Application of hydraulic based transmission system in Indian locomotives- A Review

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Abstract- This paper is basically a review of transmission system based on hydraulic applications that how the power is transmitted from engine to the axle. Hydraulic transmissions were introduced over Indian Railways way back in 1050s. Since then it has found wide range of application to meet the operational requirements. The use of hydraulic transmission has progressively changed from Mechanical to Hydro-mechanical to ultimately hydrodynamic system. Hydro-Mechanical transmission also known as Suri transmission used in WDS4 and ZDM3 class of locomotives consisting of one converter and hydro-mechanical clutch system. In this paper, loco characteristics are also discussed for WDP_2 Loco of Indian Railways.

Keywords—Hydraulic, Locomotive, Transmission

I. INTRODUCTION

Unlike the steam engine, a diesel engine has certain inherent characteristics, which do not permit a direct drive to the loco wheels. One of the above is that it cannot start under load and it requires a certain minimum rotational speed, called firing speed, before it catches the cycle and continues to run. Secondly it is not allowed to run either below the idling speed or beyond the maximum rated speed as the reciprocating parts are balanced for a particular speed range only. The other important characteristic is that the direction of rotation for running, which cannot be changed at will. Over and above, a diesel locomotive must fulfill the following essential requirements:

- It should be able to start a heavy load, hence it should exert a very high starting torque at the axles.
- It should be able to cover a wide speed range.
- It should be able to run in either direction with much ease.

Considering the fundamental characteristics of diesel engine, to satisfy the above operating requirements of the loco, it becomes necessary to introduce a device between the prime mover and the loco wheels. This device is called Transmission.Any transmission device employed in a loco should be able to fulfill the following requirements:

- It should transmit the power from engine to the wheels with minimum loss.
- It should have the provision to connect and disconnect the diesel engine from axles for starting and stopping the loco at will.
- It must incorporate a mechanism to reverse the direction of travel.
- It must provide necessary permanent speed reduction, as the axle speed is normally much lower than the engine speed.
- It must provide a high torque multiplication at start which should gradually fall with the increase of vehicle speed and vice-versa.

II. MECHANICAL TRANSMISSION

In this system of transmission, a clutch and a multi-ratio gear box are employed. the gearbox consists of several gear trains, each designed to give a specific speed ratio, the engine power is transmitted through one gear pair at a time. as the engine is connected to the loco, wheels through a fixed gear ratio in each gear set, the loco speed directly varies with the engine speed. the change over from one gear train to another is through clutch. in case of mechanical transmission, through the efficiency is high, the power utilization factor is low.

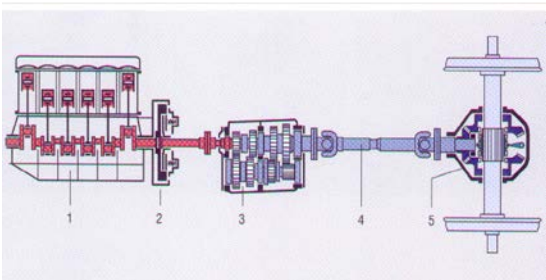

Fig.1 Mechanical underfloor drive system of a diesel rail car(1)Engine, (2)Multidrive clutch, (3)Four-speed transmission, (4)Cardanshaft, (5)Reversing final drive.

III. HYDRAULIC TRANSMISSION

Hydraulic transmissions are of two types:

- Fluid coupling
- Hydraulic torque converter

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A. Fluid coupling

A fluid coupling is a device employed in a power transmission system to transmit torque through a fluid medium. The principal members are Impeller or pump generally connected to the input side of the power transmission system and Turbine or runner connected to the output side. The impeller and turbine of the coupling are identical with respect to their inside and outside diameter, design and positioning of the blades etc. The kinetic energy and torque absorbed by the impeller is equal to that released in the turbine i.e., the torque conditions of both elements are identical. Hence, there can be no torque conversion in a fluid coupling and impeller torque is always equal to the turbine torque.

B. Hydraulic torque converter

Fig.2 Constructional view of a hydraulic torque converter.

