UNIT III
HYDROMATIC DRIVE
FLUID COUPLING CONVERTER
FLUID COUPLING

• Fluid coupling is a device which is used to transmit torque from engine to gear box with fluid as working medium.

• The purpose of fluid coupling is to act as flexible power transmitting coupling
Construction Details of Fluid Coupling

Fluid travels either in a rotary or vortex motion.
Principle of fluid coupling

Impeller converts M.E into K.E

Runner converts K.E into M.E
Direction of fluid
Imagine tubes A & B filled with fluid, A at N ‘rpm’ & B at n ‘rpm’.

Let outer end C of A closed with diaphragm.
Let outer end D of B closed with diaphragm.
Let pressure exerted at C = p_a
Let pressure exerted at D = p_b
Therefore p_a \alpha N^2 & p_b \alpha n^2
Therefore N > n, p_a > p_b
So if diaphragm is removed fluid flows from E to F.
p_a > p_b so fluid circulate between impeller & runner.
Thus because of difference in speed between impeller & runner, fluid circulates between impeller & runner.
Contd...

- At K- fluid particle at radius ‘r’,
- Rotates in a circle of radius r and angular speed of N.
- So linear speed = \(2\pi rn\)

- Therefore K.E at K = \(\frac{1}{2} \frac{W}{g} (2\pi Nr)^2\)

- Similarly K.E at L = \(\frac{1}{2} \frac{W}{g} (2\pi NR)^2\)

- Hence K.E at L > at K. So K.E of fluid is increased.
Contd....

- \( \text{K.E at M} = \frac{1}{2} \frac{W}{g} (2\pi NR)^2 \)

- K.E at M < K.E at L (so some fluid lost)

- \( \text{K.E at N} = \frac{1}{2} \frac{W}{g} (2\pi Nr)^2 \)

- K.E at N < K.E at M

- So fluid K.E is transferred to runner.

- Thus mechanical energy is transferred due to change in K.E of rotating fluid.
Principle of fluid coupling

Fluid coupling
principle of operation

- Electric fan connected
- Electric fan unconnected
- Driving member (from engine)
- Driven member (to transmission)

Driving member

Driven member
Fluid drives turbine at an angle

Figure 5-3. Fluid leaves the impeller at an angle that is a combination of the rotary and vortex flow.
Difference in speed creates a turbulence
Explanation of fluid coupling

• The fluid coupling consists of two identical castings known as rotors and one of them is fixed to the crank shaft of the engine and the other to the gear box shaft.

• It is a hydrodynamic device which transmits power without any change in torque.

• It produces a smooth vibration less coupling between the engine and gear box.

• The medium of transmission is a fluid, which at idling speeds does not transmit torque but just once the engine power beyond the idling speed, the fluid cease to slip and power is transmitted from the impeller to the runner., and the efficiency is approximately 98% at normal running.
Properties of working fluids

- It should have high density.
- It should have optimum viscosity. If low viscosity fluid is used, sealing is difficult & leakage takes place. If highly viscous fluid is used slip will be more.
- It should have low co-efficient expansion.
- It must have good heat transferable properties.
- It must have good lubricating properties.
- It must be readily available & cheaper.
- It must be non-corrosion.

Working fluids:

Mineral oils having low viscosity are used as working fluid. SAE 10, SAE 10w, oils are used in Fluid coupling.
Advantages of fluid coupling

- It provides acceleration pedal control to effect automatic disengagement of drive to gearbox at a predetermined speed.
- Vibrations from engine side are not transmitted to wheels and similarly shock loads from transmission side will not be transmitted to engine.
- No wear on moving parts and no adjustments to be made.
- No jerk on transmission when gear engages. It damps all shocks and strains incident with connecting a revolving engine to transmission.
- Vehicle can be stopped in gear and move off by pressing acceleration only.
- There is no direct firm connection between engines and wheels. So when engine is overloaded, it will not stop. But it results in slip within coupling.
- Unlike friction clutch, slip within coupling does not cause damage within working components.
Slip:

- Slip is the ratio of the different speeds of rotation of the impeller & runner, to the speed of rotation of impeller and expressed in percentage. Speed of runner always lags behind that of impeller.

