White Paper – November 2012

Drive Axle Technologies

Building on Rich Heritage and Designing More Value and Efficiencies

By Joe Elbehairy, vice president – engineering, and
Charles Allen, general manager – Axles, Meritor Inc.

According to a widely known business concept, technology alone does not provide a competitive advantage, rather it is the ability to manage it well and apply it properly that produces the advantage. In the case of drive axles for global commercial vehicles, Meritor has the heritage and the proven capability to manage and apply that technology for its customers.

Advanced drive axle solutions show up on our (end-users) customers' bottom lines. We've identified and fine-tuned the multiple technologies that benefit our customers the most, and are developing more new axles and systems -- all engineered with distinct features to provide extraordinary cost and operational benefits for customers.

For more than 100 years, Meritor (and its predecessor Rockwell) has developed and engineered axle breakthroughs, leading up to our decades-long winning steer-drive-trailer axle system. For more than 20 years, the industry has relied on the RT145 series and for good reason, given that thousands of units were purchased and are still driving multiple thousands of trucks today. The successor in North America is the 14X Series that entered the market in mid-2010, and more than 160,000 units have been produced and are in fleet operation today.

The 14X is a "smarter" tandem that offers faster and broader range of ratios, and "steps up" in terms of direct benefits to our customers like handling up to 2,050 foot-pounds of torque and provides drivers with a smooth ride due to reduced driveline vibration.

Component leadership mandates innovations add real value. Those are accomplished by comprehensive marketing-product management-engineering and testing in the lab and the real world.

One of the ways that the company verified its advanced axle program was to ask a unique “brain trust” just 50 miles from its Troy, Mich., headquarters: the Tauber Institute for Global Operations at the University of Michigan in Ann Arbor. In 2009, the company turned to the Tauber Institute for an in-depth study on the feasibility of its new 14X drive axle family.

For the near-term, truck fleets of all sizes must continue their quest for more efficient drivetrains which will only help their operating cost ratios. So it’s only natural that customers who achieve less drag and more fuel efficiency will be stronger partners with select major drivetrain suppliers.

The advanced rear drive axle concept is a mix of current technology as well as advancements we are working on for the near- and long-term future. What we are featuring in combination has the ability to enable performance-optimized weight reductions and corresponding payload increases of more than 300-400 pounds and increase fuel efficiency respectively. If the truck operator combined our axle with single wide base tires, his weight savings could approach 1,000 pounds.

With an eye focused on 2 to 4 percent fuel efficiency improvement, Meritor’s new SmarTandem axle – scheduled for limited release in 2013 – is designed to reduce weight by 30 percent, reduce axle parasitic losses by 40 percent and provide traction controls to address simple 6x2 tandem traction deficiencies. In this product introduction, the company will also put to good use its current European high efficiency 17X carrier technology with laser-welded ring gear and differential case to provide increased torque and efficiency, while electronic control technology will provide comparable tandem traction functionality by sensing operating conditions.

In the future, oil lube level control will be facilitated by the company's exclusive LogixDrive lube management smart technology.

We think that we're rather unique – from a commercial vehicle perspective – in analyzing and predicting actual field operational data for extended life-cycles of components. It's absolutely key to establishing our baseline and sustainability.

The following Meritor drive axle technologies (current and near-term) from global engineering and product development include:

- Aluminum carrier – 100-pound weight savings compared with a traditional ductile iron carrier (currently available in the RT-145 series, and to be available in the 14X series in latter 2013). The aluminum carrier is targeted at truck operators seeking cutting-edge technology to save weight and enhance fuel efficiency;
- The fastest ratio in the industry (currently available on the Meritor 14X): 2.47: 1. (up to 7.17) When paired with a direct drive transmission, this fast axle ratio can increase fuel economy by more than one percent compared with common rear axle and overdrive transmission ratios. Still-faster ratios are being developed to align with new diesel powerplants, according to Charles Allen, general manager, Axles;
- DualTrac housing is designed to optimize the use of wide base single tires or dual tires and offers the ability to improve bearing life compared to standard track axle with outset wheels, while providing the ability to convert back to duals if needed. It pro-actively addresses wheel bearing overload issues associated with wide base tire applications;
- More robust inter-axle differential to handle today's higher torque engines. It is 20 percent larger than its predecessor, the RT145, with fewer parts;
- Premium Amboid design as standard equipment on the 14X for all end-users, improving inter-axle driveline angles;
- New breather, an all-new industry benchmark on the 14X series, which prevents water and other contaminants from entering the carrier while keeping lube in place; and

- LogixDrive lube management (2014) – the industry's first intelligent axle system, which was previewed in September 2010 in Europe, controls the amount of lube in the axle based on operating conditions thereby improving fuel economy.

