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SCHOOL OF MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – I – INTRODUCTION – SAU1604

UNIT 1

1.0 INTRODUCTION

A hybrid electric vehicle (HEV) has two types of energy storage units, electricity and fuel. Electricity means that a battery (sometimes assisted by ultracaps) is used to store the energy, and that an electromotor (from now on called *motor*) will be used as traction motor.

Fuel means that a tank is required, and that an Internal Combustion Engine (ICE, from now on called *engine*) is used to generate mechanical power, *or* that a fuel cell will be used to convert fuel to electrical energy. In the latter case, traction will be performed by the electromotor only. In the first case, the vehicle will have both an engine and a motor.

- Depending on the drive train structure (how motor and engine are connected), we can distinguish between parallel, series or combined HEVs. This will be explained in paragraph 1.
- Depending on the share of the electromotor to the traction power, we can distinguish between mild or micro hybrid (start-stop systems), power assist hybrid, full hybrid and plug-in hybrid. This will be explained in paragraph 2.
- Depending on the nature of the non-electric energy source, we can distinguish between combustion (ICE), fuel cell, hydraulic or pneumatic power, and human power. In the first case, the ICE is a spark ignition engines (gasoline) or compression ignition direct injection (diesel) engine. In the first two cases, the energy conversion unit may be powered by gasoline, methanol, compressed natural gas, hydrogen, or other alternative fuels.

Motors are the "work horses" of Hybrid Electric Vehicle drive systems. The electric traction motor drives the wheels of the vehicle. Unlike a traditional vehicle, where the engine must "ramp up" before full torque can be provided, an electric motor provides full torque at low speeds. The motor also has low noise and high efficiency. Other characteristics include excellent "off the line" acceleration, good drive control, good fault tolerance and flexibility in relation to voltage fluctuations.

The front-running motor technologies for HEV applications include PMSM (permanent magnet synchronous motor), BLDC (brushless DC motor), SRM (switched reluctance motor) and AC induction motor.

A main advantage of an electromotor is the possibility to function as generator. In all HEV systems, mechanical braking energy is regenerated.

The max. operational braking torque is less than the maximum traction torque; there is always a mechanical braking system integrated in a car.

The battery pack in a HEV has a much higher voltage than the SIL automotive 12 Volts battery, in order to reduce the currents and the I^2R losses.

Accessories such as power steering and air conditioning are powered by electric motors instead of being attached to the combustion engine. This allows efficiency gains as the accessories can run at a constant speed or can be switched off, regardless of how fast the combustion engine is running.

Especially in long haul trucks, electrical power steering saves a lot of energy.

1. 1 TYPES BY DRIVETRAIN STRUCTURE

1.1.1 Series hybrid

In a series hybrid system, the combustion engine drives an electric generator (usually a three-phase alternator plus rectifier) instead of directly driving the wheels. The electric motor is the only means of providing power to the wheels. The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the batteries and the generator as shown in Fig 1

Series hybrid configurations already exist a long time: diesel-electric locomotives, hydraulic earth moving machines, diesel-electric power groups, loaders.

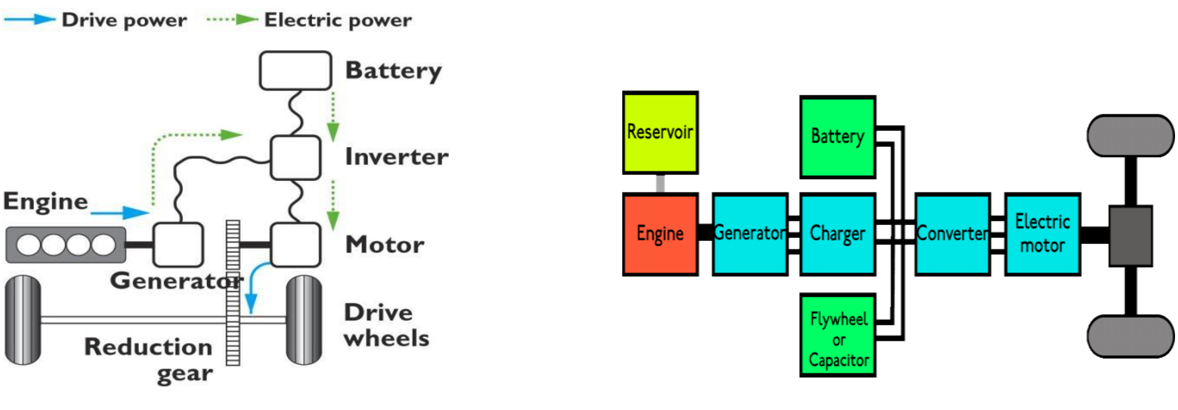

Fig. 1: Structure of a series hybrid vehicle

Series hybrids can be assisted by ultracaps (or a flywheel: KERS=Kinetic Energy Recuperation System), which can improve the efficiency by minimizing the losses in the battery. They deliver peak energy during acceleration and take regenerative energy during braking. Therefore, the ulracaps are kept charged at low speed and almost empty at top speed. Deep cycling of the battery is reduced, the stress factor of the battery is lowered.

A complex transmission between motor and wheel is not needed, as electric motors are efficient over a wide speed range. If the motors are attached to the vehicle body, flexible couplings are required.

Some vehicle designs have separate electric motors for each wheel. Motor integration into the wheels has the disadvantage that the unsprung mass increases, decreasing ride performance. Advantages of individual wheel motors include simplified traction control (no conventional mechanical transmission elements such as gearbox, transmission shafts, differential), all wheel drive, and allowing lower floors, which is useful for buses. Some 8x8 all-wheel drive military vehicles use individual wheel motors. As shown in Fig 2.

A fuel cell hybrid electric always has a series configuration: the engine-generator combination is replaced by a fuel cell.

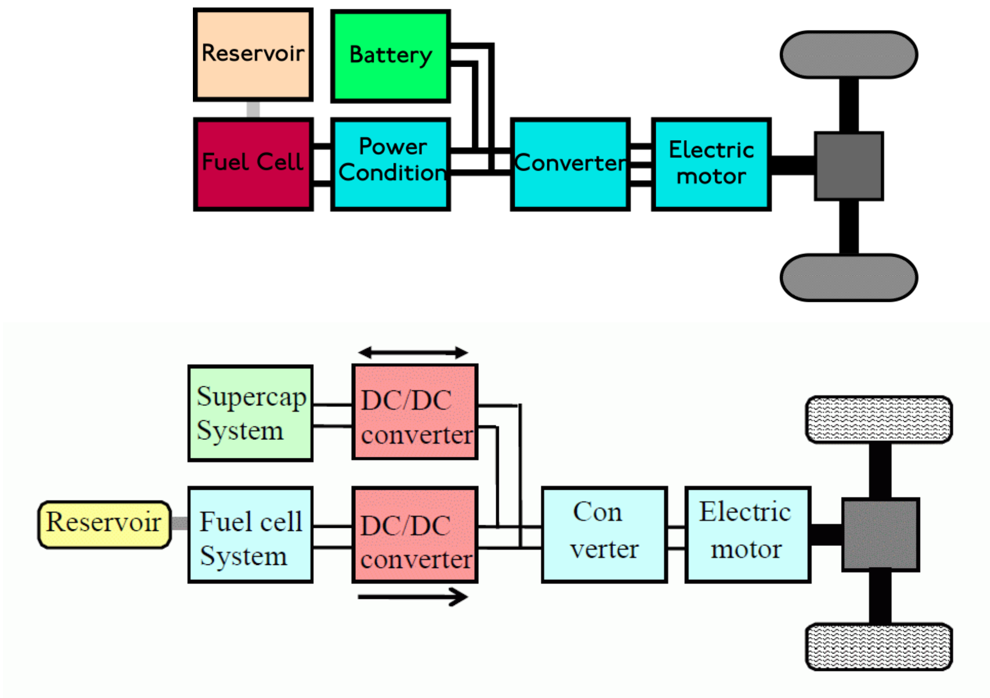

Fig. 2: Structures of a fuel cell hybrid electric vehicle

Weaknesses of series hybrid vehicles:

- The ICE, the generator and the electric motor are dimensioned to handle the full power of the vehicle. Therefore, the total weight, cost and size of the powertrain can be excessive.
- The power from the combustion engine has to run through both the generator and electric motor. During long-distance highway driving, the total efficiency is inferior to a conventional transmission, due to the several energy conversions.

Advantages of series hybrid vehicles:

- There is no mechanical link between the combustion engine and the wheels. The engine-generator group can be located everywhere.
- There are no conventional mechanical transmission elements (gearbox, transmission shafts).
- Separate electric wheel motors can be implemented easily.
- The combustion engine can operate in a narrow rpm range (its most efficient range), even as the car changes speed.
- Series hybrids are relatively the most efficient during stop-and-go city driving.

Example of SHEV: Renault Kangoo.

1.1.2 Parallel hybrid

Parallel hybrid systems have both an internal combustion engine (ICE) and an electric motor in parallel connected to a mechanical transmission as shown in Fig 1.3

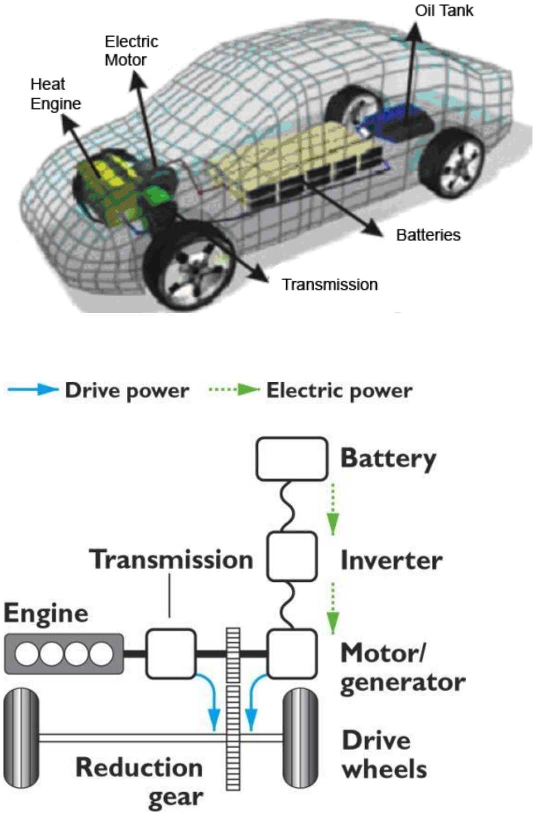

Fig. 1.3: Structure of a parallel hybrid electric vehicle

Most designs combine a large electrical generator and a motor into one unit, often located between the combustion engine and the transmission, replacing both the conventional starter motor and the alternator (see figures above). The battery can be recharged during regenerative breaking, and during cruising (when the ICE power is higher than the required power for propulsion). As there is a fixed mechanical link between the wheels and the motor (no clutch), the battery cannot be charged when the car isn't moving.

