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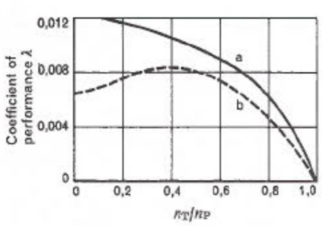
The following relationships exist between torque T_P or power P_P, angular velocity ω_P of the pump, diameter D of the Foettinger coupling and density ϱ of the operating fluid:

$$T_P = \varrho \, \lambda \, \omega_P^2 \, D^5$$
$$P_P = \varrho \, \lambda \, \omega_P^3 \, D^5.$$

The coefficient of performance λ (dimensionless) is particularly dependent on the speed ratio between the turbine and pump n_T/n_P, as well as on the design (see graph).



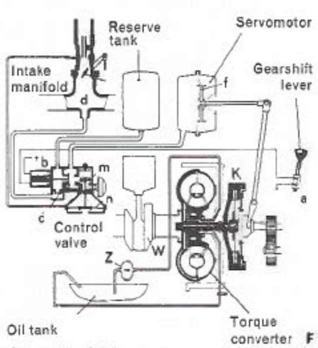
Coefficient of performance λ of Foettinger coupling
a with inner torus
b with baffle plate

Automatic clutches

Operating the clutch and gearshifting are the most tiring part of motoring. Efforts have thus been made to simplify operation by means of automatic clutches. (Gearshifting is still required but clutch operation and a clutch pedal are dispensed with).

Automatic clutches have separate or combined starting and shifting clutches. The following are employed as the starting clutch: centrifugal clutch, Foettinger coupling (today mainly the Foettinger torque converter), hydraulically actuated servo-clutch. Features common to all starting clutches: at engine idling there is no or only negligible torque transmission; clutch torque increases with increasing engine speed. Shifting clutches are operated pneumatically, hydraulically or electrically, clutch control being mostly electrical (via valves) from the gear shift lever.

Example of an automatic clutch (see diagram): crankshaft W is connected with Foettinger torque converter F. Stall-torque with turbine stationary (vehicle stationary) 2 … 2.4. (In this way first gear can usually be dispensed with). The torque converter oil circuit is fed by a special, engine-driven oil pump Z (possibly via heat exchanger). Gearshifting performed manually. Touching the gearshift lever closes contact a, which opens valve c via solenoid b. Vacuum from intake manifold d opens clutch K via servo-motor f. After releasing the gearshift lever the solenoid is de-energized and the clutch is engaged quickly or gently (via valves m and n), depending on the pressure in the carburetor throat.



Automatic clutch

Transmission

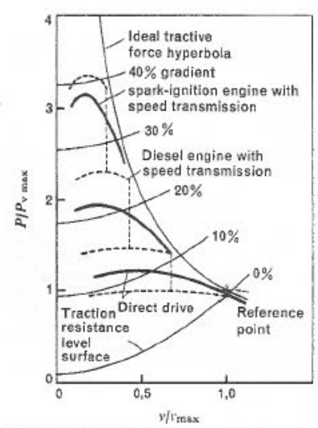
The internal combustion engine delivers a basically constant torque over the entire speed range, and hence increasing power as the rotational speed increases. A directly driven vehicle would provide only little acceleration and exhibit unsatisfactory climbing ability (see graph, direct drive). For this reason a transmission with variable ratio is provided between the engine and vehicle. The function of the transmission is to provide the maximum engine power which is present at only one engine speed, at any driving speed.

The ideal tractive force hyperbola (line of constant power in the performance map, see diagram) can be attained only approximately in practice: in the case of infinitely variable transmissions because of the lower efficiency, and in the case of step-by-step gearboxes (in spite of better efficiency) because of the steps. How good such adaptation is in the case of the latter transmissions depends on the engine torque characteristics and the number of gears. The torque of spark-ignition engines decreases in the upper speed range (favorable, "buffalo-back characteristics"), hence it adapts better to the tractive force hyperbola with fewer transmission steps. In the case of diesel engines the torque is usually virtually constant, and the maximum power is available at one engine speed only. Having a high number of transmission steps still does not completely rule out these discontinuities. The number of steps is a compromise between optimum utilization and simplification of operation.

Transmissions are mostly designed with varying steps: closely spaced upper driving gears, widely spaced lower acceleration gears. The ratio of the first gear is determined either by the adhesive force of the driving wheels or the maximum gradient taken as a basis (mostly greater than 35%).

Step-by-step gearbox

In such transmissions a number of ratios are formed between the input (drive) and output shafts by means of gears, which can be incorporated in the power train either manually or by servo assistance.



Performance map

Manual shifted transmissions

These are mostly layshaft transmissions. The power flow passes from the clutch driven plate via the drive shaft and constant-mesh driving gears to the layshaft and on to the output shaft via the engaged gear pair. In reverse gear the normal direction of rotation is reversed via a third intermediate shaft. Transmissions for passenger cars have 3 … 5 gears (mainly 4) and for commercial vehicles 4 … 12 gears (mostly 5 … 6). Transmissions with more than 6 gears are mostly of the range-change (auxiliary-range) type, where the gear pairs are used several times. Advantage: fewer gears, disadvantage: sometimes two gear pairs have to be engaged simultaneously.

"Shifting", i.e. establishing the power flow via a gear pair, is performed manually by means of sliding gears or a dog clutch.

Sliding gears

Least expensive, straight-toothed, no axial thrust, but noisy and difficult to operate. In the case of passenger cars used only for reverse and occasionally first gear; only found in lower gears of trucks (use decreasing).