Course Code:	AGE 401
Course Title:	Workshop Practice & Farm shop
Number of Units:	3Units
Course Duration:	Two Hours of Lecture and Three Hours of Practical per Week

Course Details

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Other Lecturers:	

Course Content:

Design and analysis of individual machine components – shafts, gears, chains, linkages, bearings, keys, keyways, belts, clutches, etc. Component assemblies and machine systems.
Design project.

Course Requirement:

Students must have a minimum 70% attendance and participate in all practical classes.

Reading List:

Shingley J. E , Mischke C. R. 1986. Standard Handbook of Machine Design. Mc Graw – Hill. New York

Machine Design

Design of Machine Elements

Sources of Power on the Farm

- Energy is a requisite for any kind of civilization
- Power greater than that supplied by human power required on the farm
- Human power a controlling source
- ICE is the major source of farm power

Note: Students to list available power sources on farm from various textbooks

Development of Tractor

- Tractor a wheeled/tracked selfpropelled vehicle
- Used as prime mover, or through intermediary such as PTO, belt pulley system
- See Note in Class for diagram of classification of Tractors (or From Tractor & Automobiles ref..)
- Tractor progressed from use as substitute for animal power to its present state

Internal Combustion Engines(ICE)

- ICE is an engine in which thermal energy is supplied by burning fuel is directly transformed into mechanical energy by controlled combustion of fuel in an enclosed cylinder behind a piston
- ICE classified according to method of
- Mixing
- Ignition
- No of piston strokes
- Kind of fuel
- Cooling method
- Number of cylinders
- Cylinder arrangements

Basic Notations in ICE

- Air-fuel mixture
- Combustible charge
- Spark ignition engine
- Combustion ignition engine
- TDC & BDC
- Piston stroke
- Combustion chambers, clearance volume
- Stroke, swept, compression ratio
- Basic Events in the ICE
  - Four events called the ICE cycle
  - Cylider filled with air/ air fuel mix
  - Compression of air/air-fuel mix
  - Ignition
  - Scavenging of burnt gas from cylinder

- Continuous repetition of the events in a definite sequence constitutes the cycle of operation of the engine or working cycle
- Theoretically the four events are referred to as
  - Compression
  - Expansion
  - Heating
  - cooling as shown in Fig.(to be shown in Class and explained)

- Ordinary SI engine cycle is called Otto cycle
- Each process in Otto cycle to be discussed in Class

S.I Engines

- Assumption, Occurs in Two strokes
- Piston has zero friction in cylinder
- Air is used as working fuel with constant specific heat capacity(perfect gas)
- No heat transfer takes p[lace thro the walls
- Crank strts at bottom of stroke
- Constant volume explansion and rejection of heat
- Efficiency = $(Q_{in} – Q_{out})/ Q_{in}$

Diesel Cycle

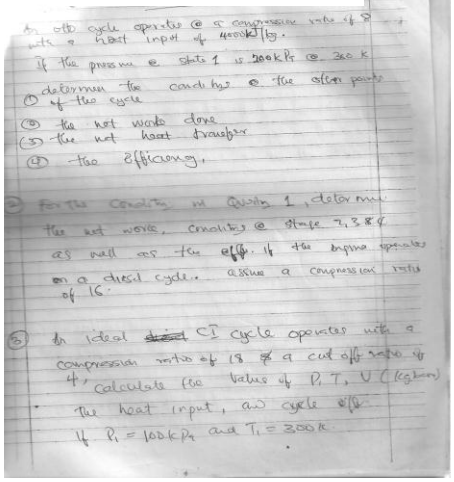
- Called Ideal air standard
- Events shown in Fig 2 in class
- Stage 1-2, 2-3, 3-4, 4-1
- Efficiency varies directly as compression ratio and inversely as cut-off ratio
- See Class note for explanation of diesel cycle

Deviation of Actual and Ideal Cycles

- Actual processes result in efficiency lower than ideal processes because:
  - Entire gas in system not air
  - Specific heat is not constant
  - Chemical reaction occurs between stages in cycle
  - Heat losses occur at cylinder walls during process
  - Intake occur less than atmospheric pressure
  - Intake valve not necessarily closed at end of intake stroke or opened at beginning of intake stroke , because of inertia.
  - Combustion is not instanteneous
  - Combustion not complete, because of poor mixing or insufficient oxygen

  The Actual P_V diagram for SI will be discussed in Class

Exercises



An otto cycle operates @ a compression ratio of 8 with a heat input of 4000kJ/kg.