- Percentage slip = (N-n/N)*100

  where runner speed n=0, slip = 100%

  Torque is not transmitted

  When N = n, slip = 0, Torque is fully transmitted
Torque capacity of fluid coupling

When slip is below 3%:

The change in KE depends on,
1. weight of fluid particles
2. speed of impeller
3. outer radius of coupling
   i.e., change in KE is proportional to \( W \),
   Proportional to \( N^2 \),
   Proportional to \( R^2 \).

Centrifugal force acting on impeller \( F_1 \) is proportional to \( N^2 \).
Centrifugal force acting in turbine \( F_2 \) is proportional to \( n^2 \).

When slip is constant,

\[ n \text{ is proportional to } N \]
   i.e., \( F_2 \) is proportional to \( N^2 \).

Resultant centrifugal force \( F_1 - F_2 \) is proportional to \( N^2 \),
   But resistance to flow = \( F_1 - F_2 \).
i.e., Resistance to flow is proportional to $v_f^2$.

$\Rightarrow$ $N^2$ is proportional to $v_f^2$

Therefore, $N$ is proportional to $v_f$

Number of flow circuits per unit time is proportional to $v_f$

Is also proportional to $N$

Power transferred = Energy per cycle $\times$ Number of cycles per unit time.

Energy per cycle is proportional to $N^2$ and $W$

Number of cycles per unit time is proportional to $N$ and $R^2$

**Case 1**

Power transferred is proportional to $N^2$ and $N$

Power transferred is proportional to $N^3$

Torque transmitted = $P/N$,

i.e., $T$ is proportional to $N^2$

**Case 2**

Power transferred is proportional to $W \times R^2$

Wt of particle = volume $\times$ density i.e., $W$ is proportional to $D^3$

Power transferred per cycle is proportional to $D^3 \times D^2$

Total power transferred in a number of cycles is proportional to $D^5 \times N$

Torque transmitted is proportional to $D^5$

From (1) and (2); $T$ is proportional to $N^2$ and $D^5$

Thus, $T = CN^2D^5$

Where, $N$= Impeller speed in hundreds of rpm

$D$= Outer diameter of coupling in m

$C$= coupling constant = 5.25
When Slip is upto 10%

\[ K.E. = \frac{1}{2} \times \frac{W}{g} (2 \times 3.14 \times N)(R^2 - r^2) \]

Power transferred = Energy per cycle x Number of cycles per unit time

\[ P = f(T, N) \leq WN^2 (R^2 - r^2) N \]

i.e., Torque T is proportional to \( WN^2 (R^2 - r^2) \)

Up to 10% of slip,

Torque is directly proportional to slip

i.e., T is proportional to S

Therefore, T is proportional to \( SWN^2 (R^2 - r^2) \)

Torque capacity \( T = C_1 SWN^2 (R^2 - r^2) \) Kgf·m

Where, \( c_1 = 0.241 \) and S is in decimal.

If slip is 10%, then S = 0.1

\[ R = (0.5(R_1^2 + R_2^2))^{1/2} \text{ m} \]

\[ r = (0.5(r_1^2 + r_2^2))^{1/2} \text{ m} \]
DISADVANTAGE OF FULID COUPLING

Even when the engine is idling, runner shaft rotates i.e., some torque is transmitted during the engine is in idling condition. Due to this the gear shifting is somewhat difficult and the vehicle will tend to move when it is parked in gear.