There are four components inside the very strong housing of the torque converter:

- **Pump:** Impeller or pump, generally connected to input side.
- **Turbine:** Turbine or runner, connected to output side.
- **Stator:** The third member is reaction wheel guide wheel. It is placed in the fluid circuit to guide the fluid, coming from the turbine, into the impeller and is normally connected to the casing and remains stationary.

- **Transmission fluid:** The housing of the torque converter is bolted to the fly wheel of the engine, so it turns at whatever speed the engine is running at. The fins that make up the pump of the torque converter are attached to the housing, so they also turn at the same speed as the engine.

C. Working of hydraulic torque converter

The converter has three member i.e. impeller, turbine and reaction elements, where as turbine has impeller and turbine only.The principal members are not identical in construction and the blades (vanes) provided in them are shaped and positioned to from different angles with respect to the axis of rotation to obtain required performance. The torque condition of impeller and turbine are not same owing to the existence of reaction member in the fluid circuit. The impeller torque gets increased or decreased in turbine according to the speed of the two members.

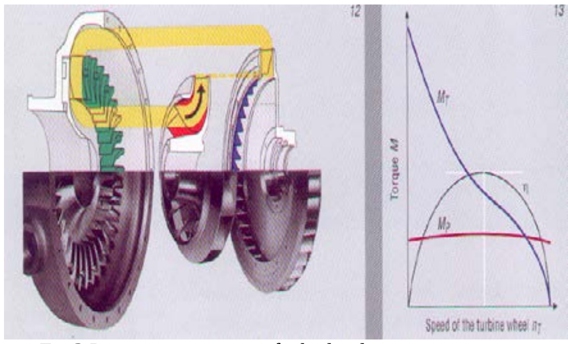

Fig.3 Power transmission of a hydraulic torque converter.

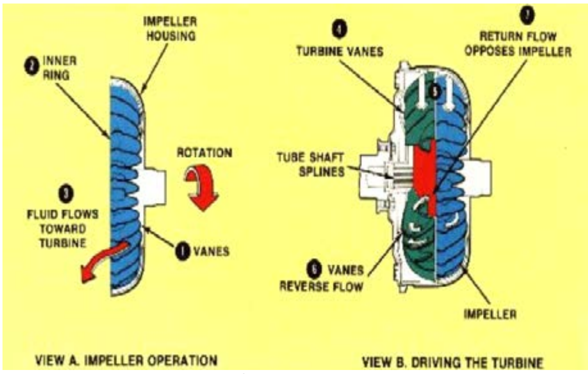

Fig.4 Working of a hydraulic torque converter.

In transmitting power, a torque converter behaves like a gearbox having infinite gear ratio and hence provides step-less variation of torque at turbine end for constant input torque. This inherent characteristics suits very well with the output torque requirement of the locomotive. Owing to conversion of energy from mechanical to hydraulic in the impeller and hydraulic to mechanical in the turbine, there is loss of power and hence efficiency of the transmission poorer than mechanical transmission. However it compares well with electrical transmission. For a definite output speed, its transmission efficiency is superior while working under part load. So it is ideal for shunting locomotive. It does not transmit shocks and vibration due to hydraulic medium.

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IV. HYDRAULIC TRANSMISSION IN USE ON INDIAN RAILWAYS

Hydraulic transmissions were introduced over Indian Railways way back in 1950s. Since then it has found wide range of application to meet the operational requirements. The use of hydraulic transmission has progressively changed from Mechanical to Hydro-mechanical to ultimately hydrodynamic system. Hydro-Mechanical transmission also known as Suri transmission used in WDS4 and ZDM3 class of locomotives consisting of one converter and hydro-mechanical clutch system. In 1983, hydrodynamic turbo reversible transmissions were introduced over Indian Railway. They are:

- L4r2U/U2: It has one converter for each direction of travel. It is fitted in WDS4D shunting locomotives and ZDM4A NG locomotives.

- L4r4U/U2: It has two converters for each direction of travel. Of the two one is for high torque low speed and the other for low torque and high speed. It is fitted in YDM2 locomotives.

A. Broad gauge locomotives

- **WDS3 class locomotive**

It is RDSO’s first diesel locomotive introduced over Indian Railways in 1968. It incorporates a large number of novel features like high efficiency and adhesion, which constitute major advances in diesel loco design. 650 hp diesel hydraulic shunting locomotive was designed with Suri **hydro-mechanical** Transmission. They have features for main line as well as shunting operation respectively.

