

Launch Devices for Turbo-Charged Engines

Philip Severyn, Jeff Hemphill, Philip George and Todd Sturgin
 Luk USA LLC

ABSTRACT

The demand for both reduced fuel consumption and increased performance has resulted in the current trend of downsizing and turbo-charging the combustion engine. This started in diesel engines and is being carried over to gasoline direct inject engines. The fuel economy benefit using this strategy is clear, however, the requirements of the launch device are not. One drawback of downsizing and turbo-charging is the effect of lag in boost pressure resulting in a decrease of vehicle performance. This is intensified at increased altitude. One way to reduce turbo lag is by operating the engine at a higher speed. In order to diminish lag, the launch device must allow for faster acceleration of the engine. At the same time, enough engine torque must be transmitted to the wheels to maintain acceptable launch feel. Using a traditional torque converter, the hydrodynamic characteristics can be made looser to allow for faster acceleration of engine speed. This however has a negative impact on fuel consumption. This paper will examine the effects of turbo-charging on launch performance and document the results of different options for launch devices including variable characteristic devices that abate turbo lag while maintaining fuel economy. These options include optimized torque converter characteristics, the Multi-Function Torque Converter, and a new launch device called the Fluid Launch Clutch. These options have been studied both through simulation and hardware testing.

CITATION: Severyn, P., Hemphill, J., George, P. and Sturgin, T., "Launch Devices for Turbo-Charged Engines," *SAE Int. J. Passeng. Cars - Mech. Syst.* 5(1):2012, doi:10.4271/2012-01-0811.

INTRODUCTION

The challenge of selecting a launch device for a vehicle equipped with an automatic transmission is a balance of achieving performance metrics and meeting the ever increasing demand for reduced fuel consumption. [Figure 1](#) shows the increasing trend in CAFE requirements for cars and trucks based on vehicle footprint [2]. To meet this demand, one of the current industry trends is engine downsizing and turbo-charging. Such engines operating under standard temperature and pressure (STP) conditions propel the vehicle as intended utilizing full boost pressure. As the vehicle is driven at higher altitude, reduced air density causes an increase in lag. This results in degraded performance. [Figure 2](#) shows the effects of altitude on measured launch performance in a vehicle with a downsized turbocharged engine. As altitude increases, there is a clear reduction in vehicle performance. To make power more quickly, the engine and turbocharger must be operated at a higher speed. Using a torque converter, the hydrodynamic characteristics can be made looser to allow for faster engine acceleration. By doing this, driving torque is wasted as a loose converter allows for higher slip and results in poor open mode driving characteristics. A better launch device needs to

be implemented to mitigate turbo lag at altitude. In this paper alternate options for launch devices will be investigated. These devices are designed to aid the performance (at STP and higher elevations) and fuel economy of vehicles with downsized turbocharged engines. The devices are also enablers to extend the range at which start/stop technology can be used.

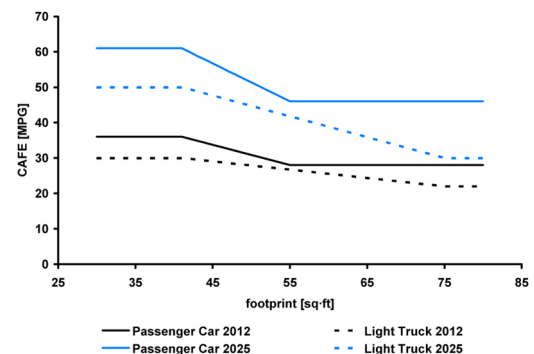


Figure 1. CAFE requirements for passenger cars and light trucks versus vehicle footprint for MY2012 and MY2025

