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Conceptualization of an Inventive Air Hybrid System

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***Abstract*—Innovation is expected to drive the automotive industry in future as the policymakers and researchers are increasing the thrust on fuel efficiency and emissions than ever before to reconcile mobility and sustainability; mainly through technological improvements and new fuel variants leading to emergence of a spectacular new generation of automobiles. The growingconcern for the environment, fueled by the intrinsic and extrinsic measureshas brought in a radical shift, making the smart and evolved customer demand greener and environmental friendly technologies, in addition to better aesthetics with no tradeoff between performance and fuel efficiency [1]. In groove with the same, the research proposes conceptualization of an inventive air hybrid, integrating two technologically distinct power sources, a conventional petrol fueled engine and an air engine and delineates the associated rule based control strategy for their optimal blending and synergization. With the ideation of a simple and robust design of the air engine with electronically controlled features the concept air hybrid is envisioned to offer an exhilarating fuel efficient and environmentally benign performance over a variety of driving situations to trounce the age old engine driven rivals.**

***Keywords*—Air Hybrid, Control Strategy**

I. INTRODUCTION

The automotive industry, triggered by the growing urbanization and increasing socio-economic development activities, coupled with soaring demand for mobility, has embraced an unprecedented growth in the recent few years.The world has gone from five million cars post-World War II to close to one billion today, and is expected to reach two billion before 2050[2].The final 2012 tally of the global auto sales struck a huge 71.2 million, a 4% up versus the previous year 2011, as could be seen in Fig.1, with the first six months sales reaching 41.5 million units.

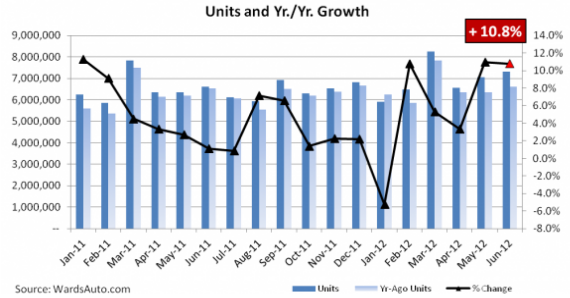

Fig. 1 Global vehicle sales (Jan 2011- June 2012) [3]

As indicated in Fig. 2, China with 14.7 million cars sold, has dominated the market, registering an increase by 7% over 2011, followed by the US with sales up 13.4% totaling nearly 14.5 million [4].

Projection scenarios for the next few decades show that demand for vehicles would continue to soar in the years to come. The global vehicle fleet, including commercial vehicles and passenger cars, is expected to grow by 10-13% in 2012-13, by 23% over the next six years [5]and by 60% to 1.6 billion by 2030[6].

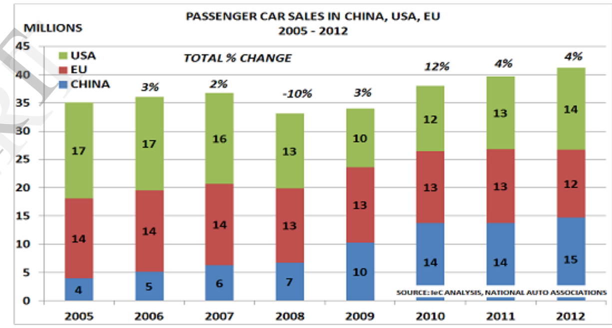

Fig. 2 Passenger car sales (2005-2012): China, US and EU [4]

However, this growth of automotive industry with increasing population of vehicles, also brings in, the associated adverse effect of putting up a huge pressure on the fossil fuel reserves, which are threatened to be gradually exhausting due to over exploitation, as could be seen in Fig.3 [7].

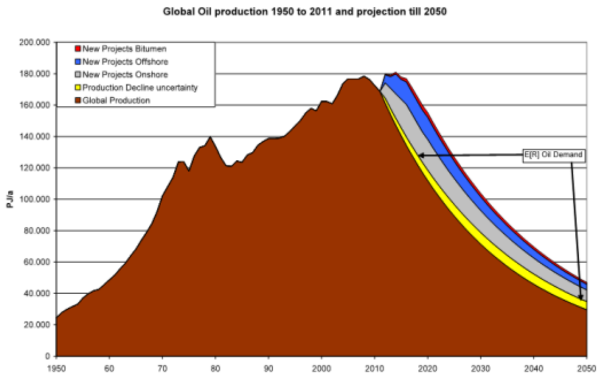

Fig.3 Exhausting fuel resources [7]

The uncertainties in terms of dwindling supply in a growing demand context further hike the fuel prices enormously as demonstrated in Fig.4 [8], thus setting up a vicious cycle.