DRAG TORQUE

The torque transmitted when the engine is in idling condition is known as drag torque. Even when %slip is 100% there is a drag on GB shafts, which renders gear changing with ordinary type of gearbox very difficult and vehicle will tend to move when it is parked.
To reduce the drag torque, following methods are used,
1) Using anti drag torque baffle.
2) Using fluid reservoir.
3) Using combination of both.
4) Fluid coupling is used on combination with epicyclic gear box.
5) Fluid coupling with conventional synchronmesh gearbox

ANTI-DRAG BAFFLE

It is a circular plate secured to either the impeller or the runner at the inner circumference of the torus, and projecting into latter, thus obstructing the path of fluid flow. At normal operating speeds the liquid is carried toward the circumference of coupling by centrifugal force, and it is found that under these conditions the baffle does not affect circulation.
Under idling and starting conditions, however, the velocity of the runner is low and the liquid then is forced by the centrifugal force of the vertex motion, so that its flow is greatly affected by the plate. As the speed of the runner increases, the centrifugal force due to runner rotation increases, while that due to vertex motion decreases, and the effect of baffle then gradually vanishes or reduced.

**FLUID RESERVOIR**

At high speeds, when the liquid is forced toward the other circumference of the coupling by centrifugal force, the fluid coupling will be completely filled with oil and the fluid coupling will transmit maximum possible torque in the reservoir.
The chief purpose of the reservoir is to reduce the drag while the engine is idling, by partly empty in the torus by returning the oil to the torus automatically with an increases in speed. It ensures allow slip and relatively high efficiency of the coupling at crossing speeds. Here we can safely ensure 100% filling of coupling. Hence the maximum torque and efficiency is increased. But the fluid reservoir increases the overall axial length of coupling.

COMBINING ANTI-DRAG BAFFLE AND RESERVOIR

Using both the anti-drag baffle and the reservoir in the same vehicle we can reduce the drag torque by about 85 to 90%.

FLUID COUPLING WITH EPICYCLIC GEARBOX

The fluid flywheel is generally used in combination with epicyclic gearboxes which eliminates the drag torque.

FLUID COUPLING WITH CONVENTIONAL SYNCHROMESH GEARBOXES

Auxiliary clutches are used during gear shift operation. This type of transmission was used in Dodge fluid drive in 1950.
Characteristics of the fluid coupling
Comparison of Fluid coupling & Torque converter

• Fluid coupling acts as an automatic clutch without torque multiplication. Torque converter is essentially an automatic clutch & torque multiplying device.

• Fluid coupling has two principal components – impeller & runner. Torque converter has three components – Impeller, runner, reactor (or) stator.

• The vanes of fluid coupling are straight & radial shaped. The vanes of torque converter are curved shape.

• Torque converter can be converted in to fluid coupling while transmitting torque ratio of 1:1.
Comparison of Torque converter & Gear box

Both are torque multiplying devices.

- In torque converter, torque ratio get varied automatically in a continuously variable manner.

Gear box has definite speed ratio & changes are in steps.

- In torque converter during torque ratio variation, there is no interruption of power from the engine to road wheels.
  In gear box during gear shifting engine power is cut – off.

- Torque converter is smooth, vibration less & silent in operation.
  Gear box has vibrations, jerks & noises.

- Separate gear drive is necessary for reversing in torque converter.
  Gear box is self – contained with reversing mechanism.

- Torque converter efficiency is maximum for a part of its speed range.
  Gear box efficiency is constant throughout.
Torque converter
Direction of fluid
Principle of torque converter
Principle of operation of Torque converter

- The phenomenon of torque conversion by hydrodynamic means is illustrated graphically by polar diagram, where distance radially outward from the base circle represent forward or positive moments of momentum of the spinning fluid and distance inward from that circle negative moments.

- The spinning velocity of fluid and its moment momentum both are maximum at the runner entrance at the top of diagram. When the runner is at rest or nearly so the spinning velocity and moment of momentum of the fluid are quickly reduced to zero, and owing curvature of the running blades a reverse or negative spinning motion is imparted to the fluid.