If the pressure @ state 1 is 200kPa @ 300 K

① determine the conditions @ the other points of the cycle

② the net work done

③ the net heat transfer

④ the efficiency.

② For the conditions in Question 1, determine the net work, conditions @ stage 2, 3 & 4 as well as the eff. if the engine operates on a diesel cycle. assume a compression ratio of 16.

③ An ideal CI cycle operates with a compression ratio of 18 & a cut off ratio of 4, calculate the value of P, T, V (kg basis) The heat input, and cycle eff. If $P_1 = 100kPa$ and $T_1 = 300k$.

ICE OPERATIONS

- CI Engines
- The four strokes are as shown in Fig 3 in Class.
  - First Stroke (Intake) Pistion is moved by the crankshaft and connecting rod downwards producing a vacuum in the cylinder. Fresh air is introduced into the cylinder thro the intake valve
  - Second Stroke (Compression) Just as the first stoke is ending, piston moves from BDC to TDC
  - Third Stroke (Power or Expansion) Atomized fluid gets in contact with hot compressed air and self ignite. Injection and burning goes on for sometime after the piston must have passed TDC. ‘cos of delay in self-ignition burning takes place during the stroke
  - Fourth Stroke (Exhaust) As the piston reaches BDC on the power stroke the exhausty valve opens to release the burn’t gases under an execcise pressure. The piston then moves up againto push out hot gases from the cylinder. As it reaches the TDC on the exhaust stroke, the exhaust valve closes and the intake valve opens to start another cycle.

  Note: Before engine is fired the crankshaft is rotated by an external prime mover; electrical starter motor, starting engine or by manual cranking , this is to provide the initial energy required for intake and compression strokes

ICE OPERATIONS

- S.I Engines
  - Intake: As opposed to CI mixture of air/fuel is drawn into the cylinder thro intake port. Mixture of unscavenged exhaust gases and air-fuel mix then forms a combustible charge
  - Compression: The piston moves to TDC to compress the charge facilitating the evaporation of gasoline(fuel) and mixing of gasoline vapour with air. At end of stroke temp is around 350 to 450oC while pressur is between 1 and 1.2MPa.
  - Power: Exhaust and intake valves are closed while the combustion chamber is ignited by a spark. Piston then moves from TDC to BDC under pressure of expanding combustion gas.
  - Exhaust: The exhaust valve is opening just as the power stroke is reaching completion (piston at BDC). Spent gases leaves thro the exhaust port. Exhaust port is then closed and intake valve is opened for the beginning of another cycle.

Comparison

- CI engines are more economical
- CI operates on heavy fuel with less harzard when handling
- CI engines are more bulky, since higher pressure requires stronger engines components
- More difficult to start in cold weather

Note: Students find out the working cycle of a two-stroke SI engine

Operations of Multi Cylinder Engines

- Power strokes must be spaced rationally to occur at regular intervals called firing order
- Firing order = Duration of engine cycle/ number of engine cylinders
- Firing Order for a four cylinder tractor engine is 1-3-4-2 as shown in Table 1
- Cylinder Arrangements
  - Inline or Two Bank
  - Inline have all cylinders in a straight line
  - Two bank have cylinders in two straight lines at an anle to each other in a V-shape.

