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Comparative Study of Fluid Coupling for Oil and water as working fluid

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Abstract:- This paper is a review of research work on working fluid of fluid coupling. the properties of filling fluid plays a vital role in operation of fluid coupling, in current scenario general fluid using in fluid coupling is lubricating oil which has high viscosity and less density. Hence the power transmission by fluid coupling has less efficient due to high viscosity of oil. In this paper we are using water as a working fluid for fluid coupling which has less viscosity and high density comparative to conventional fluid coupling filling lubricating oil.

Keywords:- Fluid coupling, Hydraulic coupling, Hydraulic clutch, Hydrodynamic coupling.

I. INTRODUCTION

Fluid Coupling is a hydraulic device to transmit rotating mechanical or torque. It is using in marine, railway locomotives, and industrial machines where variable speed operation or controlled startup without shock loading of the power transmission system is essential. It also has wide spread application in automotive transmission as an alternate of mechanical clutches and retarder.

The fluid works on hydraulic principal, in that the power transmits from prime mover to machine by hydraulic connection between them. A fluid coupling principally consists of a pump, turbine and working fluid. The pump connected to prime mover by mechanical means and this pump energies working fluid, and fluid runs the turbine which is directly coupled to machine by mechanical means.

1.1. CONSTRUCTION:

The fluid coupling is consisting of three principal parts named Impellor, Rotor and working fluid.

Impellor is finned like structure and it works as pump in the system. The impellor of the fluid coupling is directly connected to the prime mover like motor or engine by mechanical means eg. Belt drive, gear drive or a mechanical coupling. The impellor is power input component of the fluid coupling.

Rotor is also finned like structure and it works as a turbine in the fluid coupling system. The rotor is directly connected to the machine by mechanical means like Belt drive, gear drive or a mechanical coupling. The rotor is power output component of the fluid coupling.

Working fluid of the fluid coupling is the important part of the system. The working fluid in the fluid coupling is filled between impellor and rotor which gets energies by rotation of impellor and converts impellors energy in the kinetic energy of the fluid, this kinetic energy of the fluid get absorbed while striking on rotor. And by this energy the rotor rotates and power transmitted to the machine.

II. CHARACTERISTICS

2.1 CENTRIFUGAL LOADING: Fluid coupling has centrifugal loading characteristic in working condition or in other words the power output by fluid coupling is directly dependent on third power of the RPM[1], and output torque is proportional to second power of RPM.

2.2 *SLIP:* Slip is the difference between in input and output speed with respect to input speed. A fluid coupling cannot develop output torque when the input and output angular velocities are identical. Hence a fluid coupling cannot achieve 100 percent power transmission efficiency. Due to slippage that will occur in any fluid coupling under load, some power will always be lost in fluid friction and turbulence, and dissipated as heat.

2.3 *CLUTCHING AND DECLUTCHING:* Fluid coupling provides soft start to machine. Fluid coupling has an additional chamber on casing that known as delay fill chamber. This chamber is connected to the circuit of the fluid coupling through some holes. Initially when fluid coupling at rest the major quantity of oil filled inside this chamber and some quantity of oil available in circuit. When prime mover shaft starts rotating the less fluid filled inside the circuit of the fluid coupling. That can supply very less power and the speed of fluid coupling increases the oil from delay fill chamber gradually comes into the circuit the power output of the fluid coupling.

2.4 RISING TORQUE: the fluid coupling allows to prime mover at rated speed and machine at overloaded speed. That means the fluid coupling takes power constant and by reducing output speed the torque increases. The fluid coupling can increase the torque up to 270% of the rated torque.

2.5 DIRECTION OF ROTATION: the fluid coupling can be used bidirectional. The impellor of the fluid coupling is associated with the casing (housing) of the fluid coupling and the rotor is freely supported on bearing only hence the rotor has less inertia than impellor. The fluid couplings rotor and impellor can be mounted on vice versa. This is required when the prime movers starting torque is less and it can not sustain higher inertia at starting.

2.6 SET OUTPUT POWER: The fluid coupling can set the output power by varying the quantity of oil filled inside the fluid coupling for a fixed input power. The quantity of oil once filled inside the fluid coupling can not be change in working condition; hence the fixed quantity of oil can transfer a fix maximum power for a particular input power.

