FUEL EFFICIENCY IN TRUCK INDUSTRY

Ştefan Farkas
Paccar Inc. Victoria, Australia
stefan.farkas@paccar.com

ABSTRACT

This paper reports range of activities and offer information regarding activities performed at Paccar Inc. truck's plant in order to reduce of fuel consumption in truck industry. There are six major areas investigated: Aerodynamics, Component Spec'ing, Advanced Technology, Route Management, Driver Behaviour, Proper Maintenance. New technologies to improve vehicle fuel efficiency are also reported.

Keywords: fuel efficiency, aerodynamics, route management, drive behaviour, proper maintenance

1. Introduction

Fuel consumption has always been an important factor for truck manufactures and owners. Fuel is one of the leading operating costs in industrial transports. In nowadays, fuel consumption is a competitive factor between carriers due to the high prices of fuel. It is estimated that long distance transport enterprises fuel consumption of the total cost of about 30 % [5].

The U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) produce the *Fuel Economy Guide* to help car buyers choose the most fuel-efficient vehicle that meets their needs [7]. Advanced transmissions and efficient engines represent one strategy that would help an automaker meet the nation's first-ever greenhouse gas standard [2].

Each year, important track manufactures invest significant financial and human resources and conducts extensive on-the-road and in-the-lab testing in order to get a better fuel efficiency.

There are a lot of factors affecting fuel economy in the real world, presented in an Ishikawa diagram in figure 1. These are related to tires, drivers, vehicle, documentation, environment, operations.

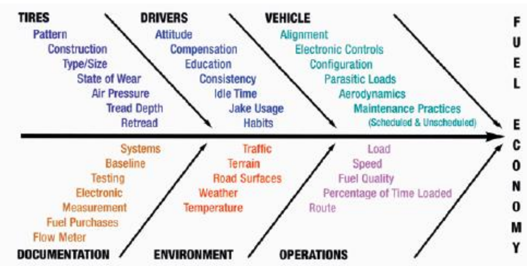

Figure 1. *Factors affecting fuel economy in the real world*

At Paccar Inc. there are six major areas that are investigated for a better fuel efficiency: Aerodynamics, Component Spec'ing, Advanced Technology, Route Management, Driver Behaviour and Proper Maintenance [6]. These areas are presented in the following paragraphs.

2. Aerodynamics

Roughly half the energy used by a truck at speed of 55 mph is used to move the air around the truck. At a speed of 65 mph, roughly two-thirds of the energy is used to cut through the air.

In order to have greater fuel efficiency Paccar Inc. uses a four-part attack consisting of [6]:

- Computational Fluid Dynamics (CFD)
- Wind tunnel testing
- PACCAR Technical Centre testing
- Real-world highway testing.

2.1. Computational Fluid Dynamics (CFD)

Paccar Inc. uses sophisticated computer technology to offer aerodynamics and fuel economy improvements. The technology – called computational fluid dynamics (CFD) – allows engineers to conduct "virtual" aerodynamic testing as shown in figure 2.

Figure 2. *Virtual aerodynamic testing*

With CFD, it is simulated a combination of real world and wind tunnel conditions on the computer screen. This tool enables to evaluate different hood shapes, cab-sleeper configurations and roof fairing designs, truck-trailer interactions, trailer modifications, and flow around all other new truck components. CFD enables to achieve a better approximation of real world truck results than a simple wind tunnel can provide. CFD incorporates variables such as rolling tires, a moving ground plane, differing wind yaw angles, and the effects of under hood and under chassis airflow with full size trailers.
The integration of CFD in aerodynamics helps to evaluate and optimize basic truck shape.
In addition to the study of external aerodynamics, CFD software is used to study the under-hood heat transfer of the fan and radiator. This enables to further fine tune the truck design under the hood. The results of this study allows for a design with better airflow management and reduced air noise. The internal flow of the Heater/ Ventilation/Air Conditioning (HVAC) system is studied in the same fashion, producing the same benefits.
The fuel consumption can be simulated with very good accuracy by both models for predefined driving cycles or under real driving conditions. The deviation between measured and simulated values of fuel consumption can be less than 5% [3].

