BITS Pilani
Pilani Campus

Automotive Vehicles
AEL ZC441

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Lecture 1 - Recap

- Introduction to Automobile
- Development of Automobile (1769 to 2005)
- General Classification (Type I & II)
- Basic Structure &
- Components of Automobile (Basic Structure, Power Plant, Transmission System, Auxiliaries, Controls, Superstructure)

Lecture 2 - Recap

- Chassis & Body
- Classification
- Conventional Construction
- Sub frames
- Frameless Constructions
- Classifications of Body

Lecture 3 - Recap

- Cylinder Block and crank case
- Cylinder Head
- Sump or oil pan
- Intake and Exhaust Manifolds
- Gaskets
- Cylinder Liners
- Piston
- Piston Rings
- Connecting Rods
- Piston Pins
- Crankshaft
- Main bearings
- Valves and Valve actuating mechanisms
- Mufflers

Lecture 4 - Recap

- Need of Cooling system
- Variation of Gas temperature
- Theory of Engine heat transfer and co-relation
- Parameters affecting Heat transfer
- Air cooled Systems

Lecture 5 - Recap

- Water Cooling system
- Types of Water cooling
- Components of Water Cooling system
- Other coolants & Anti-freeze solutions
- Intelligent cooling system

Lecture 6 - Recap

- Causes of engine friction
- Function of lubrication
- Mechanism of lubrication
- Journal bearing lubrication
- Lubrication system types
- Lubrication of Engine systems

Lecture 7 - Recap

- Definition of Clutch
- Requirements
- Classification
- Principle working of Friction Clutches
- Driving System & Plate Clutch
- Design Details (Uniform Pressure, Uniform Wear, Energy lost)

Today's Topic

Lect No.	Learning Objectives	Topics to be covered	Reference to Text
1	An introduction to automobiles	Overview of the course and evaluation scheme Development of automobiles, General classification, Basic structure and components of automobile	1TB1,1TB2
2	The chassis Construction and Body	Classification, Conventional construction, Sub frames, Frame less constructions, Classification of body, Numerical problems on chassis member bending.	11TB1, 1 TB2
3	Reciprocating Engine Construction and basics	Constructional details, Calculation of displacement velocity and acceleration of piston and connecting rod, Working of 2and 4 stroke engines. Numerical problems on the above topics	3TB1
4	Cooling systems	Need. Variation of gas temperature. Piston temperature distribution. Theory of engine heat transfer and correlation. Parameters affecting engine heat transfer. Air-cooled systems.	8TB1, 12RBa
5	Cooling systems	Types of water-cooling systems. Radiators. Fans. Correlation for the power required for engine cooling. Numerical problems on the above topics	8TB1, 12RBa
6	Lubrication systems	Causes of engine friction. Function of lubrication. Mechanism of lubrication. Journal bearing lubrication.	7TB1, 11RBa
	Lubrication systems	Types of lubrication systems. Lubrication of engine components.	7TB1, 11RBa
7	Clutch	Definition of clutch, requirements, classification, principle of working of friction clutches, Driving system and Plate clutch (uniform pressure and uniform wear).	14TB1, 3TB2

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Automotive Vehicles
Lecture 8

Revision

- L1 to L7 Slides
- Sample Format of Questions

Lecture 8

- Important Questions
- Numerical

Sample Questions

1. Development of Automobile
2. Classification of Automobile Type I & II
3. Components of Automobile
4. Detail of any two components of Automobile
5. Types & Classification of Frame
6. Conventional Construction & its defects
7. Non Conventional / Frameless & its defects
8. Body Shapes and Materials
9. Cylinder Block & Cylinder Head
10. Types of Cylinder head
11. Manifolds and its types
12. Any two components of Reciprocating Engine
13. Working of 4 Stoke / 2 Stroke Engines
14. Working of Petrol & Diesel Engine
15. Valve & Port timing diagram
16. Types of Valve actuating Mechanisms
17. Difference B/w 2 Stroke and 4 Stroke
18. Need of Cooling System
19. Modes of Heat Transfer
20. Types of Cooling System
21. Air Cooling system in detail
22. Water Cooling System
23. Thermosyphon cooling system
24. Pump Circulation Cooling System
25. Components of Cooling System
26. Lubrication – Need & Function
27. Lubrication – Requirements
28. Lubrication – Types
29. Lubrication Testing
30. Types of Lubrication System
31. Components of Lubrication
32. Clutch – Function & Requirements
33. Types of Clutch
34. Friction Clutches & its types
35. Plate clutch – Uniform Pressure and Rate of Wear

