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Indigenous Transmission for Main Battle Tank

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Abstract. Significant technical advances have been made in the design, development and in bringing out prototypes of most modern transmission for the Main Battle Tank by the CVRDE, Avadi. The transmission has been designed as a semi-automatic, heavy duty, power-transmission-cum-steering unit to provide for four forward and two reverse speeds with a steplessly variable radii of turn in each gear together with neutral turn capability. Test bed results are very encouraging and have shown the transmission's ability to transmit 1000 horsepower at an overall efficiency of around 90 per cent which is quite comparable to some of the best designs developed elsewhere.

1. Introduction

India's Main Battle Tank (MBT) for the 90s, christened *Arjun*, features a powerful 120 mm rifled gun capable of firing APFSDS rounds of exceptional lethality and best possible armour protection for a 50 MT weight class tank that gives a very high level of immunity against 120mm APFSDS rounds. It also has a most advanced gun control system and associated opto-electronics with the capability to fire on the move on a moving target. A mobile platform of this weight range gets the requisite stability in motion by hydro-gas suspension and the exceptional manoeuvreability required from both mobility as well as tactical considerations through a high power to weight ratio power pack (in the order of 25 to 30HP/MT).

The high specific output diesel engine prime-mover features only flat torque-speed characteristics and has limited useful speed range. It does not meet the torque speed characteristics expected of an idealized prime-mover for vehicular application which demands a constant power over the entire speed range of the vehicle[1]. This deficiency has, therefore, to be necessarily overcome by using a set of gear ratios through the medium of transmission. Besides, the steering of a tracked vehicle is accomplished by differential speed inputs to the two sprockets again through the medium of transmission only. Transmission's primary task is, therefore, to make available the engine power at appropriate torque and speed levels at the sprockets and to provide for the steering and braking function required for the vehicle[2,3]. The significance of the transmission, the subject matter of this paper, is thus obvious.

2. Considerations for the Choice of Transmission

The transmission for India's future MBT is expected to meet the operations envisaged in the battle field and identified as : (a) High stall torque for easy starting, (b) Good cross country speed of about 40 km/hr on undulating terrains (gradients approx. 10 per cent), (c) Ability to negotiate gradients as high as 60 per cent with a continuous speed of approx 8 km/hr, (d) Ability to achieve a flat-out speed in excess of 60 km/hr on concrete, tarmac, hard-baked grounds, etc., (e) A good accelerative ability to obtain a speed of 30 km/hr in about 12 seconds or less, (f) A good decelerative ability to come to stand-still from top speed in less than 8 seconds, (g) Capability to perform neutral turn in about 12 seconds or less, and (h) Good overall manoeuvreability etc..

The transmission for the MBTs hitherto has been designed and used with engines of lower horse-power (under 750 HP). The design features, therefore, did not place undue demands either on the powershift capabilities or on the need for steplessly variable steering. The weight range of vehicles being lower, the braking capabilities were nominal as the vehicle speeds were comparatively lower. The power shift gearbox featured the irksome band-brake mechanism for locking the annulus member and a centrifugal clutch was adequate to achieve semi-automatic operation.[4] Conventional disc brakes met the braking requirements well. These design features, however, have definite limitations in the torque transmissibility beyond a particular level.

The volumetric envelope available for the transmission in the future MBT being not significantly higher than that available in the earlier generation MBTs, the higher torque and thus higher power transmission is sought to be achieved by taking advantage of advanced technical features and better packaging of every component element.

The design layout of the transmission was evolved after a comparative study of the successful contemporary tank transmission such as that for Leopard Mark-I, T-72, Challenger, Leopard Mark-II and the American XM-1, etc. The design philosophy is based on the achievements of the transmissions in Leopard Tanks[2,5,6]. Accordingly, the transmission features : (a) A hydrodynamic torque converter to facilitate easy starting, steep gradient climbing and to provide for smooth, jerk-free gear shifts under power, (b) A most modern compounded epicyclic gearbox[7,8,9] incorporating oil immersed multiplate clutches and brakes that provides for 4 forward and 2 reverse speeds, (c) A steplessly variable hydrostatic regenerative[10] steering system with neutral turn capability, (d) A hydrodynamic retarder[11] supplementing the disc brakes to achieve a much higher braking capability, (e) An integral oil cooler with its own filtration system, (f) Specially designed light weight, high strength aluminium alloy transmission housings[6] encapsulating all the gear assemblies as also incorporating the complete hydraulic routings as precision drilled and welded integrated oil passages, (g) A solid state transmission controller[3] to facilitate easy gear changes and powerful hydraulic servo-assisted steering that makes the steering possible with a feather touch, and (h) Modular construction[3,5] to facilitate ease of maintenance and to provide for application flexibility. A schematic layout of the transmission and the tractive effort diagram is shown in Figs 1 & 2.