When the vehicle is using electrical traction power only, or during brake while regenerating energy, the ICE is not running (it is disconnected by a clutch) or is not powered (it rotates in an idling manner).

Operation modes:

The parallel configuration supports diverse operating modes as shown in Fig 1.4.

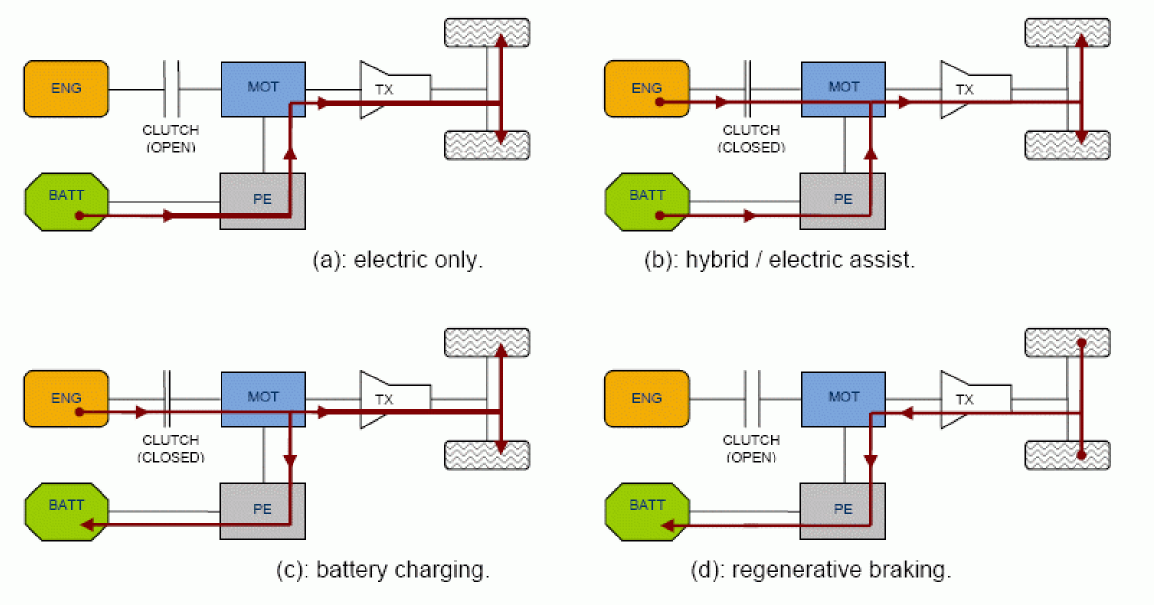

Fig. 1.4: Some typical modes for a parallel hybrid configuration

PE = Power electronics
TX = Transmission

a) electric power only: Up to speeds of usually 40 km/h, the electric motor works with only the energy of the batteries, which are not recharged by the ICE. This is the usual way of operating around the city, as well as in reverse gear, since during reverse gear the speed is limited.

b) ICE power only: At speeds superior to 40 km/h, only the heat engine operates. This is the normal operating way at the road.

c) ICE + electric power: if more energy is needed (during acceleration or at high speed), the electric motor starts working in parallel to the heat engine, achieving greater power

d) ICE + battery charging: if less power is required, excess of energy is used to charge the batteries. Operating the engine at higher torque than necessary, it runs at a higher efficiency.

e) regenerative breaking: While braking or decelerating, the electric motor takes profit of the kinetic energy of the he moving vehicle to act as a generator.

Sometimes, an extra generator is used: then the batteries can be recharged when the vehicle is not driving, the ICE operates disconnected from the transmission. But this system gives an increased weight and price to the HEV as shown in fig. 1.6.

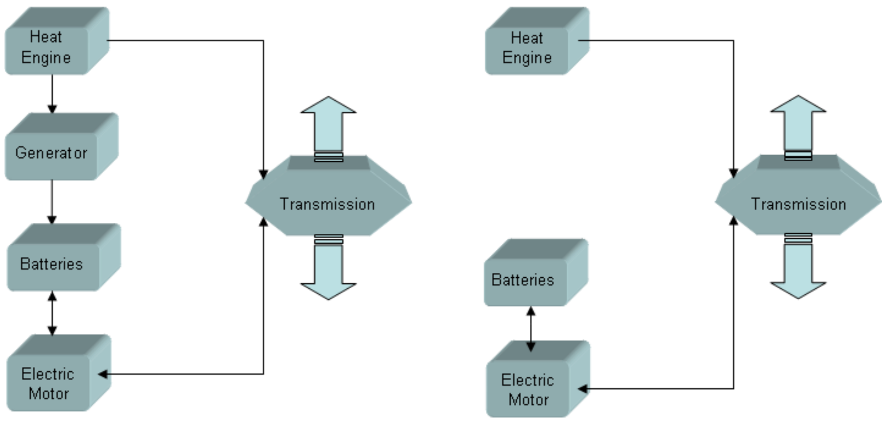

Fig. 1.5: A parallel HEV can have an extra generator for the battery (left) Without generator, the motor will charge the battery (right)

Weaknesses of parallel hybrid vehicles:

- Rather complicated system.
- The ICE doesn't operate in a narrow or constant RPM range, thus efficiency drops at low rotation speed.
- As the ICE is not decoupled from the wheels, the battery cannot be charged at standstill.

Advantages of parallel hybrid vehicles:

- Total efficiency is higher during cruising and long-distance highway driving.
- Large flexibility to switch between electric and ICE power
- Compared to series hybrids, the electromotor can be designed less powerful than the ICE, as it is assisting traction. Only one electrical motor/generator is required.

Example of PHEV:

Honda Civic. Honda's IMA (Integrated Motor Assist) uses a rather traditional ICE with continuously variable transmission, where the flywheel is replaced with an electric motor.

Influence of scale: a Volvo 26 ton truck (12 ton own weight, 14 ton max load) equipped with 200 kg of batteries can drive on pure electric power for 2 minutes only! Because of space constraints, it is not possible to build in more batteries.

1.1.3 Combined hybrid

Combined hybrid systems have features of both series and parallel hybrids. There is a *double connection between the engine and the drive axle: mechanical and electrical*. This split power path allows interconnecting mechanical and electrical power, at some cost in complexity.

Power-split devices are incorporated in the powertrain. The power to the wheels can be either mechanical or electrical or both. This is also the case in parallel hybrids. But the main principle behind the combined system is the *decoupling of the power supplied by the engine from the power demanded by the driver*.

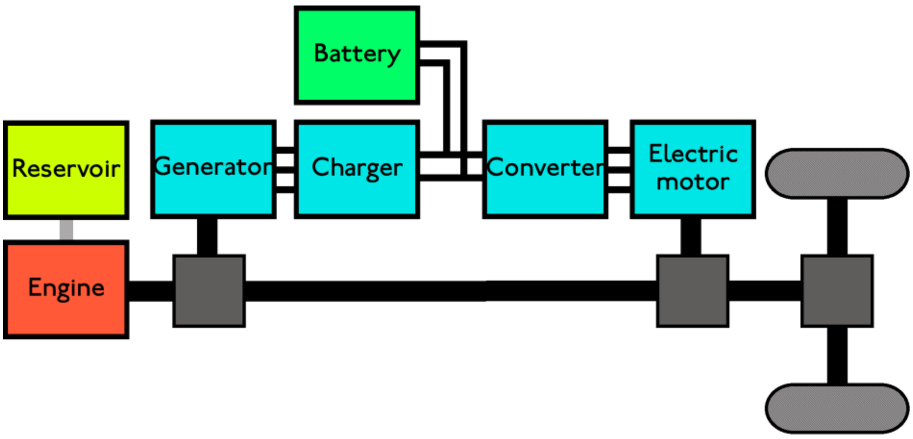

Fig. 1.6: Simplified structure of a combined hybrid electric vehicle

In a conventional vehicle, a larger engine is used to provide acceleration from standstill than one needed for steady speed cruising. This is because a combustion engine's torque is minimal at lower RPMs, as the engine is its own air pump. On the other hand, an electric motor exhibits maximum torque at stall and is well suited to complement the engine's torque deficiency at low RPMs. In a combined hybrid, a smaller, less flexible, and highly efficient engine can be used.

It is often a variation of the conventional Otto cycle, such as the Miller or Atkinson cycle. This contributes significantly to the higher overall efficiency of the vehicle, with regenerative braking playing a much smaller role as shown in Fig. 1.6.

At lower speeds, this system operates as a series HEV, while at high speeds, where the series powertrain is less efficient, the engine takes over. This system is more expensive than a pure parallel system as it needs an extra generator, a mechanical split power system and more computing power to control the dual system as shown in Fig.1.7

Combined hybrid drive modes

Weaknesses of combined hybrid vehicles:

- Very complicated system, more expensive than parallel hybrid.
- The efficiency of the power train transmission is dependent on the amount of power being transmitted over the electrical path, as multiple conversions, each with their own efficiency, lead to a lower efficiency of that path (~70%) compared with the purely mechanical path (98%).

Advantages of combined hybrid vehicles:

- Maximum flexibility to switch between electric and ICE power
- Decoupling of the power supplied by the engine from the power demanded by the driver allows for a smaller, lighter, and more efficient ICE design.

Example of CHEV: Toyota Prius, Auris, Lexus CT200h, Lexus RX400h.

1.2 TYPES BY DEGREE OF HYBRIDIZATION

Parallel and combined hybrids can be categorized depending upon how balanced the different portions are at providing motive power. In some cases, the combustion engine is the dominant portion; the electric motor turns on only when a boost is needed. Others can run with just the electric system operating.

1.3 STRONG HYBRID (= full hybrid)

A full hybrid EV can run on just the engine, just the batteries, or a combination of both. A large, high- capacity battery pack is needed for battery-only operation.