Numerical Questions

Q1. The outside diameter of a steel cylinder liner is 85mm at a temperature of 288K. In order to fit the liner in the cylinder block it was necessary to cool the linear to 218K by using liquified gas. Calculate the decrease in outside diameter of the linear at this lower temperature. Coefficient of linear expansion of Steel = 12X10^-6 /K

Solution:

Decrease in outside diameter = Original diameter × Coefficient of expansion × Temperature fall

$$= 85 \times 12 \times 10^{-6} \times (288 - 218)$$

$$= 85 \times 12 \times 10^{-6} \times 70 = 0.0714 \text{ mm.}$$ **Ans.**

Numerical Questions

Example 3.2. *A cylinder head stud has a diameter of 14 mm at the bottom of the thread. If the maximum tensile stress allowed in the material is 30 MPa, calculate the safe load the stud can carry.*

Solution.

The cross-sectional area of stud at the bottom of the thread (*i.e.* at its root or core diameter),

$$A = (\pi/4)\,(14)^2 = 154 \text{ mm}^2.$$

Allowable tensile stress, $\sigma = 30 \text{ MPa} = 30 \text{ N/mm}^2$.

Safe load, F = Tensile stress, $\sigma \times$ Cross–sectional area, $A = 30 \times 154 = 4620$ N. **Ans.**

Example 3.3. *In the above example if the head is joined to the deck top by six studs, what is the safe load the head can withstand ?*

Solution.

Safe load on each stud = 4620 N.

Since 6 studs join the head, safe load on the head $= 4620 \times 6 = 27720 \text{ N} = 27.72$ kN. **Ans.**

Numerical Question

Example 3.5. *The inlet valve of a small car engine has a mass of 50 g and reaches a maximum acceleration of 8000 m/s² during the opening period in 0.001 s from rest. Calculate the kinetic energy of the valve at the end of the acceleration.*

Solution.

Given: Mass, $m = 50 \text{ g} = 0.05 \text{ kg}$.

Acceleration, $f = 8000 \text{ m/s}^2$.

Time $t = 0.001 \text{ s}$.

Initial velocity, $u = \text{zero}$.

Final velocity of the valve, $v = u + ft = 0 + 8000 \times 0.05 = 400 \text{ m/s}$.

Kinetic energy of the valve at the end of the acceleration $= (1/2)\, mv^2$

$= (1/2) \times 0.05 \times (400)^2 = 4000 \text{ J}$. **Ans.**

Numerical Questions

Example 3.6. *Evaluate the nominal gas speed past the poppet valve of an engine having 150 mm bore and 200 mm stroke at 2100 rpm. There are two inlet valves per cylinder having a port diameter 40 mm and a lift of 12 mm, which open 14 degrees earlier and closes 48 degrees late. Discharge co-efficient may be taken as 0.6.*

Solution.

Given, $D = 0.15$ m, $n = 2$, $\lambda = 180° + 14° + 48° = 242°$, $L = 0.2$ m,

$d = 0.04$ m, $N = 2100$ rpm, $l = 0.012$ m, $C_i = 0.6$.

$$\text{Therefore gas speed } = \frac{1.5\, D^2\, L\, N}{C_i\, d\, l\, n\, \lambda} = \frac{1.5\,(0.15)^2 \times 0.2 \times 2100}{0.6 \times 0.04 \times 0.012 \times 2 \times 242} = 101.7 \text{ m/s.}$$ **Ans.**

Example 3.11. *An exhaust front pipe is 1.5 m long at 293 K. What will be its length when its temperature becomes 643 K ? The coefficient of linear expansion of the steel is 12×10^{-6}/K.*

Solution.