Firing Order for a 4-Cylinder four stroke Engine

Event No	Crankshaft Half-turn	Cylinders			
		1	2	3	4
1	0 - 180	Power (P)	Exhaust (E)	Combustion (C)	Intake (I)
2	180 - 360	Exhaust (E)	Intake (I)	Power (P)	Combustion (C)
3	360 - 540	Intake (I)	Combustion (C)	Exhaust (E)	Power (P)
4	540 - 720	Combustion (C)	Power (P)	Intake (I)	Exhaust (E)

Fuels and Combustion of Fuels

- Fuel commonly used in farm tractors are products of crude oil, though alternative fuels are being recently considered
- Crude petroleum is made of combined carbon and hydrogen in approximately 86 and 14% respectively
- Combustion process consist of chemically combining oxygen from air with carbon and hydrogen in the fuel
- Combustion calculation only serves as illustration of general principle
- Under ideal conditions or excessive air, combustion is never complete as shown in Eqn 1 (See class note), where carbon monoxide is always present as a byproduct
- In practice Octane C_8H_{18} is usually used to represent gasoline petrol) while Cetane $C_{16}H_{34}$ is for diesel oil.

Note: Students should write approximate combustion equations for Diesel and petrol

Fuel Properties

- Tested to estimate its volatility, burning characteristics, freedom from excessive impurities and storage stability
- Testys are specified by ASTM, SAE and API
- Test Standards are published by ASTM
- Properties
  - Volatility Distillation test and Reid Vapour pressure test
  - Sulphur Content
  - Specific Gravity or Density
  - Heating Value
  - Flash Point
  - Pour Point
  - Cloud Point
  - Solidification point

Combustion

- Burning of fuel is the chemical oxidation of carbon and hydrogen
  - Air-fuel ratio for petrol is 15:1.1
- Carburetion: process of meytering and mixing volatile fuel vapour and air into a combustible mixture.
- Combustion initiated by a spark___ SI engine
- Carburetor: a device for carburetion
- SI engines must have adequate volatility and knock resistance
- Combustion knock is an extreme rapid explosion like burning of fuel in the engine cylinder

- Effects of combustion Knock or Detonation
  - Heavy impact on piston and other components
  - Burning of piston and valves
  - Smoky exhaust leading to loss of power
  - Increased fuel consumption

Knock resistance of SI is evaluated in terms of Octane Rating or Octane Numbers

Octane Number; …….

The higher the Octane rating the higher its knock properties the better the fuel

SI Knocking

- Engine deposits
- Spark occurrence too fast
- Overheating and overloading
- High compression ratio

Diesel Engine Knocking

- Knocks when fuel does not burn fast enough …. Delay is required for fuel to absorb heat and mix with oxygen
- Cetane rating is the ability of CI fuels to burn without detonating
- CI fuels must have high heating value, low viscosity, high flash point and high Cetane number

- For CI fuels the higher the Cetane number the shorter the ignition delay, the smoother the engine operations

Components of Fuel System

- Air cleaner
- Fuel Injector
- Carburetor
- Fuel filters
- Fuel pump
- Injector pump

- Components of the Carburetor and Injection systems to be discussed in Class

Engine Cooling System

- ICE must be cooled to prevent over heating of various components….. Lead to failure and reduced power
- Temperature in ICE cylinder usually greater than 1000^{o}C, cooling prevent burning of lubricant in ICE
- Reduced wear and tear of components

- Objective of cooling is not to run engine as cool as possible but most efficient temp for power, economy and wear rate. ……Better called … Temperature control system
- Efficient temp range is between 80 and 95^{o}C
- Serves to remove heat from hot engine components and maintain efficient temp condition of the engine

- **Effect of Over-cooling**
  - –Reduce engine power
  - –Increased fuel consumption(poor air-fuel mixture)
  - –Increased friction loses due to poor lubricating properties at low temp
  - –Incomplete burning leading to heavy carbon deposits

  Effects of Under-Cooling

  Over-heating of system and components

  Burning of Lubricants

  Expansion(Excessive) of components.. Piston, ring etc..