Examples:

The Toyota Prius, Auris and Lexus are full hybrids, as these cars can be moved forward on battery power alone. The Toyota brand name for this technology is Hybrid Synergy Drive. A computer oversees operation of the entire system, determining if engine or motor, or both should be running. The ICE will be shut off when the electric motor is sufficient to provide the power.

1.4 MEDIUM HYBRID (= motor assist hybrid)

Motor assist hybrids use the engine for primary power, with a torque-boosting electric motor connected in *parallel* to a largely conventional powertrain. EV mode is only possible for a very limited period of time, and this is not a standard mode. Compared to full hybrids, the amount of electrical power needed is smaller, thus the size of the battery system can be reduced. The electric motor, mounted between the engine and transmission, is essentially a very large starter motor, which operates not only when the engine needs to be turned over, but also when the driver "steps on the gas" and requires extra power. The electric motor may also be used to re-start the combustion engine, deriving the same benefits from shutting down the main engine at idle, while the enhanced battery system is used to power accessories. The electric motor is a generator during regenerative breaking.

Examples:

Honda's hybrids including the Civic and the Insight use this design, leveraging their reputation for design of small, efficient gasoline engines; their system is dubbed Integrated Motor Assist (IMA). Starting with the 2006 Civic Hybrid, the IMA system now can propel the vehicle solely on electric power during medium speed cruising.

A variation on this type of hybrid is the Saturn VUE Green Line hybrid system that uses a smaller electric motor (mounted to the side of the engine), and battery pack than the Honda IMA, but functions similarly.

Another variation on this type is Mazda's e-4WD system, offered on the Mazda Demio sold in Japan. This front-wheel drive vehicle has an electric motor which can drive the rear wheels when extra traction is needed. The system is entirely disengaged in all other driving conditions, so it does not enhance performance or economy.

1.5 MILD HYBRID / MICRO HYBRID (= start/stop systems with energy recuperation)

Mild hybrids are essentially conventional vehicles with oversized starter motors, allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly and cleanly.

During restart, the larger motor is used to spin up the engine to operating rpm speeds before injecting any fuel. That concept is not unique to hybrids; Subaru pioneered this feature in the early 1980s, and the Volkswagen Lupo 3L is one example of a conventional vehicle that shuts off its engine when at a stop.

As in other hybrid designs, the motor is used for regenerative braking to recapture energy. But there is no motor-assist, and no EV mode at all. Therefore, many people do not consider these to be hybrids, since there is no electric motor to drive the vehicle, and these vehicles do not achieve the fuel economy of real hybrid models.

Some provision must be made for accessories such as air conditioning which are normally driven by the engine. Those accessories can continue to run on electrical power while the engine is off.

Furthermore, the lubrication systems of internal combustion engines are inherently least effective immediately after the engine starts; since it is upon startup that the majority of engine wear occurs, the frequent starting and stopping of such systems reduce the lifespan of the engine considerably. Also, start and stop cycles may reduce the engine's ability to operate at its optimum temperature, thus reducing the engine's efficiency as shown in Fig 1.8.

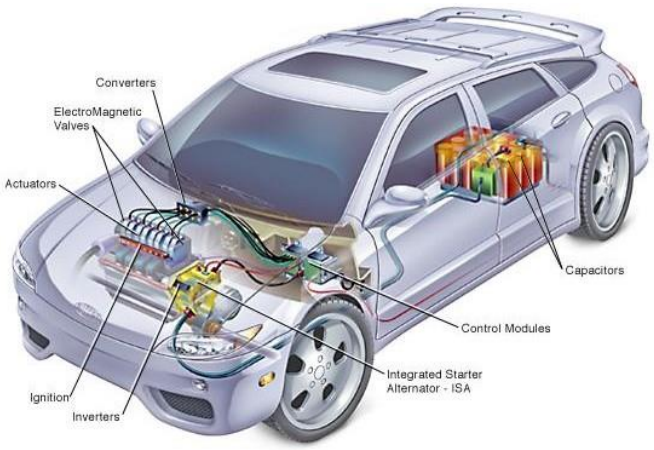

Fig. 1.8: Powertrain of a mild HEV

Examples:

BMW succeeded in combining regenerative braking with the mild hybrid "start-stop" system in their current 1-series model.

Citroën proposes a start-stop system on its C2 and C3 models. The concept-car C5 Airscape has an improved version of that, adding regenerative breaking and traction assistance functionalities, and supercapacitors for energy buffering.

1.6 PLUG-IN HYBRID (= grid connected hybrid = vehicle to grid V2G)

All the previous hybrid architectures could be grouped within a classification of *charge sustaining*: the energy storage system in these vehicles is designed to remain within a fairly confined region of state of charge (SOC). The hybrid propulsion algorithm is designed so that on average, the SOC of energy storage system will more or less return to its initial condition after a drive cycle.

A plug-in hybrid electric vehicle (PHEV) is a *full hybrid*, able to run in electric-only mode, with larger batteries and the ability to recharge from the electric power grid. Their main benefit is that they can be gasoline-independent for daily commuting, but also have the extended range of a hybrid for long trips.

Grid connected hybrids can be designed as *charge depleting*: part of the “fuel” consumed during a drive is delivered by the utility, by preference at night. Fuel efficiency is then calculated based on actual fuel consumed by the ICE and its gasoline equivalent of the kWh of energy delivered by the utility during recharge. The "well-to-wheel" efficiency and emissions of PHEVs compared to gasoline hybrids depends on the energy sources used for the grid utility (coal, oil, natural gas, hydroelectric power, solar power, wind power, nuclear power).

In a serial Plug-In hybrid, the ICE only serves for supplying the electrical power via a coupled generator in case of longer driving distances. Plug in hybrids can be made multi-fuel, with the electric power supplemented by diesel, biodiesel, or hydrogen.

The Electric Power Research Institute's research indicates a lower total cost of ownership for PHEVs due to reduced service costs and gradually improving batteries.

Some scientists believe that PHEVs will soon become standard in the automobile industry. Plug-in vehicles which use batteries to store electric energy *outperform* cars which use hydrogen as carrier for the energy taken from the grid. The following figures indicate the efficiencies of a hydrogen fuel cell HEV and a battery powered EV.

Left a battery powered plug in EV (Mitsubishi Lancer Evolution MIEV)) Right a Fuel Cell EV (Mercedes NECAR 3)

For typical driving cycles, the achieved efficiencies are lower. The battery powered EV achieves efficiencies in the range of 50 to 60%. The hydrogen powered EV has a total efficiency of about 13% only at those drive cycles.

1.7 TYPES BY NATURE OF THE POWER SOURCE

Electric-internal combustion engine hybrid

There are many ways to create an electric-internal combustion hybrid. The variety of electric-ICE designs can be differentiated by how the electric and combustion portions of the powertrain connect (series, parallel or combined), at what times each portion is in operation, and what percent of the power is provided by each hybrid component. Many designs shut off the internal combustion engine when it is not needed in order to save energy, see 2.3.

Fuel cell hybrid

Fuel cell vehicles have a series hybrid configuration. They are often fitted with a battery or supercapacitor to deliver peak acceleration power and to reduce the size and power constraints on the fuel cell (and thus its cost). See 1.1.

Human power and environmental power hybrids

Many land and water vehicles use human power combined with a further power source. Common are parallel hybrids, e.g. a boat being rowed and also having a sail set, or motorized bicycles. Also some series hybrids exist. Such vehicles can be tribrid vehicles, combining at the same time three power sources e.g. from on-board solar cells, from grid-charged batteries, and from pedals.

The following examples don't use electrical power, but can be considered as hybrids as well: Pneumatic hybrid

Compressed air can also power a hybrid car with a gasoline compressor to provide the power. Moteur Development International in France produces such air cars. A team led by Tsu-Chin Tsao, a UCLA mechanical and aerospace engineering professor, is collaborating with engineers from Ford to get Pneumatic hybrid technology up and running. The system is similar to that of a hybrid-electric vehicle in that braking energy is harnessed and stored to assist the engine as needed during acceleration.

Hydraulic hybrid

A hydraulic hybrid vehicle uses hydraulic and mechanical components instead of electrical ones. A variable displacement pump replaces the motor/generator, and a hydraulic accumulator (which stores energy as highly compressed nitrogen gas) replaces the batteries. The hydraulic accumulator, which is essentially a pressure tank, is potentially cheaper and more durable than batteries. Hydraulic hybrid technology was originally developed by Volvo Flygmotor and was used experimentally in buses from the early 1980s and is still an active area.

Initial concept involved a giant flywheel (see Gyrobus) for storage connected to a hydrostatic transmission, but it was later changed to a simpler system using a hydraulic accumulator connected to a hydraulic pump/motor. It is also being actively developed by Eaton and several other companies, primarily in heavy vehicles like buses, trucks and military vehicles. An example is the Ford F-350 Mighty Tonka concept truck shown in 2002. It features an Eaton system that can accelerate the truck up to highway speeds.

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UNIT – II – POWER SYSTEM AND NEW GENERATION VEHICLES – SAU1604

UNIT 2

POWER SYSTEM AND NEW GENERATION VEHICLES

2.1 STRATIFIED ENGINES

For many decades the researchers have pursued development of direct injection stratified charge SI engines to have overall very lean engine operation for higher fuel efficiency. Charge stratification is a means of ensuring repeatable ignition without misfire and stable combustion while using overall very lean fuel-air ratios that is otherwise not possible with homogeneous mixtures. In the stratified charge engines, the mixture composition is varied within the combustion chamber such that stoichiometric or slightly richer mixture exits near spark plug to provide good ignition characteristics and the mixture gets progressively leaner away from the spark plug. Overall air-fuel ratio in the cylinder is significantly leaner than the stoichiometric. A typical configuration of DISC engine is shown on Fig 7.1. Liquid fuel is injected in the cylinder. The fuel spray is directed by air motion or by the geometry of piston crown or by combination of the both towards spark plug. By the time fuel spray reaches the spark plug electrodes some fuel gets vaporized and forms combustible mixture with air. The vaporized fuel in spray is then ignited by spark, combustion begins and the flame spreads in the combustion chamber.