Increase in length (x) = Original length (L) × Coefficient of expansion (α) × Temperature rise (ΔT)

Thus, $x = L\,\alpha\,\Delta T = 1.5 \times 12 \times 10^{-6} \times (643 - 293) = 1.5 \times 12 \times 10^{-6} \times 350 = 0.0063$ m.

Length of pipe at 643 K = Original length + Expansion = 1.5 + 0.0063 = 1.5063 m. **Ans.**

Numerical Questions

Example 3.12. *The main journal bearings of an engine crankshaft carry a total load of 10 kN when the engine speed is 3000 rpm. If the coefficient of friction between each bearing and shaft is 0.015 and the diameter of the shaft is 60 mm, calculate*

(a) *the frictional torque on the shaft,*

(b) *the power absorbed by friction, and*

(c) *the heat generated in the bearings per minute.*

Solution.

Load on bearings, $W = 10 \times 10^3$ N.

Shaft speed, $N = 3000$ rpm.

Shaft radius, $r = 0.03$ m.

Coefficient of friction $\mu = 0.015$.

(a) Frictional torque, $T_F = \mu W r = 0.015 \times 10 \times 10^3 \times 0.03 = 4.5$ Nm. **Ans.**

(b) Power absorbed by friction $= T_F (2 \pi N)/60$ W

$= 4.5 \times (2 \pi \times 3000)/60$ W $= 1414$ W $= 1.414$ kW. **Ans.**

(c) Heat energy absorbed in bearings per minute due to friction $= 1414 \times 60$

$= 84840$ J $= 84.84$ kJ. **Ans.**

Numerical Questions

Example 7.2. *The lubricating oil from a CI engine flows through an oil cooler at the rate of 5.5 lpm. If the oil enters the cooler at a temperature of 355 K and leaves the cooler to re-enter the engine at 283 K, how much heat energy is extracted from the oil per second ?*

Specific heat capacity of the oil = 200 J / kg K.

Mass of 1 litre of the oil = 0.85 kg.

Solution.

Mass rate of oil $= 5.5 \times 0.85 = 4.675$ kg/min.

Specific heat of oil $= 200$ J/kgK.

Temperature rise $= 355 - 283 = 72$ K.

Heat energy extracted from oil by oil cooler $= 4.675 \times 200 \times 72 = 67320$ J/m

$= 67320 / (60 \times 1000) = 1.122$ kJ/s. **Ans.**

Numerical Questions

Example 8.1. *Compare the quantity of cooling water required for 100 kW SI engine and CI engine when the temperature rise in water is 25K in passing through the jackets. Percentage of heat loss to cooling water in petrol engine is 30% and in diesel engine is 27%. The thermal efficiency of petrol engine is 27% and the diesel engine is 30%.*

Solution.

Fuel input = Brake power/η_t.

Brake power = 100 kW.

SI engine.

Fuel input = 100/0.27 kW = 100/0.27 kJ/s.

Therefore, heat to cooling water = (100/0.27) × 0.3 kJ/s.

We have $Q = m\, C_p\, \Delta T$, C_p for water = 4.183 kJ/kg K.

or $(100 \times 0.3)/0.27 = m \times 4.183 \times 25$

or $m = (100 \times 0.3)/(0.27 \times 40183 \times 25)$ kg/s

$= (100 \times 0.3 \times 3600)/(0.27 \times 4.183 \times 25)$ kg/h

= 3825 kg/h.

Therefore, quantity of cooling water required in case of SI engine = 3825 kg/h. **Ans.**

CI engine.

Fuel input = 100/0.3 kJ/s.

Heat to cooling water = (100/0.3) × 0.27 kJ/s.