The expanding motorization around the world is also causing a steady increase in carbon pollution, and other toxic gases exacerbating global warming [9], being perceived as one of the most serious threats to the planet. Carbon emissions from fossil fuel combustion and cement production have increased by nearly 2.6% in 2012, with a total of 35.6 billion tonnes of CO_2 emitted to the atmosphere. More than 62% of all these carbon emissions could be attributed to energy usage &transportation [10].

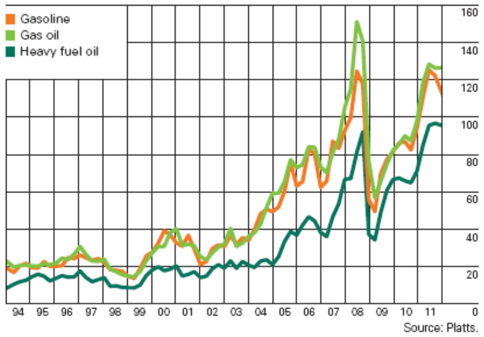

Fig.4 Fuel price fluctuations (USD/barrel) [8]

Under these circumstances, technical inabilities of the conventional, fossil fuel dependent engine technology to offer higher fuel economy and inherent tendency to engender tremendous environmental degradation by combustion by-products, are making them victims of their own success.

Underpinned by growing intrinsic and extrinsic sense of responsibility concerning worsening environment and burden of exorbitant fuel costs and its availability, a global paradigm shift is ignited systemically amidst consumers, researchers, industry players and policy-makers and an urgent need is felt internationally to explore technically efficient and environmentally benign sustainable alternative forms of mobility, resolving these engine related challenges and delivering unprecedented performance meeting up all interwoven conflicting technological requirements.

Numerous options including improved conventional fuel quality, advanced vehicle technologies and alternative fuels proposing innovative ideas for power systems far more efficient than anything that we have today have been thought of over the past few years. Many researchers [11, 12]have contributed in exploring and evaluating these alternatives from various perspectives. However, their acceptance and commercialization is plagued by high initial costs, on-board energy storage issues and lack of infrastructural and safety concerns.

In this dilemma, hybrid vehicles, employing an intelligent integration of two or more power sources for propulsion, complimenting their strengths and eliminating individual weaknesses skillfully, are topping the list to emerge out as a sustainable and environment friendly synergistic means of mobility, meeting up the criterions of fuel efficient performance and stringent emissions.

Many hybridization schemes such as fuel cell [13], gas turbine [14], solar [15], hydraulic [16], pneumatic [17], Ethanol E85 [18], electric [19] and many more have been proposed over the years.

A lot of research on their features, design, control strategies and performance analysis is found in the literature [20]. Some of the major fundamental issues these advanced vehicular technologies face presently including the challenges for market penetration and commercialization have been highlighted as well.

II. AIR HYBRID: CONCEPTUALIZATION

In groove with this harping of hybridization, a novel concept of an air hybrid [21] and the associated control strategy for yielding a consistent and efficient performance under varying driving situations is proposed in this research work.

The air hybridoffers hybridization of a conventional petrol fueled internal combustion engine and an air engine. The architecture, as could be seen in the schematic layout in Fig.5, incorporates, over and above the routine components of a conventional car, a compound planetary power split device, a microcontroller based electronic control unit and an air receiver tank mounted on the rear of the structure.

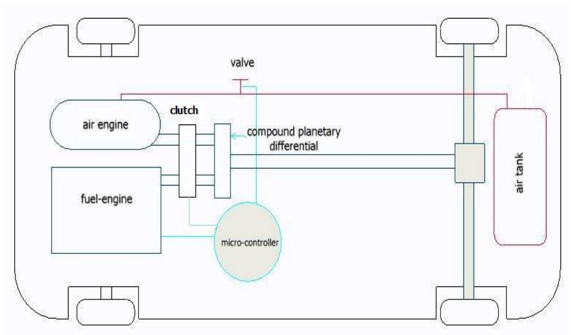

Fig.5 Air hybrid architecture [21]

The air engine, as could be seen in Fig.6is an indigenously designed modified slider crank mechanism, which could also behave as a compressor. The mechanism has a piston of the same form as would be found in any standard compressor except it having a forged together piston rod, enabling the system to be double acting. The feature eliminates the need for two separate single acting cylinders, thereby offering the benefits of a simple, compact and light weight design and construction.