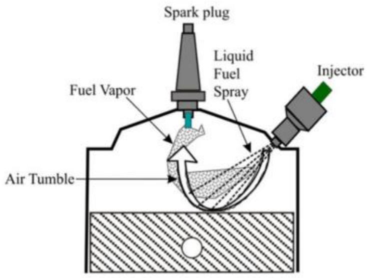

Fig. 2.1: Schematic of a direct injection stratified charge (DISC) engine combustion system

Potential Advantages of DISC Engines The direct injection stratified charge SI engines have the potential to provide following advantages over the premixed homogeneous charge engines; The mixture being rich near spark plug good ignition characteristics without misfire are obtained. High combustion temperatures obtained as a result of initial burning of rich mixtures near spark plug produce high flame speeds that burn the lean mixtures in the cylinder away from spark plug. The overall air-fuel ratio can be very lean reaching 40:1 to 50:1giving high fuel efficiency. An unthrottled engine operation is possible such that the engine power may be controlled by varying only the fuel flow. It would reduce pumping losses. The end gases being very fuel lean, precombustion reactions would be very slow leading to reduced knocking tendency. Hence, a higher compression ratio can be used further improving the fuel efficiency. Presence of rich mixture near spark plug keeps the formation of NOx at low levels. The mixture that burns early is deficient in oxygen although it attains high combustion temperatures as shown in the fig 2.1.

2.2 LEAN BURN ENGINE

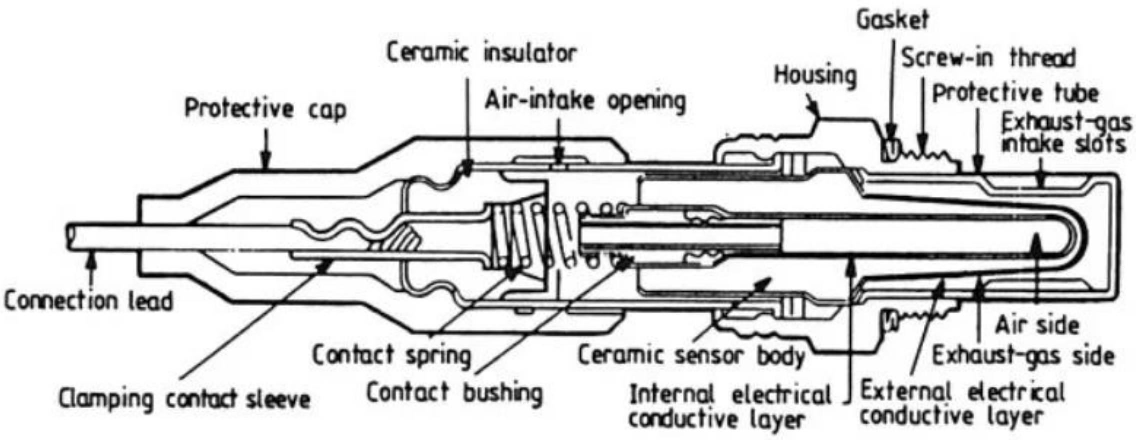

Fig. 2.2: Lean burn engine

Lean-burn means pretty much what it says. It is a lean amount of fuel supplied to and burned in an engine's combustion chamber. Normal air-to-fuel ratio is on the order of 15:1 (15 parts air to 1 part fuel). True lean-burn can go as high as 23:1.

Lean-burn engines (both gasoline and diesel) enjoy higher fuel economy and cleaner emissions than conventionally tuned engines. by nature they use less fuel and emit fewer unburned hydrocarbons and greenhouse gases while producing equivalent power of a like-sized "normal" combustion engine. They achieve leanburn status by employing higher combustion chamber compression ratios (higher cylinder pressure), significant air intake swirl and precise lean-metered direct fuel injection.

Working of Lean Burn Engine

Lean-burn engines (both gasoline and diesel) enjoy higher fuel economy and cleaner emissions than conventionally tuned engines. by nature they use less fuel and emit fewer unburned hydrocarbons and greenhouse gases while producing equivalent power of a like-sized "normal" combustion engine. They achieve leanburn status by employing higher combustion chamber compression ratios (higher cylinder pressure), significant air intake swirl and precise lean-metered direct fuel injection.

- A lean burn mode is a way to reduce throttling losses.
- An engine in a typical vehicle is sized for providing the power desired for acceleration, but must operate well below that time in normal steady-speed operation. Ordinarily, the power is cut by partially closing a throttle.
- However, the extra work done in pumping air through the throttle reduces efficiency.
- If the fuel/air ratio is reduced, then lower power are often achieved with the throttle closer to fully open, and the efficiency during normal driving (below the maximum torque capability of the engine) are often higher.
- The engines designed for lean burning can employ higher compression ratios and thus provide better performance, efficient fuel use and low exhaust hydrocarbon emissions than those found in conventional petrol engines.
- Ultra lean mixtures with very high air-fuel ratios can only be achieved by direct injection engines.
- the most drawback of lean burning is that a posh converter system is required to reduce NOx emissions.
- Lean burn engines don't work well with modern 3-way converter which needs a pollutant balance at the exhaust port in order that they can carry out oxidation and reduction reactions so latest engines run at or near the stoichiometric point.
- Alternatively, ultra-lean ratios can reduce NOx emissions

Advantages of lean burn engine

- Higher fuel economy
- Emit fewer unburned hydrocarbons and greenhouse gases
- A lean burn mode may be a way to reduce throttling losses

Disadvantages of lean burn engine

- Lean burning is that a complex catalytic converter system is required to reduce NOx emissions.
- High relatively cost

2.3 HYDROGEN ENGINES

The small number of vehicles using hydrogen internal combustion engines (HICE) makes it difficult to explain how to repair them. Therefore, this section does not serve as a repair manual, but as an outline describing the operation of a hydrogen engine and its major components, its benefits, drawbacks and how components can be modified or redesigned to reduce the drawbacks.

Combustive Properties of Hydrogen Key Points & Notes: The properties of hydrogen are detailed in Section 1. The properties that contribute to its use as a combustible fuel are its: • wide range of flammability • low ignition energy • small quenching distance • high autoignition temperature • high flame speed at stoichiometric ratios • high diffusivity • very low density

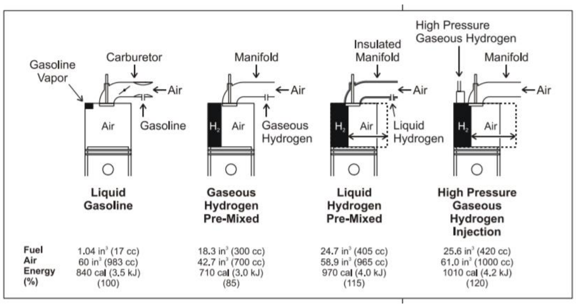

Fig. 2.3: Hydrogen engines

Working principle

Depending the method used to meter the hydrogen to the engine, the power output compared to a gasoline engine can be anywhere from 85% (intake manifold injection) to 120% (high pressure injection). Because of hydrogen's wide range of flammability, hydrogen engines can run on A/F ratios of anywhere from 34:1 (stoichiometric) to 180:1. The A/F ratio can also be expressed in terms of equivalence ratio, denoted by phi (Φ). Phi is equal to the stoichiometric A/F ratio divided by the actual A/F ratio. For a stoichiometric mixture, the actual A/F ratio is equal to the stoichiometric A/F ratio and thus the phi equals unity (one). For lean A/F ratios, phi will be a value less than one. For example, a phi of 0.5 means that there is only enough fuel available in the mixture to oxidize with half of the air available. Another way of saying this is that there is twice as much air available for combustion than is theoretically required.

2.4 SURFACE IGNITION

Surface ignition may be initiated by one of two mechanisms: mechanical hot spots or combustion-chamber deposits. Conditions determining whether or not surface ignition occurs and the surface ignition resistance of fuels are different for each mechanism. The occurrence of surface ignition may be detected by changes in engine noise, time of peak pressure, rate of pressure rise, or flame front propagation time.

Surface ignition may cause decreased engine power, increased heat rejection, and, in severe cases, component physical damage and ultimate failure. Increased compression ratio, speed, and specific output all increase the tendency of an engine to experience surface ignition.

The composition and additive treatment of both gasoline and crankcase oil have large effects on the surface ignition tendencies of accumulated combustion-chamber deposits. Minimizing the heavy aromatic content of gasoline can reduce surface ignition, but a more effective method is the use of phosphorus containing, deposit modifier gasoline additives. Minimizing the bright stock content and metallic detergent content of the crankcase oil reduces its contribution to surface ignition activity.

2.5 FLEXIBLE FUEL VEHICLES

Flexible fuel vehicles (FFVs) have an internal combustion engine and are capable of operating on gasoline and any blend of gasoline and ethanol up to 83%. E85 (or flex fuel) is a gasoline-ethanol blend containing 51% to 83% ethanol, depending on geography and season. According to IHS Markit, as of 2017, there were more than 21 million FFVs in the United States. Because FFVs are factory made and are capable of operating on gasoline and gasoline-ethanol blends, many vehicle owners don't realize their car is an FFV and that they have a choice of fuels to use. Visit Fueleconomy.gov to learn how to identify an FFV or use the Alternative Fuel and Advanced Vehicle Search to find current FFV models.

Other than an ethanol-compatible fuel system and a different powertrain calibration, FFVs are similar to their conventional gasoline-only counterparts. While fuel economy (miles per gallon) is generally lower with increased levels of ethanol (due to the lower energy content in ethanol as compared to gasoline and because the engines are optimized for gasoline), many FFVs have improved acceleration performance when operating on higher ethanol blends. For additional information on the fuel economy and performance of FFVs, see Effects of High-Octane Ethanol Blends on Four Legacy Flex-Fuel Vehicles, and a Turbocharged GDI Vehicle

2.6 FREE PISTON.

How does a free piston work

The working principle of the free piston engine is **a two-stroke engine cycle, using the linear motion of pistons sliding in a cylinder**. The piston is driven by gas pressure and other forces on the pistons and, hence, this engine functions similar to a mass spring system.

Free-piston engines have great potential for use as **generators for range-extended electric cars** or even driving a full series-hybrid in place of a more conventional crankshaft-based engine

It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is **to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod** and/or connecting rod.

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SCHOOL OF MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – III – VEHICLE OPERATION AND CONTROL – SAU1604

UNIT 3

VEHICLE OPERATION AND CONTROL

3.1 Structure and composition of atmosphere Atmosphere, composition and structure. Earth's atmosphere is composed of about 78% nitrogen, 21% oxygen, and 0.93% argon. The remainder, less than 0.1%, contains such trace gases as water vapor, carbon dioxide, and ozone.