2.2. Wind Tunnel Testing
Paccar Inc. has conducted wind tunnel testing since the mid-1970s. This database serves as an information asset in meeting today's challenges.
Paccar Inc. uses wind tunnel testing of 20% scale truck models in pursuit of fuel economy advances. Wind tunnel testing (figure 3) has the overall objective to identify opportunities to improve aerodynamic performance of the trucks, validate computational fluid dynamics (CFD) simulation results, and evaluate aerodynamic properties, such as drag coefficients.

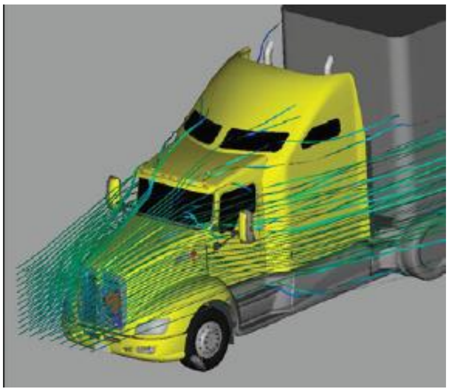

Figure 3. *Wind tunnel testing*

Wind tunnel test programs typically run over a one-week period with individual tests going five minutes or less to collect aerodynamic drag force data.
Tests that utilize a smoke (figure 4) wand enable to visualize the airflow characteristics over the vehicle. Wind tunnel testing helps to study the aerodynamics of various body shapes.

Figure 4. *Tests that utilize a smoke*

It is also exanimate the impact of all the attachments and accessories – such as mirrors, sun visors and cab extenders – on aerodynamic performance.

2.3. PACCAR Technical Centre Testing
The PACCAR Technical Centre features the latest state-of-the-art equipment for testing and product evaluation. Fuel economy tests are regularly undertaken on the facility's 1.6-mile, high-speed, banked oval track.
Testing methodology follows scientific practices developed by the Society of Automotive Engineers (SAE). Since fuel consumption performance varies according to the ambient conditions, the average temperature, wind speed and barometric pressure are recorded during the test runs. Road tests are often preceded by a one-hour warm-up of the vehicles.

Testing at the PACCAR Technical Centre's track also includes real world testing of aerodynamic drag of a tractor with a 53 foot trailer. The aerodynamic drag force is measured from a set of axle-end dynamometers when moving the vehicle at a steady speed on the banked high-speed test track. This is known as PACCAR's Drag Meter test practice, and normalizes the following variables: vehicle speed, frontal area, air density, wind speed, and tire rolling resistance.

2.4. Real-World Highway Testing

The real-world testing is used to help confirm and verify results gathered from the wind tunnel, computational fluid dynamics and PACCAR Technical Centre.

In addition, the real-world testing is used to evaluate prototype aerodynamic enhancements to various components, such as cab and cab roof extenders.

It is chosen to closely simulate the 500-mile day of a typical line-haul vehicle operation including I-5 congestion and realistic stops for breaks. The total engine-run time is 10 hours and the total trip time is nearly 12 hours including breaks.

3. Component Spec'ing

A truck uses energy to overcome aerodynamic, mechanical and rolling resistance. Enhancing fuel economy can be achieved by reducing aerodynamic drag, minimizing mechanical and rolling resistance or enhancing engine/power train efficiency. A vehicle's basic specifications and options can have a significant impact on fuel use. These enhancements are not additive, but many work in conjunction with each other where an enhancement at the front of the truck will make a difference to a component at the rear of the truck. In such cases a 2% reduction in aerodynamic drag will result in a 1% increase in fuel economy.