2.7 STALL SPEED: The stall speed is defined as the highest speed at which the impellor can rotate when the rotor is locked and maximum input power is applied. Under stall conditions all of the prime movers power would be dissipated in the fluid coupling as heat.

III. APPLICATIONS

3.1 Industrial: The fluid coupling is generally used where soft start and variable loading or variable speed required. These kinds of applications are generally works in power plants, refineries, coal mines, paper and pulp industries etc. there are some brief review of the application of the above sectors

3.1.1 Power plant: In power plant there is various equipment which requires fluid coupling some of are as follows

3.1.1.1 Fans: Fans are the important equipment of the power plant, it required to operate at variable speed for variable power generation. Hence for the variable speed the fluid coupling is needed for the SA, PA, ID FD and other fans.

3.1.1.2 Pumps: Boiler is the important part of the power plant and it operates at very high pressure. For feeding of fresh water into the boiler high pressure pumps required and these high pressure pumps required very high torque for starting. Hence fluid coupling employed into them.

3.1.2 Mines: The fluid coupling used in conveyors in mines for moving raw material from mining point to transportation point.

3.1.3 Refineries: The petroleum fluid has high viscosity and the viscosity of the petroleum fluid varies with the temperature. For transportation of petroleum special pumps required which can work with varies density of the fluid. So that the power and speed of the pump varies. So that fluid coupling employed for the varies power requirement.

3.1.4 Pulp industries: The pulp industries have to handle the slurry, the slurry has not the same density homogeneously and the pump which handles this slurry varies speed. For this variable speed and power requirement fluid coupling is useful for the application.

3.2 Automotive: The fluid coupling can work as a clutch in an automobile. Fluid coupling also used in heavy vehicle like trucks as a retarder unit.

3.3 Railways: in a railway locomotive the fluid coupling used in power transmission train for varying load and high torque required to pull the train.

3.4 Aviation: The most prominent use of fluid couplings in aeronautical applications was in the Wright turbo-compound reciprocating engine, in which three power recovery turbines extracted approximately 20 percent of the energy or about 500 horsepower (370 kW) from the engine's exhaust gases and then, using three fluid couplings and gearing, converted low-torque high-speed turbine rotation to low-speed, high-torque output to drive the propeller.

IV. PROPERTIES OF HYDRAULIC COUPLING FLUID

4.1 Density: Density of the fluid plays a great role in functioning of the fluid coupling. The power transmission from impellor to rotor transmits through oil’s kinetic energy. The kinetic energy is dependent on the density of the fluid. Hence the power output of the fluid coupling is dependent on the density of the working fluid.

4.2 Viscosity: The property of a fluid that resists the force tending to cause the fluid to flow. In the working condition of the fluid coupling the oil transfer energy in the form of kinetic energy and the viscosity opposes the motion of the fluid hence it reduces the kinetic energy of the fluid. For fluid coupling less viscosity of the oil preferred.

4.3 Specific heat: Specific heat of the fluid is the amount of heat required to increase the temperature by 1 degree centigrade at NTP. In the working of fluid coupling heat is generated inside the fluid coupling that has to dissipate, this heat is dissipated through oil.

4.4 Thermal Expansion: Thermal expansion of the fluid is the expansion of fluid by increasing the temperature by 1 degree centigrade. In working condition of fluid coupling heat generates and temperature rises hence the thermal expansion in the fluid should be as lower as possible for fluid coupling working fluid.
4.5 Lubrication: The Impellor and rotor are mechanical parts of the fluid coupling and these are support on shaft by bearing which is required to lubrication. So the fluid coupling fluid has to be lubrication properties.

V. WATER AND ITS PROPERTIES:

Water is a fluid which is ready and easily available. It has some properties which makes it feasible for working fluid for fluid coupling. The properties of the water against conventional fluid of fluid coupling (ISO VG 32) are as follows
5.1 Density: Density of the water is 0.992 gm/cc at 40 degree centigrade and density of ISO VG 32 oil is approx 0.856 gm/cc, hence water has higher density than ISO VG 32 lubricating oil.
5.2 Viscosity: Water has 0.658 cst at 40 degree centigrade and ISO VG 32 oil has 32 cst at 40 degree centigrade. water has less viscous than ISO VG 32 oil so it is more fissile as working fluid for fluid coupling.
5.3 Specific heat: Water has is 1 Kcal per kg per degree centigrade and ISO VG 32 oil has 0.49 Kcal per kg per degree centigrade. Water has higher specific heat that show water can be use as working fluid in fluid coupling.
5.4 Thermal Expansion: Water has is 1 Kcal per kg per degree centigrade and 0.49.
5.5 Lubrication: water has very poor lubrication properties. Additional lubrication system is required when water is used in fluid coupling.