Definition of Air pollutants: Substances introduces into the air, natural or manmade, in concentrations detrimental to human, plant or animal life, or to property.

3.2 Major Classification of Air Pollutants

1] Primary – Secondary

2] Natural – Manmade

3] Criteria Air Pollutants

4] Physical - chemical - biological

3.4 Primary pollutants and secondary pollutants: Primary pollutants are substances that are directly emitted into the atmosphere from sources. Primary pollutants are those that are emitted directly from identifiable sources. Secondary air pollutants are those that are produced in the air by the interaction of two or more primary air pollutant.

Primary Air pollutants

(i) Fine (less than 100μ) and coarse (more than 100μ) suspended particulate matter

(ii) Oxides of sulfur

(iii) Oxides of nitrogen

(iv) Carbon monoxide

(v) Halogens

(vi) Organic compounds

(vii) Radioactive compounds

Secondary Air pollutants

(i) Ozone

(ii) PAN (peroxi aceyl nitrate)

(iii) Photochemical smog

(iv) Acid mists

Air pollutants arise from both manmade and natural processes. The ambient air quality may be defined by the concentration of a set of pollutants which may be present in the ambient air we breathe in. These pollutants may be called criteria pollutants.

Natural Contaminants: Pollen is important natural contaminant because of its peculiar properties of irritation and allergy sometimes leading to bronchitis, asthma and dermatitis. Pollen grains are the male gametophytes of gymnosperms and angiosperms and they are discharged into the atmosphere from plants etc. The air transported pollen grains range mainly between 10 and 50 microns. Manmade refers to any pollutant produced to influence or action of humans.

Aerosols: Aerosols refer to the dispersion of solid or liquid particles of microscopic size in the air. It can also be defined as a colloidal system in which the dispersion medium is gas and the dispersed phase is solid or liquid. The term aerosol is applicable until it is in suspension and after settlement due to its own weight or by addition with other particles (agglomeration) it is no longer an air pollutant. The diameter of the aerosol may range from 0.01 (or less) micron to 100 micron.

3.5 The various aerosols are as follows

(i) Dust: Dust is produced by the crushing, grinding and natural sources like windstorms. Generally the dust particles are over 20 micron in diameter. They do not flocculate but settle under gravity, but smaller particles like 5 micron form stable suspensions.

(ii) Smoke: Smoke is made up of finely divided particles produced by incomplete combustion. Generally it consists of carbon particles of size less than 1.0 micron.

(iii) Mists: Mist is a light dispersion of minute water droplets suspended in the atmosphere ranging from 40 to 400 micron in size.

(iv) Fog: Fog is made up of dispersion of water or ice near the earth's surface reducing visibility to less than 500 m. In natural fog the size of particles range from 1.0 to 40 micron.

(v) Fumes: Fumes are solid particles generated by condensation from the gaseous state after volatilization from melted substances. Fumes flocculate and sometimes coalesce.

Gases: Following are the main air pollutant gases

(i) Sulphur dioxide: It is a major air pollutant gas produced by the combustion of fuels like coal. The main source of electricity production is by burning of fossil fuels in India and the whole world. The sulphur content of the coal varies from 1 to 4% and fortunately the Indian coal is low in sulphur content. SO2 is also produced in the metallurgical operations.

(ii) Oxides of nitrogen: Oxides of nitrogen are produced either in the production of nitric acid or in the automobile exhausts and as the effluent of power plants. Out of the seven oxides of Nitrogen (N2O, NO, NO2, NO3, N2O3, N2O4, N2O5) only nitric oxide and nitrogen dioxide are classified as the main pollutants. All the oxides of nitrogen are collectively known as NOX.

(iii) Carbon monoxide: It is produced because of the incomplete combustion of coal and other petroleum products. It is produced in the exhaust of automobiles. In the pollution check of vehicles mainly CO and unburnt hydrocarbons are measured.

(iv) Hydrogen sulphide: Hydrogen Sulphide is an obnoxious (bad smelling) gas. It is produced mainly by the anaerobic (in absence of air) decomposition of organic matter. Other air polluting sulfur compounds are methyl mercaptan (CH3SH) and dimethyl sulphide (CH3-S-CH3) etc.

(v) Hydrogen fluoride: It is an important pollutant even in very low concentrations. It is produced in the manufacturing of phosphate fertilizers.

(vi) Chlorine and hydrogen chloride: It is mixed in the air either from the leakages from water treatment plants or other industries where it is produced or used. Hydrogen chloride is also evolved in various industrial chemical processes. The main effect of chlorine is respiratory irritation which may be fatal.

(vii) Ozone: It is a desirable gas in the upper layers of atmosphere as it absorbs the UV radiation of sunlight. But near the earth surface it is a poisonous gas. It makes poisonous chemicals by photochemical reactions.

(viii) Aldehydes: They are produced by the incomplete oxidation of motor fuels and lubricating oil. They may also be formed because of photochemical reactions. Formaldehydes are irritating to the eyes.

3.6 Classification according to chemical composition: (Organic – inorganic)

1. Sulfur-containing compounds.

2. Nitrogen-containing compounds.

3. Carbon-containing compounds.

4. Halogen-containing compounds.

5. Toxic substances (any of about).

6. Radiative compounds.

Classification according to physical state:

1. Gaseous.

2. Liquid (aqueous).

3. Solid.

Criteria air pollutants are six major pollutants defined by EPA (Environmental Protection Agency) for which ambient air standards have been set to protect human health and welfare.

These include :

1. Ozone, O3.

2. Carbon monoxide, CO.

3. Sulfur dioxide, SO2.

4. Nitrogen oxides, NOx.

5. Lead, Pb.

6. Particulates, PM10.

3.7 PARTICULATES

- A high concentration of **particulate matter** (PM) is manifested as visible smoke in the exhaust gases.
- Particulates are any substance other than water that can be collected by filtering the exhaust, classified as:
- Solid carbon material or soot.
- Condensed hydrocarbons and their partial oxidation products.
- Diesel particulates consist of solid carbon (soot) at exhaust gas temperatures below 500^{o}C, HC compounds become absorbed on the surface.
- In a properly adjusted SI engines soot is not usually a problem .
- Particulate can arise if leaded fuel or overly rich fuel-air mixture are used.
- Burning crankcase oil will also produce smoke especially during engine warm up where the HC condense in the exhaust gas.

3.8 EMISSION CONTROL

Three basic methods used to control engine emissions:

1) Engineering of combustion process -advances in fuel injectors, oxygen sensors, and on-board computers.
2) Optimizing the choice of operating parameters -two Nox control measures that have been used in automobile engines are spark retard and EGR.
3) After treatment devices in the exhaust system –catalytic converter.

3.9 NOISE CONTROL

Noise control is becoming increasingly important for a wide variety of OEM designers.

Examples of products that take noise control considerations into account during their design cycles include equipment such as computer hard drives, house appliances, material handling and transportation equipment etc.

3.10 DEFINITION OF SOUND

Sound can be defined as the perception of vibrations stimulating the ear. If scientifically taken into account, sound is a periodic disturbance in fluids density or in the elastic strain of a solid, generated by vibrating objects.

These waves or vibrations propagate in two basic ways.

1. Longitudinal waves.
2. Transverse waves

3.11 TYPES OF SOURCES OF NOISE

Sources of noise are numerous but may be classified broadly into two classes as

1. Industrial
2. Non Industrial

The industrial may included noises from various industries operating in cities like transportation, air crafts, rockets, defense equipment's, explosions etc. The disturbing qualities of noise emitted by industrial premises are generally its loudness, its distinguishing features such as tonal or impulsive components and its intermittency and duration.

In non industrial source, major one is traffic mopeds and scooters with have a maximum of 75 dBA and 50 dBA respectively, according to new norms from 1st January 2003.

The present norms for petrol and diesel driven two wheelers are 50dBA and 82 dBA respectively.

Present norms for three wheelers are 82 dBA for petrol and 85 dBA for diesel will be modified as three wheelers upto 175 cc, 75 dBA and above 175 cc, 80dBA. Passenger cars can produce maximum noise of 75dBA present being 82dBA.

3.12 CLASSIFICATION OF NOISE CHARACTERISTICS

One typical engine noise classification technique separates the aerodynamic noise, combustion noise and mechanical noise.

1. Aerodynamic Noise
2. Combustion Noise
3. Mechanical Noise

3.13 LVDT

The term LVDT or Linear Variable Differential Transformer is a robust, complete linear arrangement transducer and naturally frictionless. They have an endless life cycle when it is used properly. Because AC controlled LVDT does not include any kind of electronics, they intended to work at very low temperatures otherwise up to 650 °C (1200 °F) in insensitive environments. The applications of LVDTs mainly include automation, power turbines, aircraft, hydraulics, nuclear reactors, satellites, and many more. These types of transducers contain low physical phenomena and outstanding repetition.

The LVDT alters a linear dislocation from a mechanical position into a relative electrical signal including phase and amplitude of the information of direction and distance. The operation of LVDT does not need an electrical bond between the touching parts and coil, but as an alternative depends on the electromagnetic coupling.

What is an LVDT (Linear Variable Differential Transformer)?

The LVDT full form is "Linear Variable Differential Transformer" is LVDT. Generally, LVDT is a normal type of transducer. The main function of this is to convert the rectangular movement of an object to the equivalent electrical signal. LVDT is used to calculate displacement and works on the transformer principle.

The above LVDT sensor diagram comprises a core as well as a coil assembly. Here, the core is protected by the thing whose location is being calculated, while the coil assembly is increased to a stationary structure. The coil assembly includes three wire-wound coils on the hollow shape. The inside coil is the major, which is energized by an AC source. The magnetic flux generated by the main is attached to the two minor coils, making an AC voltage in every coil.

Linear Variable Differential Transformer

The main benefit of this transducer, when compared with other LVDT types, is toughness. As there is no material contact across the sensing component.

Because the machine depends on the combination of magnetic flux, this transducer can have an unlimited resolution. So the minimum fraction of progress can be noticed by an appropriate signal conditioning tool, and the transducer's resolution is exclusively determined by the declaration of the DAS (data acquisition system).