In order to enhance aerodynamics and fuel economy performance aerodynamic treatments to the tractor are necessary. This includes a roof fairing for use with van type trailers, chassis fairings, cab extenders and aerodynamic mirrors. A roof fairing and cab extenders typically may reduce aerodynamic drag by 10% to 20%. A chassis fairing may reduce drag by 2% to 4%.

Aerodynamic treatments to the trailer will also enhance fuel economy performance. This includes trailer gap reducing technologies, side skirts, and tail devices. The most efficient bogie setting of a standard 53-foot trailer is 12 feet from the rear without trailer fairings.

To reduce mechanical resistance one have to select components that are sized for the job – larger gear sets generally have lower efficiencies. Larger capacity tires have more resistance. Spec'ing the tires with the least rolling resistance will give the most fuel efficient tire.

It is recommended to select the right engine and gearing for the intended operation: Engine power settings have unique torque, horsepower, and fuel-consumption curves. Selecting an engine with excessive power can lead to inefficiencies. It is recommended to size the engine for a specific job. Selecting a power train that meets an specific application is very important to optimizing fuel economy. The transmission and rear axle ratio gear sets should be selected to insure the correct cruise RPM to match the engine's sweet spot. Gearing starts with selecting the appropriate cruise RPM, but transmission selection can affect the start ability and grad ability of the truck in an application – the wrong RPM may decrease fuel economy by 10% to 15%.

In order to enhance driver control the driver needs some feedback into how their decisions affect the performance of the truck. It is recommended a Cummins Road Relay display (figure 5) to give the driver average and instantaneous feedback, as well as many other insights to their trip, performance, and driver reward status.

Figure 5. *Cummins Road Relay display*

Selecting tires with low rolling resistance is important because tire rolling resistance accounts for about one-third of a truck's fuel consumption. A 3% reduction in rolling resistance produces about a 1% gain in fuel economy.

All axle positions are not equal; tires on different axles make different contributions to fuel economy. Changing trailer tires to fuel-efficient types produces a larger effect than changing tractor tires to fuel-efficient types.

All tires are not alike. Some are better than others when it comes to fuel economy. Increased tire pressure generally means less rolling resistance and better mileage. But conversely, it can mean more tire wear.

The EPA SmartWay program is an easy and accurate method in picking the best tires for fuel economy. All tires have been tested and the SmartWay program has selected the tire models with the lowest rolling resistance based upon data provided by the tire manufacturers.

4. Route and Idle Management

Route management is another important factor in fuel economy. In trucking, there are different ways to go from Point A to Point B. The goal is to get from Point A to Point B in the most efficient and economical manner while also meeting delivery deadlines.

This can be easier said than done because even veteran truck drivers may sometimes have trouble finding a delivery location. Some companies and drivers make many deliveries to new locations – especially on backhauls. Searching for a customer's location can add stress to driving. Out-of-route miles and lost time can result if a driver misses a turn, impacting on-time delivery.

It is estimated that out-of-route miles may account for 3% to 10% of a driver's total mileage each year. Paccar Inc. offers the factory installed Kenworth GPS in-dash navigation system to aid in these savings.

A navigation system based on the concept of fuel-economy (minimal energy consumption) that is able to provide travellers the shortest travel time/distance is constructed from data collected with closed circuit television (CCTV) and on the platform of Visual Basic.NET [4].

Idle management also plays a significant role in overall fuel economy. Unnecessary idling can result in substantial cost to the owner. Idling should be minimized by spec'ing the truck with the Kenworth Clean Power System. This factory installed system provides heating, cooling and hotel load power for up to 10 hours. The system uses stored energy for cooling and hotel load power rather than running a diesel engine.

5. Driver Behaviour

Excessive speed is the largest single factor in reduced fuel mileage. Reduce speed to a reasonable level of 60 mph and eliminate all non-essential stops. A general rule of thumb is that every mph increase above 50 mph reduces fuel mileage by 0.1 mpg. Extra fuel is burned every time when regain speed. Constant speeds save fuel. There are controllable factors like speed, load quality driving route, but also uncontrollable factors like road surface conditions, climate, traffic lights, etc [5].