In March 2011, at the Mid-America Trucking Show, the company displayed an advanced drive axle 6x2 configuration with future concepts. It included such "potential" items that could be developed as:

- Carbon fiber bowl – extremely lightweight future technology weighing roughly one-fifth the weight of steel: a savings of approximately 25 pounds. Additionally, the technology offers the ability to mold to various shapes to house internal axle advancements
- Aluminum tag axle – another possible use of lightweight aluminum that results in major weight reductions with optimized section modulus in critical areas to deliver needed strength with larger payload gains
- Titanium Brackets – every pound matters and the potential opportunities are vast. For example, the use of high-strength titanium brackets instead of traditional steel cuts, approximately 30 pounds.
- Intelligent traction control – automatic differential lock and enhanced load transfer to the drive axle, engages and disengages below and above 25 mph in instances of low traction providing a 6x2 with 6x4-like traction in most operating conditions.

No other axle supplier knows axles, gearing, and axle technologies like we do at Meritor. The company's entire global axle engineering workforce accounts for carrier architecture, gear design and finish, lube formulation and level, high efficiency bearings and seals, and lightweight materials. We fully understand the need for super fast ratios beyond 2.47 and 2.64, and what's going on with diesel engines as cruise speeds decrease and torques go up, and Meritor can optimize the drivetrain with the right axle for direct or overdrive transmissions and the complete drivetrain.

Two More Axle Innovations

To address the growing weight-conscious fleets, Meritor introduced last March another breakthrough axle technology, the FUELite™ tandem axle, the first member of its SoloDrive Series axles which features 6x2 tandem rear axles. Based on the proven Meritor 160 series drive axle, the FUELite tandem axle is designed for linehaul applications to maximize weight savings and increase fuel efficiency, usually in a direct drive and fast axle ratio configuration.

We engineered the FUELite axle to accommodate all 40,000-pound linehaul suspensions, delivering an optimum solution that is lightweight yet heavy on performance. This new series of axles is designed to provide lightweight axle solutions with greater efficiency by providing one driving axle in a tandem configuration.

It delivers nearly 400 pounds in weight savings and approximately a 2 percent* increase in fuel efficiency when compared to a traditional 6x4 configuration. Other benefits like a 2.50 to 4.10 ratio range and a 12.7-millimeter wall housing are compatible with all current 40,000-pound tandem air suspensions.

And just four months ago at the 2012 IAA Exposition in Hanover, Germany, the company unveiled another European axle engineering innovation -- the 17X system designed and engineered to be the industry's lightest axle system in the 13-ton class, the new 17X Light has been updated in all areas – axle housing, carrier and brake integration to optimize axle efficiency.

This new axle bundles several leading technologies in one axle system to provide customers with superior performance, efficiency and reliability. Other improvements include a 20 percent lighter axle housing; axle bowl optimized for more efficient oil flow, new torque plate design gives customers a choice of radial or axial brake mounting; a 70 percent lighter differential lock cover due to a light allow, and improved ratios, including the two fastest: 2.31 and 2.47, to meet the upcoming emission regulations.

Each component in a drivetrain system impacts the vehicle's fuel efficiency. Major energy consumption points on a Class 8 tractor include: aerodynamics (50 percent), accessories (10 percent), tires (34 percent), and drivetrain 6 percent (due to lower parasitics).

Our charter is clear and the challenges are steep. First and foremost, the truck operator must experience first-hand component durability and million-mile-plus life expectation of the drive axle system.

Component weight is critically important. The more you can improve power-to-weight ratio, the less power and fuel is needed to propel the vehicle through the air or over the road.

Another overlooked "key component" of the drivetrain's efficiency is the driver – who starts, drives and stops the vehicles. He has to start the vehicle and control it's drivetrain operation…if he is erratic, shifts too much, over-revs the engine or allows it idle too long he can degrade fuel efficiency instantly.

Clearly fuel costs will go up which is spurning many alternative fuel supplies. Those are still some time away before they can truly be integrated in a mass production, cost efficient manner for the trucking industry.

Boxed Information -- **Practical Pointers in Specifying Drive Axles**

- **Remember the function** of the rear drive axle – to take the engine power and turn it at 90 degree angles to drive the wheels. Drive axles are ratio dependant on the vocation, application, cruise speed and transmission ratios selected for the job. There will be some parasitic loss in the gears. However, a properly specified axle ratio that works in conjunction with the engine and transmission will give the desired road speed. Common ratios for axles these days include

2.64 and 2.79 with the direct drive transmission and 3.21, 3.36 and 3.42 with an overdrive transmission.