Linear Variable Differential Transformer Construction

LVDT comprises a cylindrical former, which is bounded by one main winding in the hub of the former and the two minor LVDT windings are wound on the surfaces. The amount of twists in both the minor windings is equivalent, but they are reversed to each other like clockwise direction and anti-clockwise direction.

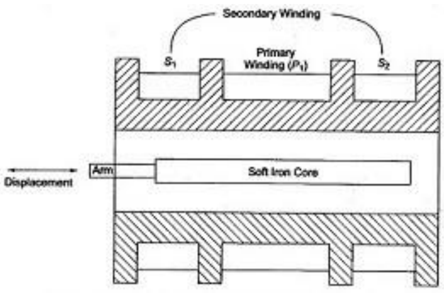

Fig. 3.1: Linear Variable Differential Transformer Construction

For this reason, the o/p voltages will be the variation in voltages among the two minor coils. These two coils are denoted with S1 & S2. Esteem iron core is located in the middle of the cylindrical former. The excitation voltage of AC is 5-12V and the operating frequency is given by 50 to 400 HZ.

Working Principle of LVDT

The working principle of the linear variable differential transformer or LVDT working theory is mutual induction. The dislocation is nonelectrical energy that is changed into electrical energy. And, how the energy is altered is discussed in detail in the working of an LVDT.

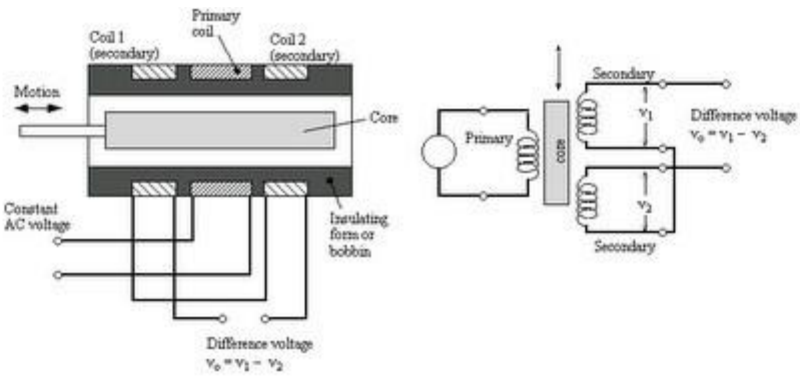

Fig.3.2: LVDT Working Principle

Working of an LVDT

The working of the LVDT circuit diagram can be divided into three cases based on the position of the iron core in the insulated former.

- **In Case-1:** When the core of the LVDT is at the null location, then both the minor windings flux will equal, so the induced e.m.f is similar in the windings. So for no dislocation, the output value (e_{out}) is zero because both the e1 & e2 are equivalent. Thus, it illustrates that no dislocation took place.
- **In Case-2:** When the core of the LVDT is shifted up to the null point. In this case, the flux involving minor winding S1 is additional as contrasted to flux connecting with the S 2 winding. Due to this reason, e1 will be added as that of e2. Due to this e_{out} (output voltage) is positive.
- **In Case-3:** When the core of the LVDT is shifted down to the null point, In this case, the amount of e2 will be added as that of e1. Due to this e_{out} output voltage will be negative plus it illustrates the o/p to down on the location point.

3.14 INTRODUCTION TO TRANSDUCERS, SENSORS, AND ACTUATORS

Introduction

Three types of transducers: light bulb, microphone, and electric motors. A transducer is any device which converts one form of energy into another. Examples of common transducers include the following:

- A microphone converts sound into electrical impulses and a loudspeaker converts electrical impulses into sound (i.e., sound energy to electrical energy and vice versa).
- A solar cell converts light into electricity and a thermocouple converts thermal energy into electrical energy.
- An incandescent light bulb produces light by passing a current through a filament. Thus, a light bulb is a transducer for converting electrical energy into optical energy.
- An electric motor is a transducer for conversion of electricity into mechanical energy or motion.

An actuator is a device that actuates or moves something. An actuator uses energy to provide motion. Therefore, an actuator is a specific type of a transducer. Which of the previously mentioned examples is an actuator?

A sensor is a device that receives and responds to a signal. This signal must be produced by some type of energy, such as heat, light, motion, or chemical reaction. Once a sensor detects one or more of these signals (an input), it converts it into an analog or digital representation of the input signal.

Based on this explanation of a sensor, you should see that sensors are used in all aspects of life to detect and/or measure many different conditions. What are some sensors that you are familiar with or use daily?

Human beings are equipped with 5 different types of sensors.

Eyes detect light energy, ears detect acoustic energy, a tongue and a nose detect certain chemicals, and skin detects pressures and temperatures. The eyes, ears, tongue, nose, and skin receive these signals then send messages to the brain which outputs a response. For example, when you touch a hot plate, it is your brain that tells you it is hot, not your skin.

This unit describes the basic concepts of transducers, sensors, and actuators and introduces the different types in both the macro and micro scales.

Objectives

- Explain the differences between sensors, transducers, and actuators.
- Describe three types of sensors. Include at least one microsensor.
- Describe three types of transducers. Include at least one microtransducer**.**

Basic Concepts of Transducers

There are many variables which affect our everyday lives: the speed of a car, the velocity of the wind, and the temperature in a home. In most situations these variables are continuously monitored.

It is these variables that are the feedback that is used to control the speed of a car, the operation of an air conditioner, heater levels, and oven temperatures. The elements that sense these variables and convert them to a usable output are transducers. For example, a transducer known as a thermocouple, is able to sense changes in temperature and produce output voltages representative of those changes.

A transducer is defined as a substance or a device that converts (or transfers) an input energy into a different output energy. Because of this broad definition, transducers come in many varieties converting many different types of energy. Following are different types of transducers.

Electrochemical Transducers

- Converting a Chemical Reaction to Electrical Energy (left: Fuel Cell, right: battery)
- Some common electrochemical transducers include the following:
- pH probe – Converts chemical energy into an electrical energy
- Molecular electric transducer – Converts motion in an electrolytic solution into electrical energy
- Battery – Converts chemical energy directly into electrical energy
- Fuel cell – Converts the energy from a reaction within a fuel cell to electrical energy Let's take a closer look at the electrochemical battery illustrated above. This battery converts chemical energy directly into electrical energy. A cathode and an anode (typically two dissimilar metals) are each immersed in an electrolyte solution containing salts of their respective metals. A medium (the salt bridge) separates the two electrodes, but allows ions to flow between the two solutions. Due to the flow of ions between the two solutions a potential difference (or voltage) is created. An electrical current flows if a wire is connected between the two pieces of metals. The amount of voltage developed between the cathode and the anode depends on the materials that make up the battery.

The fabrication of micro batteries has been a challenge but a challenge that needs to be met. Microsized sensors require micro-sized batteries in order to operate, especially when those sensors are placed in remote areas such as the ocean floor or embedded below the surface of bridges and roads.

So how do you get a long-lasting electrochemical battery from a device that is smaller than the diameter of a strand of hair? "Traditional batteries have a two-dimensional array of positive and negative electrodes stacked on top of one another like sheets of paper. Increasing battery power means adding more electrode layers, more weight and more size."1 Electroacoustic, Electromagnetic, and Electrostatic Transducers

Common electroacoustic transducers:

- Loudspeaker – Converts an electrical signal into sound
- Microphone – Converts sound waves in air into an electrical signal
- Hydrophone - Converts sound waves in water into an electrical signal.

Common electromagnetic transducers:

- Magnetic cartridge – Converts motion in a magnetic field into an electrical energy
- Generator – Converts motion in a magnetic field into electrical energy

Common electrostatic transducers:

- Electrometer – Converts static or energy from a vibrating reed into electricity

Electromechanical Transducers – (Some are also called actuators)

- Strain gauge – Converts the deformation (strain) of an object into electrical resistance
- Galvanometer – Converts the electric current of a coil in a magnetic field into movement
- Generators – Converts mechanical energy (motion) into electrical energy.
- Motor – Converts electrical energy into mechanical energy (graphic below)

As with other types of transducers, electromechanical transducers come in all sizes from macro to micro. Microgenerators have been developed that may someday replace batteries. A Georgia Tech MEMS Project has developed a 10 millimeter wide generator that spins a micro-sized magnet above a mesh of coils fabricated on a chip. The micromagnet spins at 100,000 rpm, producing 1.1 watts, enough power for a cell phone. 4

Other Types of Transducers

- Converts Electrical Signals into Light Energy
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Photoelectric Transducers:

- Cathode ray tube (CRT) –Converts electrical signals into light energy for a visual output (graphic above)
- Light bulb –Converts electrical energy into visible light and heat (explained in next section)
- Laser diode – Converts electrical energy into light energy
- Photodiode - Converts light energy into electrical energy

Thermoelectric Transducers:

- Thermocouple – Converts heat energy into electrical energy
- Temperature sensitive resistor (Thermister) – a variable resistor affected by temperature changes (heat energy to electrical energy)

Other types of Transducers:

- Geiger-Müller tube – Converts radioactive energy into electrical energy
- Quartz Crystal – Converts mechanical stress into electricity (electrical energy)

Micro-sized transducers that use temperature, chemical reactions, and mechanical stress to produce changes in voltage, resistance, resonant frequency, or light are used throughout microsensors. Such transducers are used in MEMS pressure sensors, temperature sensors, chemical sensor arrays, and optical modulators.

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UNIT – IV – VEHICLE AUTOMATED TRACKS – SAU1604

UNIT 4

VEHICLE AUTOMATED TRACKS

4.1 AUTOMATED HIGHWAY SYSTEMS

A major long-term element of Intelligent Transportation Systems research and development is Automated highway Systems (AHS). The AHS program is a broad international effort "to provide the basis for, and transition to, the next major performance upgrade of the vehicle/highway system through the use of automated vehicle control technology" [NAHSC96].

The detailed definition of the Automated Highway System is as follows [Plan93]:

The term "fully automated intelligent vehicle-highway system" is interpreted to mean a system that:

Evolves from today's roads (beginning in selected corridors);

Provides fully automated "hands-off" operation at better levels of performance than today's roadways in terms of safety, efficiency, and operator comfort; and,

Allows equipped vehicles to operate in both urban and rural areas on highways that are both instrumented, and not instrumented.