VI. TEST SETUP

Here we used 325 HP test bench for carry out performance test on fluid coupling. Test is carried out with varying the load on fluid coupling by a dynamometer.

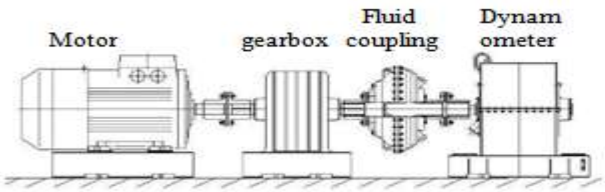

Fig 6.1 test bench typical arrangement

Test setup for performance test is consist of following instruments
6.1 Motor: the electric motor worked as prime mover for test bench. Technical specification of the motors is

Rated Power	325 Hp
No of pole	6 pole
Full load efficiency	95.9
No of phase	3 phase
Rated voltage	440 V
Rated current	52 A
Insulation class	F
IP class	55

6.2 Dynamometer: the dynamometer worked as load for test bench. Technical specification of dynamometer is

Rated Power	1000 Hp
Speed	600 to 3000 RPM
Type	Hydraulic
Control	Scoop tube controlled
Cooling	Water cooled
Arm length	1525 mm
IP class	55

6.3 Gearbox: the gearbox is used to run fluid coupling at 1500 RPM. The motors rated speed was 1000 RPM and we require testing of fluid coupling at 1500 RPM. Technical specifications of gear box are

Rated Power	1000 Hp

Speed	600 to 3000 RPM
Type	Bevel gear
Gear material	Cast Iron
Speed ratio	1.5:1
Cooling	Water cooled
IP class	55

6.4 Fluid coupling: the fluid coupling we used in this experiment is of reputed indigenous make. The fluid coupling is of aluminium body. The ratings of fluid coupling are mentioned in table below

Rated Power	200 Hp
Rated Speed	1500 RPM
Type	Constant speed
Filled media	ISO VG 32
mounting	Shaft mounting
Cooling system	Self cooled
IP class	55

VII. TEST PROCEDURE

The performance test is carried out with the following procedure

a) Fill the fluid coupling with ISO VG 32 oil with a known quantity of oil, and mount between gear box and dynamometer.

b) Start the motor and wait until it reaches to steady state than set the load on dynamometer, and again wait for steady state, takeout the reading of input RPM, output RPM and dynamometer load.

c) Now change the load on dynamometer and take all the readings again. Follow same procedure to 2 to 3 times.

d) Stop the motor and reduce the oil quantity into the fluid coupling and perform the same procedure.

e) Now dismount the fluid coupling from the test bench and fill the water into them and carryout same procedure from the beginning for water.

VIII. TEST RESULTS

The performance test is carried out with ISO VG 32 oil and water. The results observed with the oil and water is as follows

8.1 Readings with ISO VG 32 oil:

S. No.	Torque (Kgm)	Input Speed (RPM)	Output speed (RPM)	Slip (%)	oil filling (liters)	Output power (HP)
1	66.05	1494	1464	2.0	15.4	135.76
2	96.42	1486	1441	3.0	15.4	197.12
3	125.40	1479	1408	4.8	15.4	255.16
4	37.60	1514	1493	1.4	14.9	78.32
5	50.31	1510	1481	1.9	14.9	104.51
6	105.39	1495	1441	3.6	14.9	216.76
7	124.87	1488	1420	4.6	14.9	255.63

8.2 Readings with Water:

S. No.	Torque (Kgm)	Input Speed (RPM)	Output speed (RPM)	Slip (%)	filling (liters)	Output power (HP)
1	76.21	1494	1464	2.0	15.4	156.64
2	112.54	1486	1441	3.0	15.4	230.08
3	130.20	1479	1408	4.8	15.4	264.93

4	159.21	1470	1396	5.0	15.4	321.98
5	60.25	1510	1481	1.9	14.9	125.16
6	121.59	1495	1441	3.6	14.9	250.08
7	143.89	1488	1420	4.6	14.9	294.56

1) Filling 15.4 Liters:

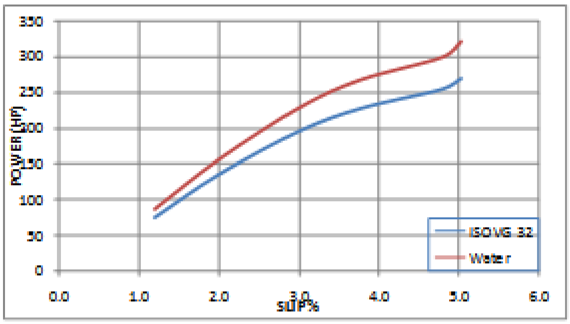

Fig 8.1 Power vs. slip at 15.4 liter water and oil fill

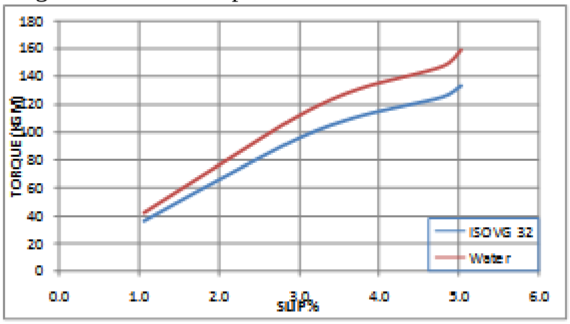

Fig 8.2 Torque vs. slip at 15.4 liter water and oil fill

1) Filling 14.9 Liters:

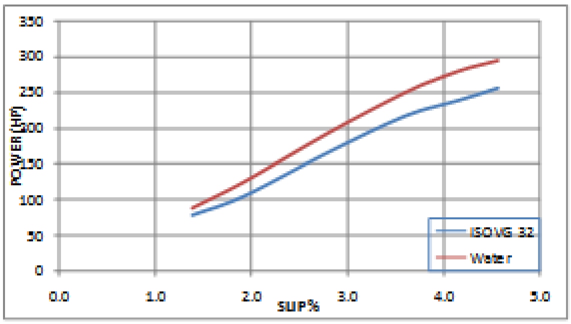

Fig 8.3 Power vs. slip at 14.9 liter water and oil fill

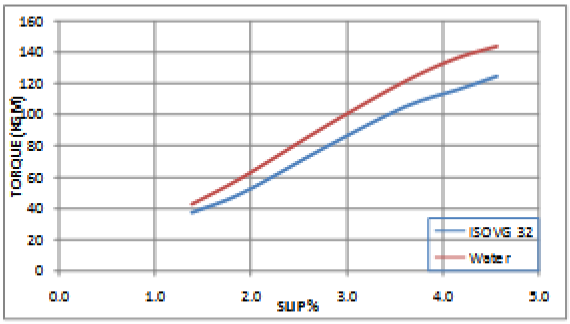

Fig 8.4 Torque vs. slip at 14.9 liter water and oil fill

IX. CONCLUTION

On the basis of above observations and the results of the experimental investigations on a Fluid Coupling with ISO VG 32 oil and water. The performance of fluid coupling with water is better than the ISO

VG 32 oil. Output of the fluid coupling increases with water is about 15 percent than with oil. But special lubrication to be required when using water, because water has poor lubrication properties.
This arrangement (water filled fluid coupling) can be use where explosion proof or fire proof protection is required like refineries, coal mines etc.

This arrangement reduces cost of fluid coupling because water is freely available, but some design modifications to be required to use water as working fluid.
One more problem arise while using water that the water starts evaporation when temperature increases, hence continues cooling and temperature control is special precaution while using water.

X. FORMULE USED

Slip $S = \frac{N_1 - N_2}{N_1}$

Output power $p = \frac{2 \times \pi \times N_1 \times T}{60 \times 746}$

9. ABBREVIATIONS

RPM	Revolution or rotation per minute
Circuit	Space inside and between impellor and rotor.
NTP	Normal temperature and pressure at sea level
Hp	Horse Power
Kgm	Kilogram-meter
N1	Input speed
N2	Output speed
T	Torque
P	Power in HP
ISO	International standard organization
VG	Viscosity grade
IP class	Instrument protection class
kcal	Kilo calories
cst	Centi-stokes
gm/cc	Gram per cubic centimeter
KW	Kilo watt
SA	Secondary air fan
PA	Primary air fan
ID	Induced draught fan
FD	Forced draught fan

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