Heavy Truck Cooling Efficiency

DISCUSSION ON IMPROVING COOLING EFFICIENCY AND AMBIENT CAPABILITY OF HEAVY TRUCKS

By Norm Mathers 16/05/2008

Introduction

The modern heavy truck (GVM > 22.5t), often has its rated power output limited by available engine cooling rather than the design of the engine. The recent introduction of Euro 4 and US 4 emission requirements for vehicles sold in Australia from 2008, has in some cases worsened the problem due to even greater cooling demands. This discussion paper presents a case for using alternative methods of cooling heavy trucks, with benefits such as increased ambient capability, reduced noise and reduced fuel consumption and emissions.

The answer is more power. What was the question?

The automotive industry globally is in constant competition with itself to extract more power from every succeeding model, largely in an attempt to give potential buyers a reason to buy the new model. Sadly more power is not always sourced by greater engine efficiency and often results in both increased fuel consumption and engine cooling requirements.

Design limitations on the cooling capacity of trucks.

Most modern truck engines can be electronically programmed to provide a sizable range of power outputs without any internal mechanical modification. Depending on the intended application, truck design and operating environment, a maximum power output will be specified based on the cooling system's capacity to maintain a healthy engine operating temperature, not just the maximum power available from a particular engine design. So in hotter climates, a particular truck configuration may not be capable of producing the same power as in a cooler climate. A truck's ability to operate at maximum power at a specified ambient temperature is known as its ambient capability. Higher ambient air temperatures mean reduced heat transfer from cooling pack to cooling air, and hence reduced cooling capacity which leads to a reduction in available power output since the engine is not able to dispose of its excess heat.

The physical size of a truck cooling pack is most often constrained by the vehicle's space and packaging limitations. Chassis rails internal width generally restricts the maximum width of the cooling pack since the pack has to fit between them and not in front of them for various other reasons. The height of the cooling pack is controlled from below by the vehicle's approach angle ground clearance, and from above by driver visibility. For example, a cooling pack positioned low in the chassis, will reduce ground clearance and risk damage, and a cooling pack high in the chassis will force the front corner of the hood higher in a conventional bonneted truck, thus reducing the driver's frontal visibility. For cab-over trucks internal cab packaging is seriously affected by the height of the cooling pack since it impacts available space on the firewall.

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It can be seen that design and layout of the vehicle controls the height and width of the cooling pack, and thermodynamics control the thickness of the cooling pack since heat transfer becomes less efficient for each successive core added to the rear of the cooling pack. Since the amount of heat energy transferred from the cooling pack to the air is proportional to the mass of air passing through it, obviously the faster the truck moves through the air, the greater the cooling capacity. Consequently, a truck moving along at high way speed does not require a great deal of cooling, and at speed above 60km/h the air forced through the cooling pack is sufficient. The problem of insufficient cooling air flow occurs at lower speeds such as pulling a heavy load up a hill. To provide sufficient airflow, all trucks have a belt-driven fan that is engaged by a thermostatically controlled, air-operated clutch.

Belt driven cooling fans as used on trucks are a cheap, reliable and relatively efficient means of pulling air through a cooling pack. Unfortunately, their circular shape contrasted with the rectangular cooling pack means that a very large portion of the cooling pack receives minimal airflow and consequently offers minimal cooling effect, even though shrouds provide some assistance. In addition, belt driven fans are run at a speed proportional to that of the engine and as with most axial flow fans, loose efficiency either side of an optimum rotational speed. Because engine speed may vary anywhere from 800rpm to 1850rpm, the cooling fan may not always be operating in an efficient zone.

These factors lead to two main points.

- Truck power output is often limited by the amount of cooling available.
- Design and packaging requirements dictate a tall rectangular cooling pack which is inefficiently cooled by an engine-driven circular fan.

If a larger area of the cooling pack could receive sufficient airflow, the following three positive outcomes could be achieved:

- The ambient capability of the truck could be increased allowing it to operate in hotter conditions.
- The power output could be increased for a set ambient capability
- The size of the cooling pack could be reduced to minimise weight and improve packaging.

All three of these options could provide a competitive advantage for truck manufacturers. To achieve greater airflow over the cooling pack area, it follows that more than one fan is required. With a conventional belt driven arrangement, this remains possible, but is likely to become difficult once factors such as belt routing and mounting of the drives to the front of the engine are considered. Electric fans are also a possibility but the power requirement would necessitate overly long and heavy electric motors and wiring due to the relatively low voltage available.

Benefits of using hydraulically driven cooling fans

Hydraulic power may offer a viable solution to this issue for several reasons.

- The high pressures used in modern fluid power (>350Bar) means the power delivery for a given motor size is extremely high. This is especially important due to the lack of space in a modern truck engine bay.
- Hydraulic energy is readily available on every truck with power steering, and additional hydraulic

pumps can be readily added to almost any truck. The “on demand” nature of engine cooling can be catered for by hydraulic pumps and motors such as Mathers Hydraulics FSV vane pump. This is discussed in greater detail below.

- Hydraulically driven fans can be easily positioned to offer the greatest coverage area on the cooling pack. This would immediately provide greater cooling pack efficiency.
- If two or three small hydraulically driven fans were used, they could be automatically set to operate in a staged manner, drawing only the minimum amount of power required for cooling at any given time. This would reduce the negative effect of one large fan suddenly cutting in during a hill accent, immediately sapping engine power to the extent of forcing the driver to downshift gears and losing momentum.
- Hydraulically driven fans could be mounted directly on the cooling pack to offer improved fan efficiency. Tighter clearances between the blade tips and the fan shroud generally result in less recirculation of the air around this area and consequently greater fan efficiency. Fans mounted directly to the cooling pack would however add negatively to the stresses in the cooling pack mounts.
- There is a possibility that a series of smaller fans may be quieter in operation than one large fan. This alone may prove to be a great advantage due to the implementation of “ADR 83/00 external noise”. Truck manufacturers are at the point of chasing individual components in efforts to meet this difficult design rule. Whilst there may be reduced noise from smaller fans, there may be extra noise from the hydraulic system when compared to the conventional belt drive.

Benefits of using the FSV by Mathers Hydraulics.

The FSV (Fuel Saving Vane Pump) designed and developed by Mathers Hydraulics, offers features perfect for hydraulically driven cooling fans in truck. The key function of this pump is its ability to be activated and deactivated electrically from its pumping mode, and consume negligible power when at idle. As a motor, the same applies. When used for this application as both a pump, the system would eliminate the losses incurred by a constantly running belt drive when the fan is disengaged. Used in a series of fan drive motors, they would happily freewheel when disengaged, and provide the ability to be staged for progressive on demand cooling.