The consensus in the AHS community is that AHS will evolve over a series of smaller steps in technology. The final step of full automation will not be a leap, but a logical consequence of previous development and deployment efforts. Each step in the technology will have its own benefits and be self-sustaining. Vehicle and infrastructure evolutions will be "synchronous" [James94]. We will briefly mention the steps of this evolution here before introducing the AHS program and discussing automatic vehicle control technologies in detail.

When the cruise control was first developed, there was much concern over the safety and user acceptance of the new system; however, it has become widely accepted and used. In the near

future, obstacle and headway warning and Automatic Vehicle Identification (AVI) will be added to modern cruise control and existing communications infrastructure. The success of AHS depends on linking the power of cellular communications and the emerging range of high performance computers to the ongoing vehicle based developments. Ideally, the highway system can be divided into a number of "cells" which contain local radio receivers or beacons that will be linked together through a fiber-optic network. Vehicles will also be equipped with a transceiver unit carrying several user services. The first applications of this technology are the Automatic Vehicle Identification (AVI) and Electronic Toll Collection (ETC). Obstacle and headway warning is the next step in AHS development in vehicles. Vehicle on-board radar (VORAD) systems in many commercial vehicles are already in use for the last two years. An important issue in warning systems is the capabilities of the sensor modules. Differentiating between a large vehicle and a small animal may not be possible using a simple system. A consequent application of the headway warning system is the automatic headway control. Adaptive cruise control systems are currently designed by many automobile manufacturers.

Roadside-to-vehicle and vehicle-to-vehicle communications are also important for the future of AHS. Automatic braking systems may be activated by decelerating vehicles in front, or by the infrastructure sending a deceleration request to the headway control system. The vehicle must be *very* sure about the imminent danger, and knowledge of following vehicles and their speeds is an important factor to be considered. Inter-vehicle communications and rear sensing both would help in automatic braking.

Evolution of the AHS system will continue with lane departure warning. It will be the first system to control lateral movement of vehicles. The lane holding feature will consequently be added to the adaptive cruise control, shortly after the lane departure warning feature.

Automatic lane holding will provide a "hands off/feet off" driving situation where the driver is still responsible for all command decisions in the vehicle and must be aware at all times of his surroundings. If the infrastructure knows the location of each vehicle, possesses the information about its current path, and is communicating with the vehicle, then the lateral control can be coordinated from the infrastructure.

Further advances in technology will force the driver to "lose" his control of the vehicle. In order to gain any additional benefit of safety and efficiency, the driver must be removed as the primary source of command and control. Of course, this change requires that the automated system perform better than a good driver, *i.e.*, no more than 1 critical error in 108 seconds be

made. This step will be the natural consequence of the previous progress. Obviously, not all vehicles will be equipped with this technology right away. Automated and manually driven vehicles have to coexist for some time.

A vehicle that can "predict" the actions of neighboring vehicles is an important step for safer highway transportation. Locating the position of all the vehicles in close proximity to the automated vehicle with high accuracy is essential. This can be accomplished through multisensor systems for adjacent vehicles and possibly inter-vehicle communications to give an idea of what to expect beyond adjacent vehicles. Alternatively, the "roadside control" may have knowledge of the positions of the vehicles relative to fixed reference points. This knowledge is obtained by either vehicle based or roadside based detection, and/or by communicating with the vehicle.

This technology requires extreme accuracy in vehicle location at all times. If the system is infrastructure-based, the infrastructure needs to know the locations of the non-automated vehicles, for safe and efficient implementation. The minimum update rate of information must be larger than 100 times per second with an accuracy less than 10 cm for the desired level of safety [James 94]. Automated vehicle control (AVC) systems are expected to boost the capacity by 50% even for mixed vehicle traffic. Once the system has knowledge of the surrounding environment to all extents, it can make decisions on merging and passing in addition to the headway control and lane keeping performed under driver control. Full system optimization and higher efficiencies can then be obtained as the percentage of automated vehicles on the road increases.

Highways contain many characteristics that simplify the problem of automation, such as uninterrupted traffic flow, controlled access. Therefore automation on arterials will lag significantly behind automated highways. However, many safety measures can be taken on arterials using the equipment already designed for the highway. For example, the problem of intersection collision can be reduced by activating the onboard warning systems and automatic braking systems with electronic signal lights in addition to the normal traffic signal. If the intersection detects a potential for a collision it can notify equipped vehicles. Problems to be encountered during AHS deployment on arterials include integration of cyclists and motorcyclists to the AVC system, and the effects of pedestrian and animal traffic.

The final step in the AHS' future is fully automatic control, wherein the driver will have no control over the vehicle. All trip decisions will be automatically made using AVL and ATIS information. The driver may be able to include additional criteria for route selection. Once the trip decision is made, the infrastructure, utilizing AVC, will guide the vehicle while constantly updating the routing strategy based on the current information obtained through Advanced Traffic Management System (ATMS).

4.2 AHS PROGRAM PHASES AND THE NATIONAL AUTOMATED HIGHWAY

Systems Consortium

The AHS program in United States is planned around three broad phases: Analysis (1993-96), System Definition (1994-2001), and Operational Tests and Evaluation (starting in 2001). The National Automated Highway System consortium (NAHSC) is responsible for conducting the second phase.

The Analysis Phase established an analytic program foundation. It consisted of Precursor Systems Analyses (PSA) [PSA94] by 15 contractor teams that addressed automated vehicle control requirements and issues in 16 topic areas, a human factors study effort to develop an AHS human factors design handbook, and National Highway Traffic Safety Administration (NHTSA) analyses to investigate other ITS automated vehicle control-based services that avoid collisions through warning and control. The PSA identified issues and risks associated with various AHS concepts and design areas. All contract teams submitted final reports in November 1994. The NAHSC is actively using these findings in their research.

The Systems Definition Phase is currently underway. The NAHSC is working in partnership with the federal government. The consortium includes representatives from the vehicle industry, highway industry, State and local governments, regional and metropolitan transportation agencies, and electronics/communications industries associated with the vehicle and communications market.

The milestones of the consortium program are as follows: (a) establishment of performance and design objectives, (b) a 1997 proof-of-technical-feasibility demonstration, (c) identification and description of multiple feasible AHS system concepts, (d) selection of the preferred AHS system configuration, (e) completion of prototype testing, and (f) completion of system and supporting documentation.

The Operational Test and Evaluation Phase is currently not funded. It would logically follow a successful completion of the Systems Definition Phase.

The National Automated Highway System Consortium (NAHSC) was formed to "specify, develop, and demonstrate a prototype Automated Highway System (AHS)" [NAHSC96]. The specification provides for an evolutionary deployment that can be tailored to meet today's transportation needs. The Consortium will seek opportunities for early introduction of vehicles and highway automation technologies to achieve benefits for all surface transportation users, while incorporating public and private stakeholder views to ensure that an AHS is economically, technically, and socially viable.

The consortium's proof-of-technical-feasibility demonstration is one of the major milestones of the AHS program, and is scheduled for October 1997. This demonstration will be a full-scale exhibition with multiple vehicles on a segment of the I-15 interstate highway near San Diego, integrating the technological achievements of the participants of the consortium and the transportation industry. The demonstration will focus on existing technologies and concepts that can be integrated quickly to provide a solid proof of feasibility.

The selection of the final AHS system configuration will be made during 1999, and the final decision on the preferred AHS configurations will be made in February 2000. Immediately after that date, the design, development and testing of the prototype system will begin. The design process will be finished before the end of year 2000; the development will conclude in 2001, and the prototype system's testing will be completed in August 2002.

4.3 VEHICLE CONTROL

Vehicle control is probably the most important part of the advanced AHS applications. Implementation of AHS necessitates automatically controlled vehicles as mentioned previously.

Achieving the optimal solution to congestion and safety problems requires extensive research in system modeling, lateral (steering) controls and longitudinal (speed and headway) controls. In a fully automated highway system, these control systems will rely on vehicle-to-vehicle communication, as information on velocity and acceleration of other vehicles will be utilized in individual vehicle controllers [Varaiya93]. The same information and much more (*e.g.*, desired speed and lane) may also be received via vehicle-to-roadside communications. Here, we will briefly discuss the previous research on lateral, longitudinal and combined lateral and longitudinal control of vehicle

4.4 **Lateral Control**

Hessburg and Tomizuka [Hessburg91] designed a fuzzy rule-based controller for lateral guidance of a vehicle. This system is based on human-type reasoning. Advantages of such a controller include flexibility in the choices of input/outputs, and on-line/off-line training capability. Their focus was achieving good tracking for a variety of roadway curves over a range of longitudinal vehicle speeds. Simulations to demonstrate its performance under parameter variations and external disturbances gave satisfactory results.

An alternative approach is presented in [Lubin92]. It concentrates the intelligence in the vehicle, using the visual sensing approach described in [Kornhauser91]. In this model, no infrastructure modification is needed, but considerable cost and complexity is added to each individual vehicle. With the current rate of technology improvement, this system may become feasible for production purposes. During the last five years, the research on lateral vehicle control and lane changing maneuvers was extensive. For a (non comprehensive) list of publications on the subject, see [PathDb96].

Besides the theoretical modeling and simulations for lateral control of vehicles, there are a few important experimental accomplishments: the use of magnetic markers, and the use of visual information for lateral position handling. The first method was designed by the PATH Program [PATH96] and employs magnetic markers imbedded into the road to detect the lateral displacement from the center of the lane [Tan96]. Current tests with a vehicle equipped with magnetic sensors on its front bumper are reported to be successful [Lee95].

4.5 LONGITUDINAL CONTROL

Longitudinal control is an important aspect of the future AHS. One of the major concepts in this area is *platooning*, which is a formation of traveling vehicles that maintain close spacing at highway speeds. The concept requires inter-vehicle communication links to provide velocity and possibly acceleration information from the lead vehicle to each of the following vehicles, as well as the velocity and acceleration of the preceding vehicle in the platoon. Sheikholeslam and Desoer [Sheikholeslam89] showed that inter-vehicle communications increases the stability of the platoon formation in the case of identical vehicle platoons.

4.6 COMBINED LATERAL AND LONGITUDINAL CONTROL

Although much of the research to date has focused primarily on either lateral or longitudinal control, an overall automated driving system combining both lateral and longitudinal control is vital for future automated highway systems. System models which incorporate longitudinal and lateral dynamics are very rare.