- **WDS4 class locomotives**

Subsequently, WDS4 class locomotives were introduced on Indian Railway, Which are 700 hp upgraded version of WDS3 locomotives. They have features for main line as well as shunting operation at 65 and 27 km/h speed respectively. Main feature are:

- Equipped with a single Mak model 6M282A (K) turbocharged after cooled diesel engine, set to deliver at site a constant 700 hp in the speed range 700 to 1000 rpm by means of reverse governing for better fuel efficiency.
- **Suri hydro-mechanical** type transmission consisting of a Trilok converter coupling and synchronizing fluid coupling with plate clutch for higher efficiency
- Jack shaft gear box for operation in main line and shunting
- Electro pneumatic reversing system
- Provided with compressed air brakes system for locomotive with arrangement for operating vacuum brakes on the trailing stock.

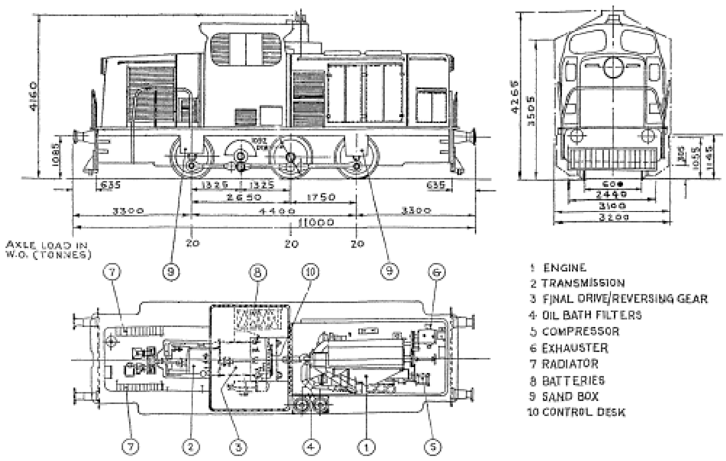

Fig.5 WDS4 Claas Locomotive

- **WDS4D class locomotives**

Successful introduction of Voith Hydrodynamic transmission in ZDM4 locomotives, prompted the introduction of Voith turbo reversible hydrodynamic transmission in WDS4 class locomotives. WDS4D is such locomotive. They have features for main line as well as shunting operation at 65 and 27 km/h speed respectively.

B. Narrow gauge locomotives

- **ZDM3 class locomotives**

For dieselization of the narrow gauge sections, it was decided to adopt a basically B-B design of 8.5t axle load with provision to modify the same to 1B’-B’1 design to reduce the axle load to 6t. First ZDM3 class locomotive was introduced in Kalka-Shimla section of Northern Railway. The design of power equipment is similar to that of WDS4 class locomotives. equipped with a single Mak model 6M282A (K) turbocharged after cooled diesel engine with voith governor

- Fitted with Voith turbo-reversible transmission having one converter for each direction of travel.
- Complete elimination of mechanical reversing system,
- Dynamic braking by emptying the filled converter and filling opposite direction converter.

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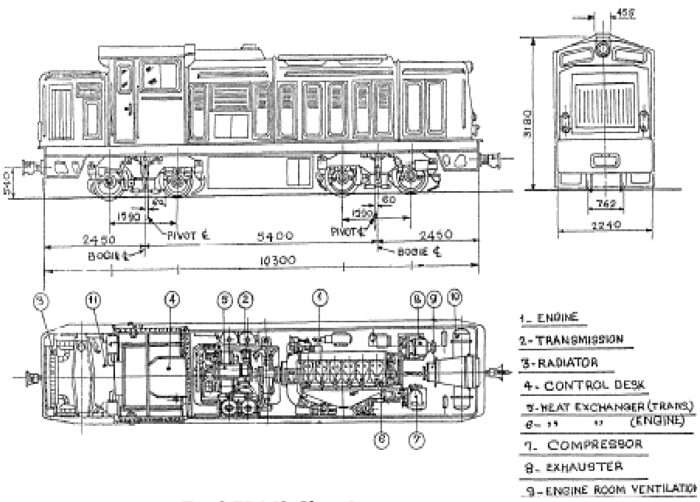