Hence, $m = (100 \times 0.27)/(0.3 \times 4.183 \times 25)$ kg/s

$= (100 \times 0.27 \times 3600)/(0.3 \times 4.183 \times 25)$ kg/h

= 3098 kg/h.

Therefore, quantity of cooling water required in case of CI engine = 3098 kg/h. **Ans.**

Numerical Questions

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Example 8.2. *The output from a car engine is 80 kW. The thermal efficiency of the engine is 25% and heat lost to the coolant is 30% of the heat supplied. How much heat should be dissipated from the radiator of the car ? The engine coolant (water) is to be cooled in the radiator from 353 K to 303 K. Estimate the quantity of water to be circulated for proper engine cooling.* C_p *of water is 4.183 kJ / kg K.*

Solution.

Thermal efficiency = 25%.

Engine output = 80 kW.

Therefore, engine input = 80/0.25 = 320 kW.

Since 30% of the supplied heat is lost to coolant, heat lost to coolant

$$= 320 \times 0.3 = 96 \text{ kW. } \textbf{Ans.}$$

Also $Q = m\, C_p\, \Delta T$.

Substituting $Q = 96 \text{ kW} = 96 \text{ kJ/s}$,

$C_p = 4.183 \text{ kJ /kg K}$,

and $\Delta T = 353 - 303 = 50 \text{ K}$,

gives $96 = m \times 4.183 \times 50$

or $m = 0.459 \text{ kg/s} = 1652.4 \text{ kg/h}$.

Quantity of water to be circulated = 1652.4 kg /h. **Ans.**

Numerical Questions

Example 11.3. *A bus chassis, 5.4 m long, consists of two side members and a number of cross members. Each side member can be considered as a beam, simply supported at two points A and B, 3.6 m apart, A being positioned 0.9 m from the front end of the frame and subjected to the following concentrated loads;*

Engine support (front) 2 kN, engine support (rear) 25 kN, gear box support 0.5 kN, and body W kN. The distances of these loads from the front end of the frame are respectively 0.6m, 1.8m, 2.4m and 3m. If the reaction at A is 8.5 kN, determine

(*a*) *the magnitude of the load W due to vehicle body,*

(*b*) *the magnitude of the support reaction at B.*

Figure 11.29 represents diagrammatically the loading system.

Solution.

(*a*) To determine the magnitude of W, take moments about B. For equilibrium, the resultant moment must be zero.

This means clockwise moment about B = Anticlockwise moment about B

Thus, $8.5 \times 3.6 = 2 \times 3.9 + 2.5 \times 2.7 + 0.5 \times 2.1 + W \times 1.5$

or $30.6 = 7.8 + 6.75 + 1.05 + 1.5\ W$

or $W = (30.6 - 11.6)/1.5 = 10$ kN. **Ans.**

Numerical Questions

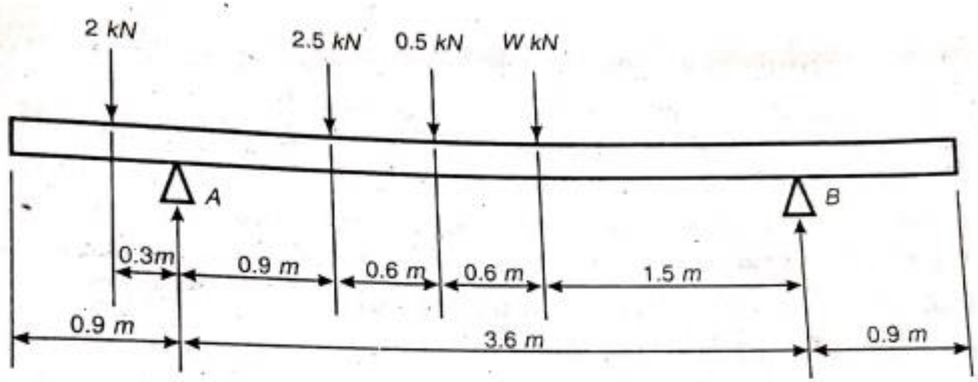

Fig. 11.27. Bus-chassis loading for example 11.3.