  Increase fuel consumption… inefficient air-fuel mixture

COOLING SYSTEMS

- Cooling achieved through
- Force cooling by some liquid(Liquid Cooling)
- Cooling by the ambient air (Air cooling)
- Combination liquid and Air cooling (Hybrid)

Liquid Cooling

- More common where cooling medium or coolant is either water or some low-freezing liquid called anti-freeze
- Includes
  - Cooling jacket…..cooling cylinder head and block
  - Radiator (heat exchanger)
  - Water pump, fan, Thermostat, connecting hoses, drain cocks, coolant temp gauge(Thermometer)

  Modern engines use ……………Pressurized (Sealed) cooling system where radiator is sealed.

  See Class drawing of Sealed radiator system

Air Cooled System

- Through induction of Air to flow around the cylinders and the head
- Volume provided by a rotary blower with large number of blades/vanes
- Rate of cooling controlled by oil-fed regulator.

** Diagram and further explanation would be discussed in class

The Lubrication System

- ICE have many close fitting, rapid moving parts and components that would wear out quickly due to dry friction
- Dry friction increases heat and accelerated wear of working/moving poarts
- A thin film of fluid called a lubricant is introduced between rubbing parts to reduce dry friction

- Purpose of engine lubrication system is to supply lubricant continuously to the rubbing engine parts and remove heat from them.
- Acts as sealant between cylinder walls and piston rings by reducing compression losses

- One important property of lubricant is Viscosity
- Ability to resist flow
- Viscosity of lubricant varies with temp, lub gets thicker as it becomes colder and gets lighter with increased temp.

- Single temp range lub are called Single grade Lubricant Eg SAE 30, SAE 25 etc
- Multi grade lubricants are designed to have multiple viscosity depending on temp of operation. Eg 20W50, 40W50, etc

- Universal tractor oil is used for the most lubricated parts of a tractor including engine, transmission, hydraulic system and brake system.

- Oil contamination may consist of solid particles, such as dirt, grit, etc
- Water enters engine thro combustion, with the inclusion of water in lubricating oil leading to formation of sludge and emulsion. This should be prevented and avoided

Types of Lubricating System

- Forced oil Circulation
- Splash
- Gravity Fed or
- Combination

Electrical System

- Components
  - Battery/Accumulator
  - Generator and regulator
  - Stator
  - Ignition system
  - Lights and accessories

Charging Circuit

- Consist of a generator and a regulator
- D-C charging or A-C charging
- D-C   Regulator, Ammeter, generator, battery and grounding
- A-C   Ignition switch, regulator, ammeter, alternator, battery and grounding

** Connection to be shown in Class and Laboratory

- Starting Circuit
  - Battery
  - High torque motor called the starter
  - Stator
- Ignition Circuit
  - Battery I S …… battery, switch, resistance, ignition condenser, distributor rotor, coil breaker points, wires and spark plugs.
    - Electronic ignition replaces breaker points with magnetic electronic switch less prone to maladjustment and lead deposits
  - Magneto I S ……Engines that does not require a battery to start, Battery and ignition coil replaced by a moving permanent magnet and a coil making a miniature high voltage generator

ENGINE DESIGN

- ICE designed to countinuously output about 90% of maximumbrake power at rated speed for a long period of time.
- Steps in design
  - Selection of speed, type, number & size of cylinders and arrangements
  - Calculation of sizes and materials of parts or components to withstand designed stress

  ***Important Components**
  - Block, crankshaft, connecting rod,piston , bearings and valves

  - Valve Design
    - Used for closing/opening a passage

  Combustion Process Design
    to create turbulence
  Combustion Chamber Design
    aimed at reducing ignition lag
    types
      open chamber
      pre-combustion chamber
      turbulence chamber (Ricardo turbulence)
      ……not water cooled
      Auxiliary chamber

Fuel-Injection systems in CI

- Individual or In-Line
  - Constant stroke lapped plunger operated by a cam
- Distributor
  - Pump, a metering device, distributor & governor
- Unit injection
  - Combination of injection nozzle with a fuel-injector pump
  - Usually used with open chamber conb. Chamber
  - No high pressure line involved