- The torque imposed on the runner is proportional to the sum of the forward moment of momentum at the entrance and reverse moment of momentum at the exit as shown.
• But while fluid undergoes a great change of motion in runner and as a result subjects the latter to heavy torque it gives up little energy to the runner because latter is either standstill or turning at a very low speed.

• On leaving the runner the fluid therefore still possesses most of the kinetic energy with which it entered the member.

• In reaction member the spinning motion is reversed and the fluid leaves that member with a positive moment of momentum nearly equal to the negative moment of momentum with which it entered.

• The reaction member is subjected to a torque opposite in direction to that on the runner and proportional to the difference between the negative moment of momentum at entrance and positive moment of momentum at exit, of course it is proportional to the sum of the two.
• The fluid now enters the impeller already possessed of a certain forward spinning velocity and the impeller needs to add only enough to bring the total velocity up to that at which the fluid entered the runner.

• In the case represented by the diagram, if the moment of momentum added to the fluid in the impeller is represented by 1, the change of moment of momentum in the reactor is about 1.4, and the change of moment of momentum in the runner is 2.4.

• Therefore torque ratio in this particular case is 2.4.
Vanes are curved to accelerate fluid flow.
Stator Operation

- Stator assembly mounts on One-way clutch.
- Stator multiplies torque
- At 90% speed ratio, the stator rotates same speed as turbine and impeller and “coupling phase” occurs.
Construction of Torque converter

• A hydrodynamic torque converter is a device used for multiplying torque (or) turning moment by hydrodynamic means, that is making use of kinetic energy of a fluid in motion.

• It consists of three vaned members.

• An impeller secured to the input shaft, a runner secured to the output shaft and a reaction member fixed in position.

• An three being enclosed in a housing filled with hydraulic fluid.

• The impeller serves to impart a whirling motion to the fluid, the runner is kept rotating by the whirling fluid, and the reaction member changes the direction of the whirling motion between runner outlet and impeller inlet in such a way that the K.E left in the fluid will help to drive the impeller.
• The input torque which the converter is able to take is proportional to the difference between the moments of momentum of the fluid at the entrance and exit of the impeller.
• Since the moment of momentum is proportional to the product of the spinning velocity and the radius of the spinning motion, it is obvious that the torque capacity increases with the exit diameter of the impeller and as the entrance diameter decreases.
Variation of Efficiency & torque with speed ratio
Variation of Efficiency with speed ratio

• When starting from rest, efficiency = 0 i.e both output speed and output are zero.
• Efficiency = 0 when the load is removed, runner is allowed to race.
• As the runner gains speed, efficiency increases.
• Max value of efficiency at design point (arbitrarily set).
• Max efficiency is of 85% to 90% based on
  1. No of stages   2. No of blades   3. Refinement of blades
  4. Blades entrance & exit angles
• At a certain speed ratio, coupling point output torque = input torque.
Variation of torque with speed ratio

- Output torque is max when starting $\alpha 1/ N^2$
- T.C of cars has stall – torque ratio of 2.0 & 2.5.
- Possible to get high torque ratios, but not practical, since is low, trouble of overheating.
- Reducing gear is used for high ratios
- Another reason for moderate stall torque – its efficiency as F.C decreases further. i.e, for high torque ratio vanes have to be curved sharply.
- Single stage T.C – 2 to 4
- Two stage T.C – 3 to 5
- Three stage T.C – 4.5 to 6
Multi stage torque converter
Poly phase torque converter

Vortex velocity

Stalled turbine

Input

Output

Medium speed

High speed

Vane (blade)

Fluid path

Impeller

Turbine

$V_e = \text{Impeller exit velocity}$

$V_L = \text{Relative linear velocity of both pump and turbine}$

$V_R = \text{Resultant effective velocity and direction of flow}$
Poly phase torque converter

\( V_t = \text{Velocity & direction of fluid leaving turbine} \)

\( V_c = \text{Linear velocity of turbine blade} \)

\( V_n = \text{Rank moment effective velocity & fluid direction of fluid} \)