Kachroo and Tomizuka [Kachroo95c] studied combined longitudinal and lateral control to investigate the resulting behavior of the coupled system. It is shown that longitudinal controllers that directly control the wheel slip are inherently more stable, especially during lateral maneuvers on very slippery road conditions. Spooner and Passino [Spooner95] also developed sliding mode controllers for longitudinal and lateral control. Their fault tolerant algorithms were found to be stable for a variety of faults such as braking, powertrain, and steering systems. Yu and Sideris [Yu95] considered combined control using partial state-measurements of longitudinal and lateral deviations, longitudinal velocity and yaw rate. The research on combined control of vehicles is moving toward more realistic systems. New control approaches for more platoon operations in more complex situations such as entry and exit maneuvers are being studied [Yang96].

The PATH program investigates the use of machine vision for guiding lane change maneuvers [Malik95]. The vision system is modularly interfaced with the existing magnetic sensor system for lateral position measurements, and with active range sensors. Özgüner [Özgüner95] also described a vehicle-roadway system in which the control of vehicle movement is based on instrumentation located both in the vehicle and the roadway. A radar based system is used for both cruise control, and for providing position information in lateral maneuvers.

Combined lateral and longitudinal control experiments are yet to be designed and implemented; the 1997 AHS Demonstration will be a good occasion for combined control tests.

4.7 SENSORS AND COMMUNICATION

The realization of full AHS needs hardware both in infrastructure and the vehicle. Roadside monitors will measure traffic flow and speed, and vehicle paths will be calculated based on this information. Such measurements are currently made with loop detectors, ultrasonic sensors, AVI tags or vision systems. Information may be communicated by infrared beacons, broadcast and cellular radio, or using emerging ultra wideband technologies [James96]. The vehicles need a longitudinal sensor to measure distance and relative speed of the preceding vehicle. Such sensors may be based on radar, ultrasound, or vision [Özgüner95, Hedrick96, Pomerlau96]. Microwave radar sensors perform very well in fog and heavy rain, but they are very expensive. Laser radar systems are low-cost, but cannot handle low visibility conditions [Yanagisawa92].

To facilitate lane changes at a range of relative speeds, the vehicle must be equipped with sensors that locate vehicles on the side with a longitudinal range of about 30m. Infrared and laser range finding techniques may prove to be useful in this area.

Besides headway and side sensor information, longitudinal and lateral velocity and acceleration, yaw rate, front steering angle, and lateral deviation data is needed to obtain a robust combined lateral and longitudinal control. All of these except the last one can be obtained using on-board accelerometers and encoders. For vehicle position sensing, there are two alternatives: magnetic markers [Lee95], and vision systems [Pomerlau96]. Recent research done on vision systems showed significant promise, however these systems are more expensive than magnetic markers which, in turn, require infrastructure deployment as well as on-board sensors.

A sequence of single magnetic markers can also form a "word" that transfers information such as curvature, and number of lanes. However, this magnetic marker data contains only the static information (roadway characteristics), not dynamic information (such as information on other vehicles incidents), unlike the vision system.

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UNIT – V – SUSPENSION BRAKES AND AERODYNAMIC SAFETY – SAU1604

UNIT 5

SUSPENSION BRAKES AND AERODYNAMIC SAFETY

5.1 AIR SUSPENSION SYSTEM

These types of suspension systems are commonly used in a long-distance vehicle like buses. Due to the benefits of the air suspension system, nowadays this system is widely used in many vehicles. Schematic representation of this type of air suspension system is shown in the figure. It consists of four air springs which may be a bellow type or piston type. Air compressor is used to pressurize the purified air (through filter) from the atmosphere and stored in the accumulator at a pressure maintained between 5.6 to 7 kg/cm^2. To release the excess air and to maintain the pressure inside the accumulator, a safety relief valve is used. The high pressure compressed air enters into the air spring through levelling valve and lift control valve. The lift control valve was operated by a manual lever which is located in the panel board.

Advantages

1. It reduces noise, vibration, and harshness due to which passenger and driver attain better ride comfort. It reduces the journey tiredness of the driver and the passenger.
2. Change of spring deflection is quite low when compared with a conventional suspension system for both loading and unloading condition. This helps to reduce the load transfer on the vehicle.
3. Headlamp alignment remains constant though the vehicle is travelling over irregular roads.
4. With the help of automatic controlling tools, this system will provide some space for required wheel movement.

5.2 SHOCK ABSORBER

The spring system prevents the travelers and truckloads that do not cause any shocks when climbing up the sudden disturbance on the road. However, if the spring are stiffer than expected, it will not absorb the road shock. The spring will keep on oscillate even after crossing the disturbance till the energy is completely die out. Hence, to quickly dissipate the stored energy in springs, dampers are used. According to the working principle shock absorber are classified into three types they are,

1. Friction type
2. Hydraulic type
3. Air type

5.3 FRICTION TYPE

When one body is allowed to slide over the other, the surface of one body offers some resistance to the movement of the other body on it. This resisting force is called friction force. In leaf spring, the interleaf friction is act as a damper. It is not widely used with other types of springs.

5.4 WHAT IS ANTI-LOCK BRAKING SYSTEM?

Anti-lock Braking System also known as anti-skid braking system (ABS) is an automobile safety system which prevents the locking of wheels during braking and avoid uncontrolled skidding. The modern abs system allows steering during braking which gives more control over the vehicle in case of sudden braking. The main advantages of using ABS system in vehicle is that it provides better control over the vehicle and decreases stopping distance on dry and slippery surfaces. Since in ABS installed vehicle the chance of skidding is very less and hence it provides a better steering control during braking. Without ABS system, even a professional driver can fail to prevent the skidding of the vehicle on dry and slippery surfaces during sudden braking. But with ABS system, a normal person can easily prevent the skidding of the vehicle and get better steering control during braking.

Principle of Working

It works on the principle of threshold braking and cadence braking. Cadence braking and threshold braking is a technique in which a driver applies the brakes and releases it before locking up the wheel and then applies the brakes and releases it again before locking. This process of applying and releasing the brakes on the wheel is done in pulse form to prevent it from locking and stop skidding of the vehicle. The driver practices this technique to achieve better control over the vehicle during instant braking and stop skidding of the vehicle. The ABS system automatically does this cadence braking to prevent locking of wheel and skidding of vehicle when brakes are applied.

Why Anti-lock Braking System (ABS) is essential in vehicles?

To understand this in a better way lets us take an incident. When you are driving your car on a highway and suddenly an obstacle comes in front of you and you apply brake with full power. This will locks wheels of your car and your car will start skidding on the road and also during skidding you lost your steering control and unable to move the car in desired direction in which you want. Finally you hit that obstacle and meet an accident.

Let's us take another situation, now you are driving a car which is equipped with anti-lock braking system. When you encounter with an obstacle on the road and suddenly apply the brakes. But this time the ABS system of your car prevent the locking of the wheel and avoid skidding. At this time you can control your steering and can stops your car hitting from the obstacle. This is how the abs system prevents the skidding of the vehicle and provides greater control over it and prevents accidents.

Main Components of ABS System

It has four main components

1. speed sensors
2. Valves
3. Pump
4. Controller

1. Speed Sensors

It is used to calculate the acceleration and deceleration of the wheel. It consists of a toothed wheel and an electromagnetic coil or a magnet and a Hall Effect sensor to generate signal. When the wheel or differentials of the vehicle rotates, it induces magnetic field around the sensor. The fluctuation in this magnetic field generates voltage in the sensor. This voltage generated sends signals to the controller. With the help of the voltage the controller reads the acceleration and deceleration of the wheel.

2. Valves

Each brake line which is controlled by the ABS has a valve. In some of the systems, the valve works on three positions.

1. **In position one**, the valve remains open; and pressure from the master cylinder passed through it to the brake.

2. **In position two**, the valve blocks the line and separates the brake from the master cylinder. And this prevents the further rise of the pressure to the brakes. Valve operates in second position when the driver applies the brake harder.

3. **In position three**, some of the pressure from the brake is released by the valve.

   The clogging of the valve is the major problem in ABS. When the valve is clogged, it becomes difficult for the valve to open, close or change position. When the valve is in inoperable condition, it prevents the system form modulating the valves and controlling pressure to the brakes.

3. Pump

Pump is used to restore the pressure to the hydraulic brakes after the valve releases the pressure. When the controller detects wheel slip, it sends signals to release the valve. After the valve releases the pressure supplied from the driver, it restore a desired amount of pressure to the braking system. The controller modulates (adjust) the status of the pump so as to provide desired amount of pressure and reduce slipping of the wheel.

4. Controller

The controller used in the ABS system is of ECU type. Its main function is to receives information from each individual wheel speed sensors and if a wheel loses its traction with the ground, a signal is sent to the controller, the controller than limit the brake force (EBD) and activate the ABS modulator. The activated ABS modulator actuates the braking valves on and off and varies the pressure to the brakes

Working of Anti-lock Braking System (ABS)

- The controller (ECU-Electronic Control Unit) reads the signal from each of the speed sensors of the wheel.
- As the brakes are suddenly applied by the driver, this makes the wheel to decelerate at faster rate and may cause the wheel to Lock.
- As the ECU reads the signal which indicates the rapid decrease in the speed of the wheel, it sends signal to the valve which makes the valve close and the pressure to the brake pad reduces and prevents the wheel from locking.

- The wheel again starts to accelerate, again the signal sends to the controller, this time it opens the valve, increasing the pressure to the brake pad and brakes are applied, this again reduces the speed of the wheel and tries to make it stop.
- This process of applying brakes and releasing it happens 15 times in a second when a driver suddenly applies the brake harder. Due to this the locking of the wheel is prevented and the skidding of the vehicle eliminated. During braking with ABS system, the driver can steer the vehicle and reduces the risk of vehicle collision.

Advantages

1. It prevents the locking of the wheel and thus eliminates the chance of skidding.
2. The skidding of the vehicle is completely removed, which results in excellent control during braking?
3. A better steering control is obtained with the ABS system.
4. It reduces the chance of collision by 30 %.

Disadvantages

A vehicle equipped with ABS (Anti-lock Braking System) is costlier as compared with a vehicle without ABS.

5.5 REGENERATIVE BRAKING

It is a **form of braking in which the kinetic energy of the motor is returned to the power supply system**. ... It is very interesting to note that regenerative braking cannot be used to stop a motor but to control its speed above the no-load speed of the motor driving the descending loads.