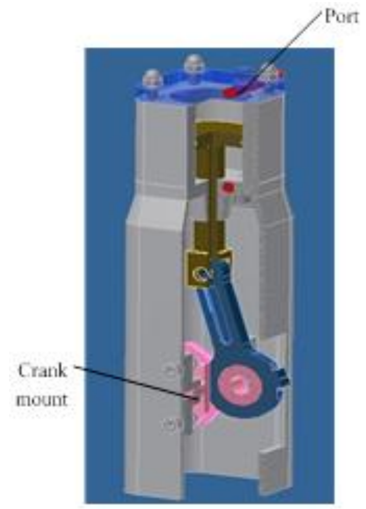

Fig.6 Double acting slider crank mechanism [21]

The valves enabling admission and delivery of the air are operated by a belt drive and have two through holes with their axis perpendicular to each other, as could be seen in Fig.7. The ratcheted connectionof the driving pulley with the crank shaft allows these holes to align with the inlet and outlet ports alternately through a servo turning them through 90 degrees with respect to the current position at the time of switchover between the power developing, i.e. air engine and power consuming, i.e. air compressor modes.

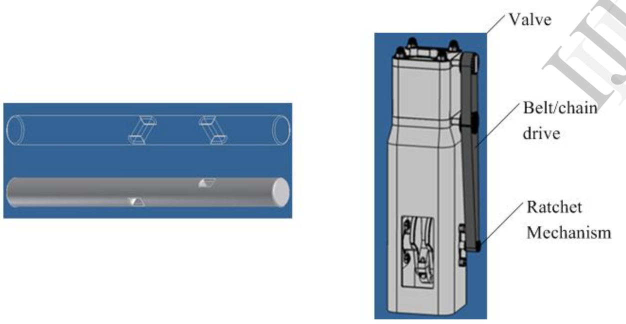

Fig.7 Valve and ratchet mechanism [21]

In the power developing mode, the air engine would be fed with high pressure compressed air exerting a force on the piston and eventually torque on the crank mechanism, which would be utilized to drive the wheels. In contrast with the previous mode, in the power consuming mode, the air engine would be run by the gasoline engine or by the wheels of the vehicle to compress the air, which in turn would be deposited into a receiver tank for running in the first mode whenever required.

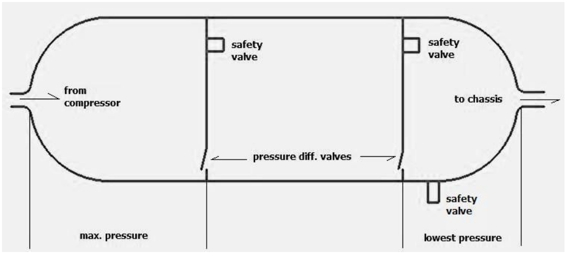

Fig.8 Air receiver tank structure[21]

The air receiver tank is basically a modified container with three partitions, viz. high pressure, medium pressure and low pressure partitions as could be seen in Fig.8. Each partition has a safety valve and an NRV, which facilitate an uninterrupted flow of air into and from the air tank during the power consuming and power producing modes, respectively. The air stored in the low pressure partition could also be used to drive the auxiliary systems like, air-conditioner compressor, fuel pump etc.

III. CONTROL STRATEGY

As the most crucial feature deciding the achievable performance enhancement, a unique rule based energy management strategy [22,23,24,25], commanding an optimal power distribution between the involved power systems, i.e. the gasoline and air engine, under transient, diverse driving conditions, aimed at achieving high fuel economy and low emissions, while assuring adequate energy reserves in the storage devices has been defined.

The defined strategy allows the air hybrid to be operated under multiple driving modes. The execution of the strategy and the energy synchronization during these driving modes has been explained schematically in the following sections.

The air hybrid would be started by the air engine drawing compressed air from the receiver tank, as could be seen in Fig.9. The gear system does not work actually in this situation, though it has to be operated by the driver in the usual way as in a conventional car. Thus, even when the driver shifts the gear shifter to first position or any other, that would not make any difference as the gasoline engine is off and is not started yet.