- **Four key factors in drivetrain specifications are startability, gradeability, gearing and fuel economy**, both of which are impacted by the engine, tire size, transmission and axle ratio. Fleets often express desires to operation 1300-1400 rpm at cruising speed, with a maximum fuel economy. A trend exists to faster ratios as well. For proper component specification, dealer and OEs must know the truck's purpose and application. Including desired road speeds and routes. Use the engine manufacturer's software to specify a fuel efficient drivetrain.
- **Choose the right components from the start.** Many trucks are incorrectly spec'ed with components that do not fit the vocation and application. Specifying the wrong components from the start will contribute to less than optimal performance of the component and the vehicle, and contribute to higher repair costs. Component compatibility is also imperative. A computer analysis of the components should be run to prevent trucks from being built with axle ratios or transmission gearing that is not ideal for the customer's application.
- **Know the exact application** and vocation of the vehicle, such as will the vehicle be 80,000 pounds on flat ground or 110,000 pounds on 5 percent grades for 50 percent of the time. Also remember the desired cruising speed of the vehicle. It does no good to save a few dollars up front by "under spec'ing" components because the customer/dealer will undoubtedly pay for them in downtime and repairs later. Warranty coverage of components is dictated by the vocation.
- Provide your dealer as much information as possible on the **vocation**, including unusual duty cycles, terrain, heavy loads, loads both ways, specialty market, on- or off-highway. On purchasing stock trucks, be certain to match the truck operator's exact application to the right or even special componentry (dump truck vs. P&D vs. linehaul). Also be sure that the truck's GVWR and/or GCWR is sufficient for the operator's vocation. For special applications, a truck operator should check the frame strength and gear capacity to ensure the truck can handle the gross vehicle weight. Be sure to understand the definition of exact

applications. High grades and poor road surfaces, GCW's, quantity of start/stops etc…all impact a vehicle-drivetrain's performance and life. Less than expected components fatigue life can be avoided by specifying the right product for the right application.

- **Axle gearing and bearings** can be impacted by improper use/specification of brake retarders. Be certain not to use more brake retardation than is specified by the component-and-vehicle maker.
- **Know the difference** in specifying and using Driver Controlled Diff Lock (DCDL) and Automatic Traction Control (ATC). A driver's behind-the-wheel performance can extend drivetrain life – i.e., proper use of the vehicle's IAD lock, DCDL and ATC. In some cases, truck operators use DCDL and electronically controlled active suspension system (ECAS) to help shift the load onto the drive axle for more traction.
- **Match tires on tandem wheel ends**. For example, placing an older steer tire in a drive wheel position can make the interaxle differential work harder and cause undue wear. Also, tires with different tread depths or air pressures can lead to a premature loss of axle life. Another result of mismatched tires is elevated lubricant temperatures and thus shorter lubricant and axle life.
- If spec'ing single wide tires, be sure to check hub specification to avoid severe strain on the axle housing. Consult the manufacturers' guidelines as needed.
- **Identify the "sweet spot"** for the most efficient range of the engine chosen. The balance of power and performance does not necessarily have to mean a sacrifice. For optimum performance of a particular engine, a balance between axle ratio and transmission performance will have a direct effect on several factors including fuel economy. Make sure tire size is spec'ed in coordination with engine torque; axle ratio and speed at which the vehicle will be driven.
- **When spec'ing components, pay attention to the weight.** Lightweight components, such as aluminum carriers and lightweight drums can take out up to 300 pounds per drivetrain. Since the components are lightweight, it takes less energy to move the truck, resulting in improved fuel economy. While many

lightweight components are premium items at the front-end of the sale, the initial cost will be paid back through the life of the component through lower maintenance costs and less downtime.

- **Components should be checked for compatibility** by running a computer performance analysis. This would prevent trucks from being built with axle ratios or transmission gearing that is not ideal for the customer application. Components must be replaced if a truck is built with mismatched parts. This is very expensive, and could cause customer dissatisfaction.
- The dealer and customer should have a general understanding of the **true life cycle cost** of the component, i.e., residual values, fuel economy improvements, reduced maintenance, decreased driver training, etc.
- **Use lift axles properly** to save on tire wear and to extend life of drive axle. Overloading the drive axle (resulting in cracked housings) can be caused by too much vertical load and not employing the tag or pusher axle (see Issues & Trends). One tip is to look for the sticker(s) on the cab door to understand all load limits.
- **All drivetrain specifications** directly affect how efficiently the energy output of the engine is transferred to the tires. Reducing the rotating mass of drivetrain components and reducing the amount of heat generated within drivetrain components both help to improve energy loss from the engine to the tires. Meritor assists its customers with specifying the Class 8 drivetrain that results with the engine consuming the least amount of fuel for their road cruise speed.
- **Service parts** – consider closely the nationwide, fast accessibility of all axle parts at all the OEMs. This includes the availability of engineering-approved remanufacturing axle differentials via regional distribution-logistics centers.

<u>Other questions</u> to ask of your fleet management team or your OE dealer for maximum fuel efficiency of the drivetrain?

- What kind of freight will you be transferring and how much does it weigh?
- Where do your vehicles operate geographically – mountains, snow, and ice?

- Are you on the highway all the time? 70 or 90 percent of the time?
- Are you more interested in performance or fuel economy, or the best of both?
- What size tires and tire brand?
- How important is resale, and are you willing to pay up front for a premium specification?

For more information or specification assistance for your application or for a visit by a Meritor DriveForce sales professional, visit www.meritor.com/driveforce. For communications assistance, please contact Krista Sohm, vice president-communications, at 248-435-7115.