Fig.6 ZDM3 Claas Locomotive

- **ZDM4 class locomotives**

This overcome the recurring problem in electro-pneumatic reversing arrangement, these locomotives were designed with Voith turbo- reversing Hydrodynamic transmission. These locomotives were first introduced in 1983-84 in Kurudwadi section of Central Railway. The main features are:

- equipped with a single Mak model 6M282A (K) turbocharged after cooled diesel engine with voith governor
- Fitted with Voith turbo-reversible transmission having one converter for each direction of travel.
- Complete elimination of mechanical reversing system,
- Dynamic braking by emptying the filled converter and filling opposite direction converter.

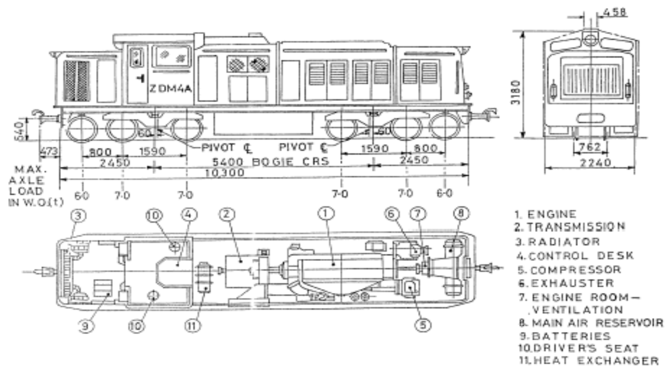

Fig.7 ZDM4 Claas Locomotive

C. Metre gauge locomotives

- **YDM2 class locomotives**

The development of design YDM2 class diesel hydraulic locomotive was further progress in introduction of Voith transmission with Hydro-dynamic feature in passenger service application. It contains

- equipped with a single Mak model 6M282A (K) turbocharged after cooled diesel engine with voith governor
- Fitted with Voith turbo-reversible transmission having two converter for each direction of travel.
- Complete elimination of mechanical reversing system,
- Dynamic braking by emptying the filled converter and filling opposite direction converter.

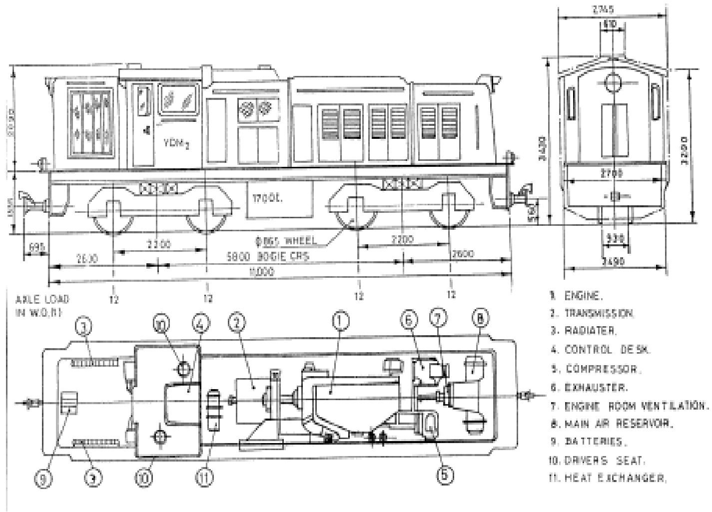

Fig.8 YDM3 Claas Locomotive

V. LOCO CHARACTERSTICS

TABLE:1 HAULAGE CAPACITY OF WDP2 LOCOMOTIVE

HAULAGE CAPACITY (Passenger)											
LOCO:-WDP$_2$			**GAUGE: B.G.**				**WT OF LOCO: 117t**				
Trailing load in tonnes at km/h on tangent track, ICF stock (With 0.005 m/sec^{2} ^{a} acceleration reserve)											
GRADE	**SPEED (Km/h)**										
	20	30	40	50	60	70	80	100	120	130	140
LEVEL	Above 1900t						2025	1245	815	640	530
500					1890	1500	1235	805	545	435	365
400					1700	1355	1125	735	500	400	335
200				1385	1115	900	755	500	345	275	230
150			1530	1110	900	725	610	405	280	220	-
100	1860	1545	1080	785	635	515	430	285	-	-	-
50	945	785	540	385	305	240	195	-	-	-	-