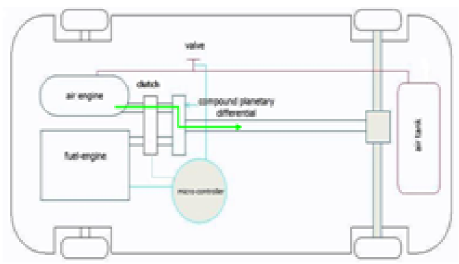

Fig.9 Control strategy: Starting and slow speed cruising[21]

Near the critical value of change over, at a predetermined speed of the car, the engine would be cranked by the generator as in a conventional engine driven car, by drawing energy from the batteries. Once the engine gets started, the generator would be driven by the engine and in turn would be charging the batteries. The generator would be coupled with the engine via a speed reducing unit and a magnetic clutch. A DC-DC boost converter is incorporated too, for effective charging.

At a particular speed the engine would get engaged as shown in Fig.10, and would start driving the air hybrid. The controller designed would be then gradually reducing the input to the air engine with further depression of the pedal. Under circumstances such as while cruising at constant speed or reduced air levels in the tank as sensed by the microcontroller unit, the surplus power from the engine would be diverted for simultaneously driving the air engine for restoring the compressed air in the tank for later use, as conveyed schematically in Fig.11.

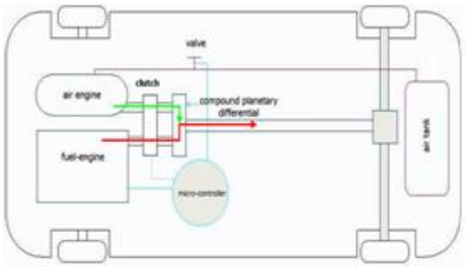

Fig.10 Control strategy: Engine engagement [21]

During racing or overtaking, there would be a requirement of high torque and power, which neither air-engine nor gasoline-engine alone could supply. So, for this situation both the engines woulddrive the hybrid simultaneously, as could be seen in Fig.12 and their output would be added up by the compound planetary gear set to get highest output and so the maximum acceleration.

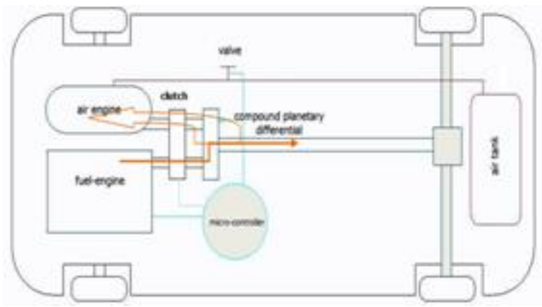

Fig.11 Control strategy: Constant speed cruising [21]

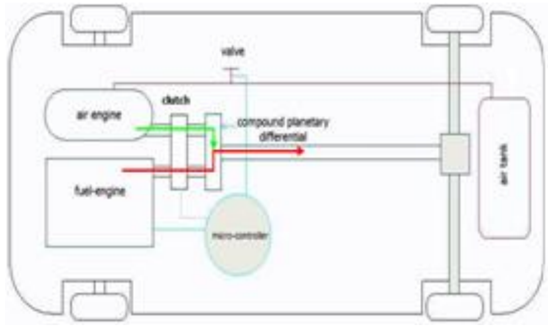

Fig.12 Control strategy: Overtaking[21]

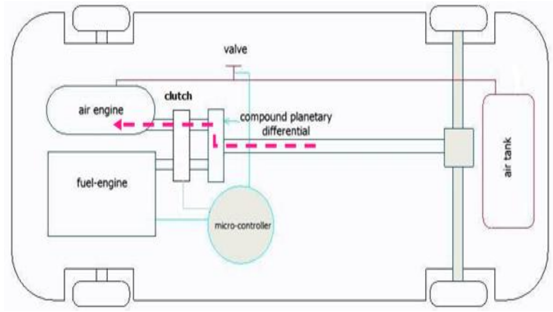

Fig.13 Control strategy: Braking[21]

The inherent regenerative braking feature of the design would facilitate compression of the air as could be seen in Fig.13 with the captured energy while braking, which otherwise would have been wasted.

IV. CONCLUSIONS

An innovative concept of hybridizing conventional fossil fuel driven internal combustion engine with an air engine has been proposed. The conceptual design of the air engine, encompassing an indigenously modified double acting slider crank mechanism with valve assembly and a receiver tank with partitions ensuring an uninterrupted air flow and a unique rule based control strategy relying on high end electronics that continuously monitors and balances the energy flow onboard has been delineated. With further research spotlighted on a detailed engineering design and analysis for manufacturability and cost aimed at resolving the issues related to compressed air like safety and extended range, the concept is envisaged to be an emulating alternative offering sustainable mobility with the avoidance of disruptions in societal, environmental and economic wellbeing.

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