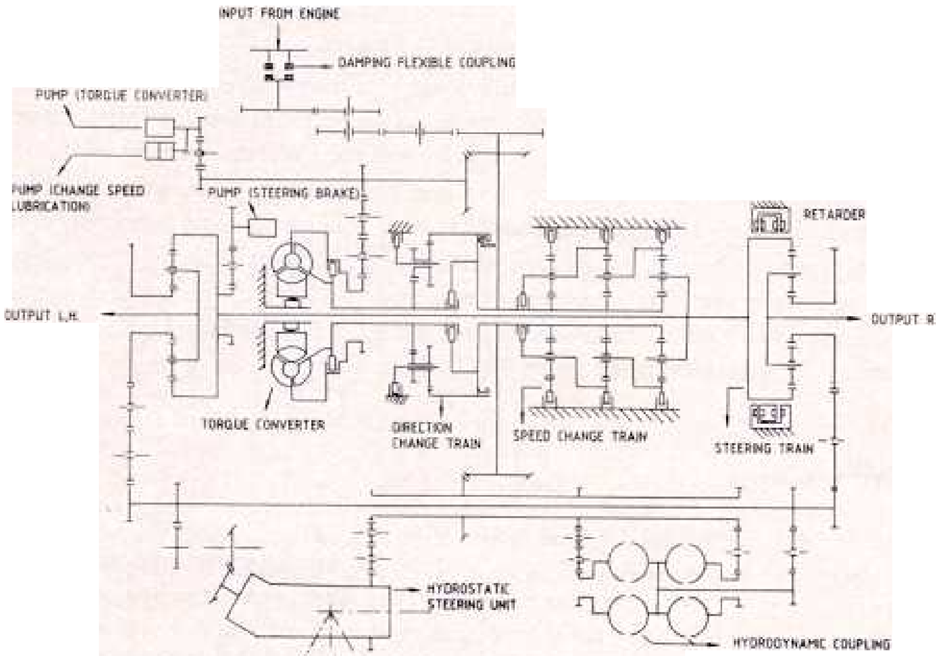

Figure 1. Transmission schematic with hydrostatic steer.

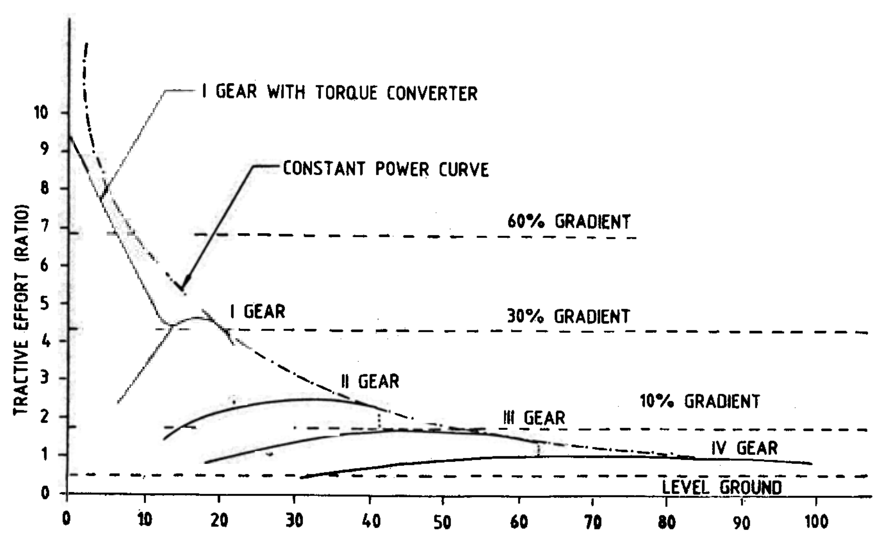

Figure 2. Tractive effort diagram.

3. Development of the Transmission

The development of the transmission incorporating features cited above have brought many developmental problems to the fore. These problems relate to both the design and manufacture of transmission components and the test set-ups for the performance evaluation of the component systems. Many problems relating to manufacture had to be tackled carefully to execute this complex work with available facilities. A number of such problems in high technology areas have been resolved and the indigenous design of the hydrodynamic torque converter and the hydrodynamic retarder and the highly intricate planetary gear sets and the transmission housings have all proved successful. Through sustained efforts, it has been possible to come almost at par with advanced countries both in design capability and in the construction of these units. A hydrostatic steer unit has also been developed, but, to cut short the developmental time, an imported unit as used in the transmission for the Leopard Mark-II has been adopted in transmission for the *Arjun* MBT.

4. Performance

To-date, two prototype transmissions complete in all respects including the hydrostatic steer system have been built and both are presently undergoing performance evaluation. The transmission which has been cumulatively tested for about 150 hours has shown its ability to transmit a power of approx. 1000 HP and a maximum torque of 3500 N-M with an overall efficiency of about 90 per cent which compares favourably with the efficiencies reportedly achieved with the transmissions for Leopard Mark-II. The transmission using twin L-60 engine prime-movers each developing approx. 650 HP appropriately coupled through a linking gearbox in the absence of a single engine prime-mover of the required capacity is presently being load-tested. The creation of this test facility itself was a challenging task and has been successfully accomplished.

5. Conclusion

The performance of the transmission prototypes so far has been quite encouraging. After continued load-test for about 400 hours, it is expected to bring out a power pack comprising the transmission appropriately married with a 1100 HP engine for fitment onto the tank by end of 1986. With this, the status of indigenous transmission as an acceptable assembly for the MBT will become a reality.

A series of transmissions incorporating advanced features for military track laying vehicles encompassing the power range 300 to 1500 HP to cater for vehicle weights from 10 MT to 60 MT are planned to be developed over the next two decades. Efforts are being made to make use of the products developed by the CVRDE such as gearbox, hydrodynamic torque converters, couplings and retarders, etc. in special purpose vehicles such as heavy tank transporters, tractors for handling heavy equipment trailors, mining trucks, etc. Tentative layouts of the design for a family series of gearboxes and torque converters have been evolved. A layout of an eight speed gearbox for use in dump-trucks has also been prepared. Thanks to the encouragement and support of successive Scientific Advisers and particularly of Dr. Raja Ramanna, India is confident of achieving self-reliance in building transmissions for the MBTs in the near future.

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