(*b*) For equilibrium, total upward forces must be equal to total downward forces.

Hence, $R_A + R_B =$ Total downward forces

or $8.5 + R_B = 2 + 2.5 + 0.5 + 10$

or $R_B = 15 - 8.5 = 6.5$ kN. **Ans.**

Numerical Questions

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Example 14.1. *An automobile power unit gives a maximum torque of 13.56 Nm. The clutch is of a single plate dry disc type, having effective clutch lining of both sides of the plate disc. The coefficient of the friction is 0.3 and the maximum axial pressure is 8.29×10^4 Pa, and external radius of the friction surface is 1.25 times the internal radius.*

Calculate the dimensions of the clutch plate and the total axial pressures that must be exerted by the clutch springs.

Solution.

Refer section 14.2.1,

$$T = 13.56 \text{ Nm}, \ \mu = 0.3, \ p_{max} = 8.29 \times 10^4 \text{ Pa, and } r_2 = 1.25 r_1.$$

But $$T = \pi \mu C (r_2^2 - r_1^2),$$

where $C = p\, r_1 = 8.29 \times 10^4\, r_1$.

Substituting,

$$13.56 = 2\pi \times 0.3 \times 8.29 \times 10^4\, r_1 (1.5625\, r_1^2 - r_1^2) = 2\pi \times 0.3 \times 8.29 \times 10^4 \times 0.5625\, r_1^3$$

or $$r_1^3 = \frac{13.56}{2\pi \times 0.3 \times 8.29 \times 10^4 \times 0.5625} = \frac{1.5435}{10^4}$$

or $$r_1 = 53.6 \text{ mm and } r_2 = 1.25 \times 53.6 = 67 \text{ mm.} \quad \textbf{Ans.}$$

Total axial pressure, $W = 2\pi C (r_2 - r_1) = 2\pi \times 8.29 \times 10^4\, r_1 (r_2 - r_1)$

$$= 2\pi \times 8.29 \times 10^4 \times 0.0536 (0.067 - 0.0536)$$

$$= 2\pi \times 8.29 \times 5.36 \times 1.34 = 373.92 \text{ N.} \quad \textbf{Ans.}$$

Numerical Questions

Example 14.3. *A motor car engine develops 5.9 bkW at 2100 rpm. Find the suitable size of clutch plate having friction linings riveted on both sides to transmit the power, under the following conditions:*

(a) *Intensity of pressure on the surface not to exceed 6.87×10^4 Pa.*

(b) *Slip torque and losses due to wear etc. is 35% of engine torque.*

(c) *Coefficient of friction on contact surface is 0.3.*

(d) *Inside diameter of the friction plate is 0.55 times the outside diameter.*

Prove any formula used in finding the clutch plate size.

Solution.

Now, $$T = \frac{p_\omega \times 60000}{2\pi N} = \frac{60000 \times 5.9}{2\pi \times 2100} = 26.84 \text{ Nm.}$$

Taking account of the losses, the total torque, $T = 26.84 \times 1.35 = 36.23$ Nm.

Also, $$T = \pi \mu C (r_2^2 - r_1^2)2$$

or $$36.23 = 2\pi \times 0.3 \times 6.87 \times 10^4 \times r_1 \left[\left(\frac{r_1}{0.55}\right)^2 - r_1^2\right]^2 = \pi \times 4.122 \times 10^4 \left(\frac{1}{0.303} - 1\right) r_1^3$$

or $$r_1^3 = \frac{36.23 \times 0.303}{\pi \times 4.122 \times 10^4 \times 0.697} = \frac{1.22}{10^4} \text{ m}^3.$$

or $$r_1 = 49.5 \text{ mm and } r_2 = 90 \text{ mm.}$$

Hence inside diameter = 99 mm, and outside diameter = 180 mm. **Ans.**