6. Proper Maintenance

Proper maintenance is also important in the fuel economy equation. There are some things to remember: spend the time to set up a new truck, make sure to maintain proper tire inflation pressure, check tire wear, replace air and fuel filters at the proper intervals, minimize the air leaks on the truck, keep all axles properly aligned to minimize rolling resistance, monitor the fuel quality at the pump, repair anybody damage, use of a good synthetic or semi-synthetic oil in the engine and drive axles, use of a good synthetic transmission fluid, etc.

7. **Advanced Technology**

The use of advanced technology further enhances the fuel economy of tomorrow's truck. Through the substitution of more efficient hardware and better integration with existing vehicle system in paper [1] a cooling system and vehicle aerodynamics integration is presented.

There are a few key areas for research and development to study advanced technologies that impact fuel economy. GPS Navigation system that is essential in helping drivers reduces their out of route miles and boosting their overall fuel economy.

The use of an anti idling system allows the driver to run normal sleeper loads without the need to idle the truck. This system may enhance fuel economy by 8% for customers with high idle times.

The parallel hybrid system provides vehicle launch assist, blended torque, and electric PTO operation. Kenworth's goal is to enhance fuel economy by up to 30%, and up to 50% in utility applications by eliminating engine idle time to run the hydraulic PTO.

8. Future Technology

Paccar Inc. is continuously evaluating new technologies to improve truck fuel efficiency. Examples of these include:

Advanced tire pressure monitoring systems: These monitoring systems will keep drivers updated on the status of pressure of all tires and ensure low rolling resistance. The systems will also provide early warning of tire-pressure changes that can lead to premature wear or sudden tire damage. Tire rolling resistance accounts for about one-third of a truck's fuel consumption. In other words, a 3% reduction in rolling resistance produces about a 1% gain in fuel economy.

Heavy Duty Hybrid vehicles: Hybrid configurations are being evaluated for multiple applications of heavy duty vehicles. This system builds upon medium duty hybrid technologies and shows promise of similar savings to heavy duty applications.

Alternative power for auxiliary equipment: a lot of work has been done for research in hydrogen power, heat recovery systems, liquefied natural gas (LNG) fuel systems, and advanced battery storage technology.

9. Conclusion

After evaluation of directions to research for fuel efficiency in truck industry we main conclude that it is important to investigate the following areas: Aerodynamics, Component Spec'ing, Advanced Technology, Route Management, Driver Behaviour and Proper Maintenance. Each of these areas offers possibilities to reduce fuel consumption. Also there are future technologies that will improve vehicle fuel efficiency.

References

[1] Bayraktar Ilhan. Advanced Aerodynamics and Cooling System Solutions for Higher Fuel Efficiency and Decreased Emissions, 2009, Volume 41, The Aerodynamics of Heavy Vehicles II, Page 195;

[2] Leber Jessica. How Will American Automakers Meet New Fuel Efficiency Standards? Scientific American. April 1, 2010;

[3] Rexeis Martin et al. Emissions and Fuel Consumption from Heavy Duty Vehicles. COST 346-Final report. Edited by: Sturm P. J. Hausberger S. Graz University of Technology Institute for Internal Combustion Engines and Thermodynamics, 2005;

[4] Shokri Foad et al. Best Route Based on Fuel-Economy. European Journal of Scientific Research Vol.32 No.2 (2009), pp.177-186;

[5] Zhi-zhong Li, Min-ye Chen and Hong-guang Yao. "Trucks Trailer Plus" Fuel Consumption Model and Energy-Saving Measures. Communications in Computer and Information Science, 2010, Volume 106, Part 4, pp. 204-211;

[6] http://www.paccar.com/;

[7] http://www.fueleconomy.gov/.