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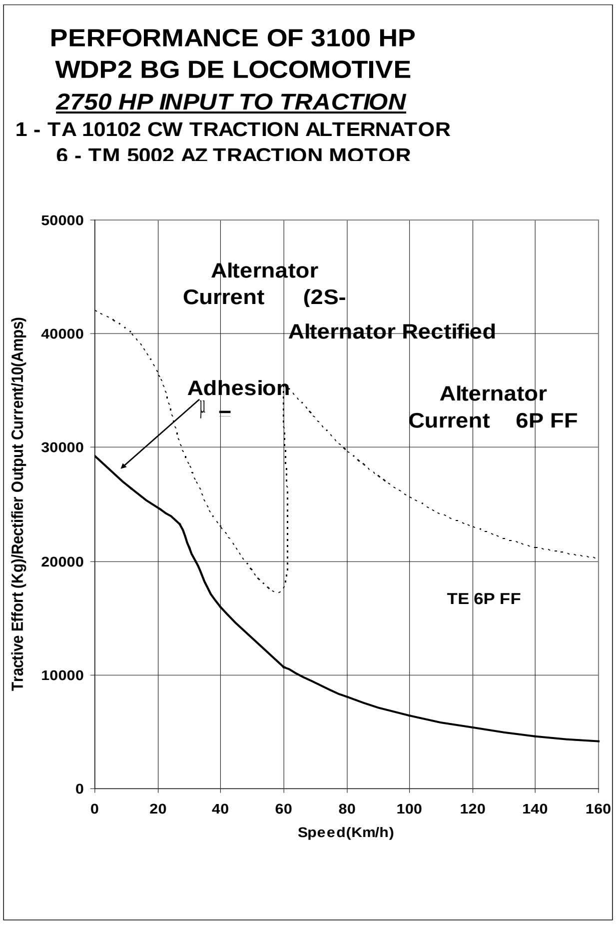

Fig.9 Performance of 3100 HP WDP2 BG DE Locomotive

VI. CONCLUSION

Hydraulic transmissions were introduced over Indian Railways way back in 1950s. Since then it has found wide range of application to meet the operational requirements. In this paper, transmission system based on hydraulic applications are discussed that how the power is transmitted from engine to the axle. Hydraulic transmissions were introduced over Indian Railways way back in 1050s. Since then it has found wide range of application to meet the operational requirements. The use of hydraulic transmission has progressively changed from Mechanical to Hydro-mechanical to ultimately hydrodynamic system. Hydro-Mechanical transmission also known as Suri transmission used in WDS4 and ZDM3 class of locomotives consisting of one converter and hydro-mechanical clutch system. In this paper, loco characteristics are also discussed for WDP_2 Loco of Indian Railways.

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BIOGRAPHY

Mohd Anees Siddiqui was born in Kanpur, India, in 1988. He received the B.Tech degree in Mechanical Engineering from Integral University, Lucknow, India, in 2011, and pursuing M.Tech in Production & Industrial Engineering from Integral University.

In 2011, he joined the production department, Technical Associates Ltd, Lucknow and worked in manufacturing sector for a period of one year. He worked as a Lecturer in Lucknow Institute of Technology, Lucknow. Presently, he is working as a Lecturer in Department of Mechanical Engineering, Integral University Lucknow. He has undergone internship and training programmes at Tata Motors Ltd, Hindustan Aeronautics Ltd. and Research Development & Standards Organisation. He is a member of International Association of Engineers, International Association of Computer Science & Information Technology, and International Association of Engineers & Scientists. His area of interest is Manufacturing, Production & Industrial engineering. He has published several papers in International journals. He has attended several national & international conferences on mechanical engineering. He received 2nd Award in model presentation Geothermal Energy Exploration Plant on celebration of Rajiv Gandhi Renewable Energy Day at Non-Conventional Energy Development Agency, Lucknow, in Aug, 2010.

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