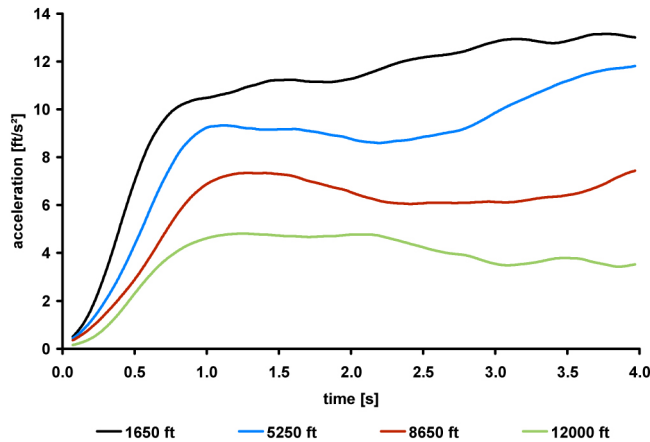


Figure 2. Effect of altitude on measured launch performance

LAUNCH DEVICES IN TURBO-CHARGED ENGINES

For well over a half century the torque converter in a traditional sense has been used to mate the engine with the drive train in a vehicle equipped with an automatic transmission [1]. The demand for increased performance while reducing fuel consumption has resulted in smaller displacement engines outputting higher torque with the help of a turbo charger. This has created a road-block for the torque converter: use a stiff characteristic to conserve fuel, or a loose characteristic to aid boost. Hydro-dynamic converter characteristics can be optimized, but there is still a tradeoff. New launch devices are needed to meet the dynamics of a turbo-charged engine. They should allow for quick turbo spool up while effectively transmitting torque through the drive train. Two such devices are the Multi-Function Torque Converter (MFTC) and the Fluid Launch Clutch (FLC).

MULTIFUNCTION TORQUE CONVERTER

The MFTC is essentially a torque converter with the ability to de-couple the impeller using a disconnect clutch. It has three modes of operation: idle disconnect, torque converter mode, and lock up mode with the possibility of clutch modulation in between each defined mode. For the purpose of this paper, two-pass (two passages in the pressure chamber area) designs were chosen for investigation. To function in a two-pass environment, a Belleville spring is used to hold back the lock up mode clutch until a certain pressure threshold is reached (Figure 3). This torque/pressure profile can be tuned based on application requirements and capacities.

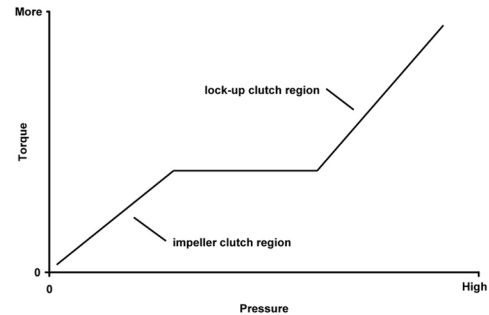


Figure 3. Representative torque-pressure graph

In idle disconnect mode (Figure 4) equal pressure (slightly less pressure behind the piston plates to minimize drag) is applied on both side of the pistons. This allows the transmission oil pump to still be driven and supply pressure to the transmission, yet de-couple the impeller which reduces fuel consumption at idle. During a launch event the impeller clutch is engaged. How this clutch is engaged determines initial launch performance and can be tuned based on application. This clutch can be slipped to allow for faster time to boost, which is crucial at higher altitudes. Once required engine torque output or boost pressure is achieved, the impeller clutch is hard locked.

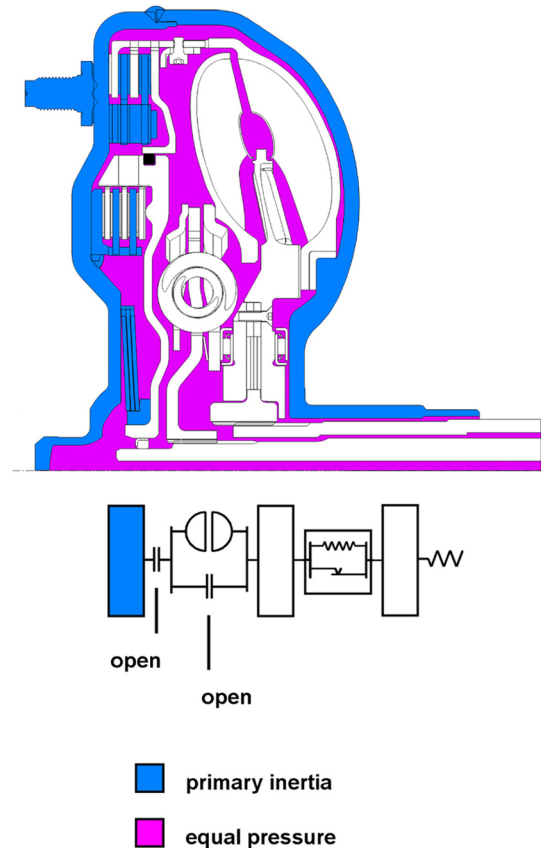


Figure 4. Multifunction torque converter idle disconnect mode

Figure 5 shows a simulated MFTC launch demonstrating impeller slip. The impeller slip profile is designed to provide a proper balance between torque being transmitted through the drive train and an increase of turbo-charger boost pressure. This profile can be tuned for given air densities to reduce the effect of turbo lag at altitude, yet still provide the required performance at STP.

