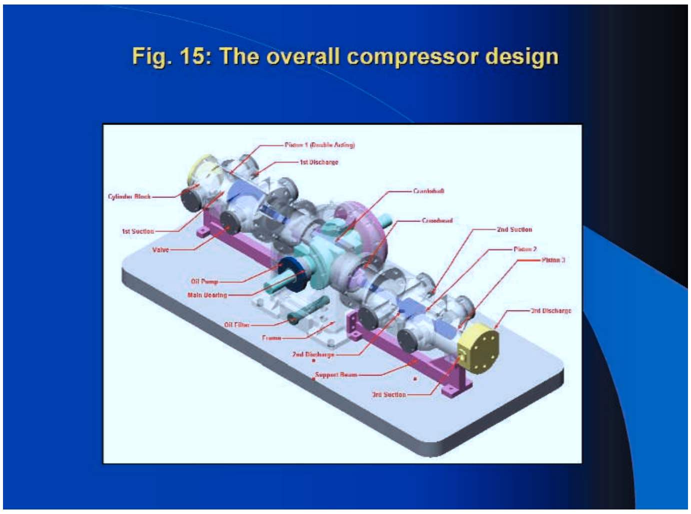
Fig. 15: The overall compressor design

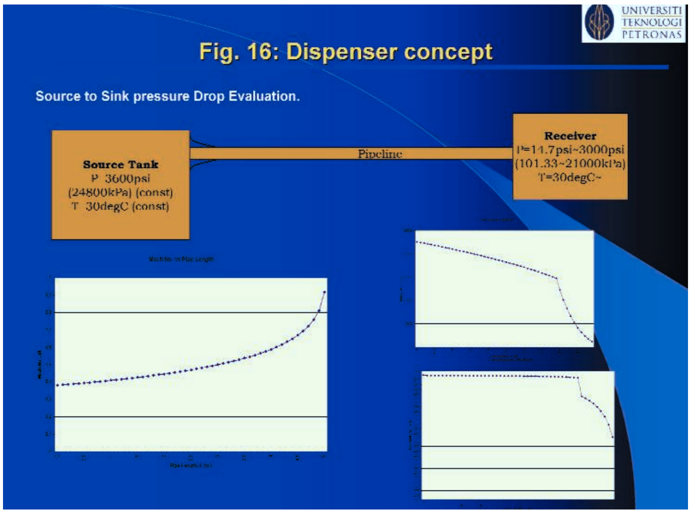

Fig. 16: Dispenser concept

emissions, in particular NOx to Euro 4 standard for passenger cars. To achieve this, a catalytic converter was designed. The concept of the catalytic converter is shown in Figure 11. A vehicle platform was developed to adapt the CNG tanks with the main considerations including safety, tank shape, number and weight, mileage and refueling time. The important design criterion was platform structural safety during crash and these were simulated using various designs of structural reinforcements, weights and tank mountings. The analysis of the design selected is shown in Figure 12 and 13. For the refuelling work, the concept design is shown in Figure 14, the gas compressor in Figure 15 and the dispenser in Figure 16. Due to the high pressures involved, rigorous analysis such as mode shape and stress analyses were performed on the components to ensure safety. A prototype refueling station was constructed. The CNG/DI prototype vehicle is as shown in Figure 17.

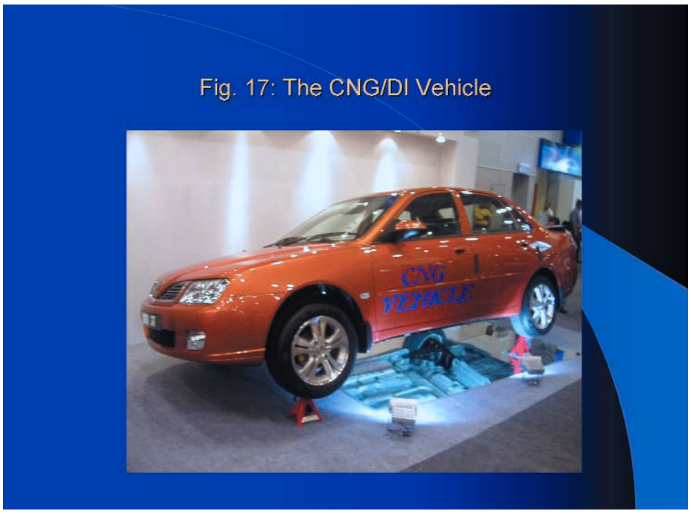

Fig. 17: The CNG/DI Vehicle

6. ISSUES AND CHALLENGES

The issues and challenges faced in carrying out R&D in automotive can be divided into three categories; technical, institutional and industrial support.

6.1. Technical support

The most part of the R&D work involves major design, analysis, fabrication and testing. There is a need for highly skilled manpower and these resources, in turn, had to be tenured for a specified period of time. Specialised manpower is usually difficult to obtain because most graduates prefer jobs which offer a more permanent role. The mechanism of skilled manpower mobility between institutions is required. For the CNG/DI project, this is possible through a collaborative effort between these institutions. Another challenge faced is the fabrication of prototypes. Rapid prototyping is usually needed. For epoxy type models, it can be constructed either in-house or outsourced to a third party within the country. However, for more delicate and complex components and metal rapid prototyping, usually a third party from outside Malaysia is required. It costs more and in terms of purchasing procedures, it takes longer to process. Researchers also have to be aware of intellectual property and the disclosure of technical information that might jeopardise patent filings. On the supply side, technically competent suppliers in providing technical information, equipment, software, testing work, fabrication work, raw materials, electronic components and specialist consumables should be readily available. Provision of good support from suppliers is crucial to the success of the research work.

6.2. Institutional support

The support from the research institutions is very important, particularly, during the kick off and the early stages. This support includes administrative and suitable laboratory space for both researchers and equipment. The timeliness in personnel recruitment, procurement of equipment and materials is crucial. In this regard, a more appropriate and suitable procurement procedure conducive for research is very much needed. This will reduce, if not eliminate, unnecessary delay in research activities. For automotive research, there is a need for collaboration between several Institutions and industries. This requires a shift in paradigm from the normal single institutional research to a multi-institutional research. This shift requires full institutional commitment and support to achieve a "win-win" situation for all the collaborating institutions and industry. In this regard, it is the authors view that the CNG/DI program has received the necessary support.

6.3. Industrial support

The support from the automotive industry is as important as that from the institutions. This could be in kind, such as base vehicle, base engine, information or data, expertise, fabrication and testing standards, procedures and services. For NGV, in Malaysia, as shown in Table 1, the number of refueling stations is still low (40) compared to Pakistan (828), India (198), and Bangladesh (106). To promote the use of NGV, Petronas may have to take the lead and invest in more refueling stations. Currently, there are 40 stations and this figure could increase to 94 by 2010 [7]. While this is a positive step, the numbers could be higher. Also, there should be emergency response rescue teams to cater to mono-fuel NG vehicles that runs out of fuel on a particular journey. This is because it is not possible to purchase NG in a can. The rescue team may provide offroad refueling services.

7. CLOSING REMARK

With retrospect to the entire article, we can conclude that:

a) R&D in automotive engineering depends on the two main factors, namely, the available fuel and the engine technology in development. The R and D's main focus is to utilise the fuel to its fullest and to meet the standards with regards to the environment,

b) For the short term, natural gas seems to be the fuel of choice for Malaysia. It is abundant, clean and within means of storage and distribution. Hence R&D on NGV should continue to be given priority, especially in the development of Original Equipment (OE) and commercialisation and promotion of NGV. However, the number of refuelling stations needs to be increased to reduce the gas refuelling queue.

c) The longer term automotive R&D has also been identified to include development of new and alternative fuels, such as bio-fuel, hydrogen, fuel cells and nuclear, in line with the development of the respective new engines such as linear generators.

d) In terms of mechanism and management of research in automotive engineering, a multi institutional collaboration effort that comprises local Universities, Research Institutes and the automotive Industry appears to be necessary to utilise all the available resources and expertise in the respective institutions. It is therefore, proposed that, such collaborations be encouraged, if not a prerequisite, for R&D in automotive engineering.

e) To enhance R&D activities, especially in automotive engineering, a special procedure for procurement of equipment and services is very much needed to reduce unnecessary delay.

f) Three main issues and challenges has been identified; namely technical, institutional and industrial support. These issues need to be addressed properly especially in formulating research proposal and its implementation.

8. ACKNOWLEDGEMENTS

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