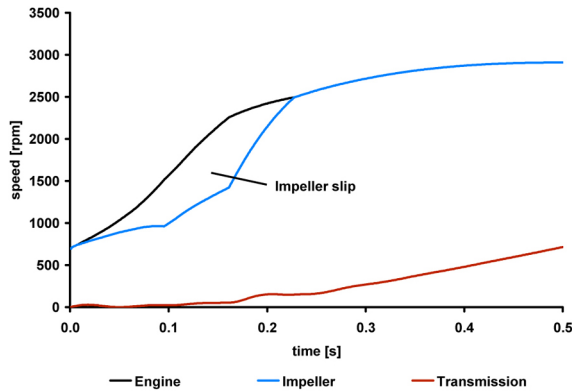
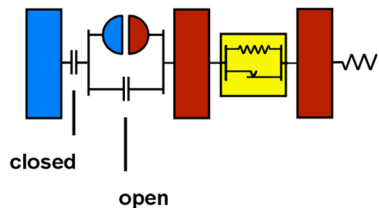
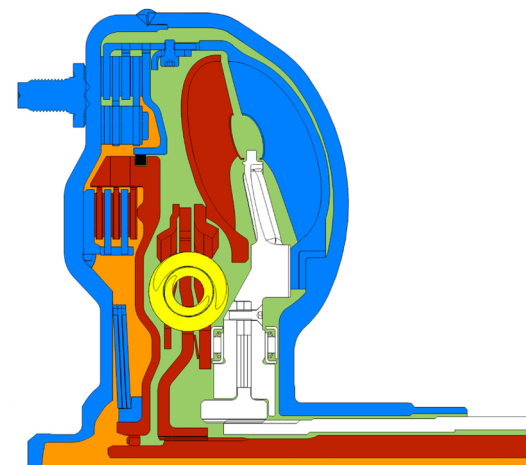


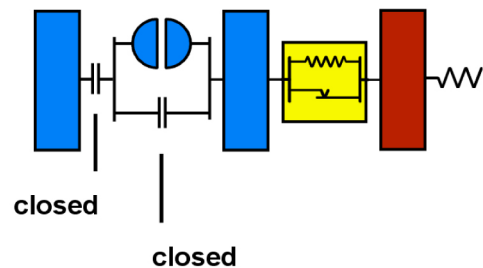
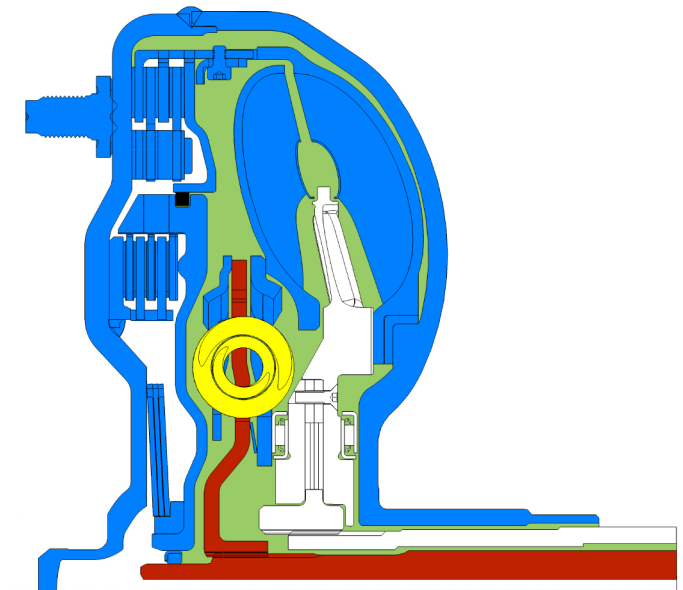
Figure 5. MFTC & FLC launch event demonstrating impeller slip



- primary inertia
- secondary inertia
- high pressure
- low pressure

Figure 6. MFTC in torque converter mode

In torque converter mode (figure 6) pressures behind the pistons are low. The device is operating in the impeller clutch region as shown in figure 3. The Belleville spring holds off the lock-up clutch in torque converter mode. Torque converter mode would only be used in first gear, as the strategy for the MFTC is early lock-up (launch and lock) in first (or possibly second gear).



- primary inertia
- secondary inertia
- high pressure

Figure 7. Multifunction torque converter in lock up mode

In lock up mode (figure 7) pressure behind the piston plates is further reduced resulting in lock-up piston stroke applying force to the Belleville spring which then deflects. As the spring deflects, the lock-up clutch begins to apply. This clutch can be controlled in the same manner as a conventional torque converter clutch (slip and hard lock).