DANA SPICER® Drivetrain Systems

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The right solution for downsped engines.

Managing Higher Driveline Torques to Maximize Fuel Economy

New U.S. fuel economy standards are coming for commercial vehicles, and your fleet will look much different as a result. President Barack Obama earlier this year called on the U.S. Environmental Protection Agency (EPA) and the Department of Transportation (DOT) to create and issue new fuel economy and greenhouse gas standards for medium-duty and heavy-duty vehicles by March 2016. This announcement increased the pressure on truck manufacturers to accelerate their efforts to squeeze more miles out of every gallon.

Every vehicle system is ripe for scrutiny, but the primary target is the engine, which is responsible for up to 60% of all energy losses on any given linehaul truck. Modifications to the engine, however, can carry substantial risks. How can we make the engine more efficient without giving up a single horsepower of performance when we need it?

These days, the answer is engine downspeeding. This is not a reduction in the size of the engine; instead, it's a reduction in the rpm of the engine, especially at highway cruising speeds between 61 and 68 miles per hour. Downspeeding allows the engine to cruise in its sweet spot, reducing friction and increasing fuel efficiency.

Where most truck engines today run at around 1450 rpm at cruising speed to provide the 200 hp needed at the wheel end, engine downspeeding allows the truck to operate consistently in a more efficient range, generally between 1100 to 1200 rpm, while maintaining the same 200 hp at the wheel end. As a result, fuel efficiency will increase substantially.

However, for every 100 rpm drop in engine speed, torque goes up significantly to maintain full power. We'll outline strategies for addressing the increased torque later in this paper.

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Engine Downspeeding Packages

OEMs and Tier 1 suppliers

- *Volvo introduced the XE13 powertrain in 2011, and then upgraded this package from 425 hp to 455 hp in 2012.* [2]
- *The TC10 range-type, 10-speed fully automatic twin-countershaft transmission from Allison is optimized for downspeeding, with hydraulic clutches allowing full power shifting and close ratio steps in the 7th through 10th gears.* [3]
- *Cummins and Eaton announced the SmartAdvantage Powertrain in 2013. It features Cummins' SmartTorque 2 technology, which automatically senses vehicle weight, grade and operating gear, and then selects the optimum torque for the best fuel economy and performance at every gear.* [4]
- *The peak torque of the Paccar MX engine has been adjusted to 1,000 rpm, and it features compacted graphite iron in the block and head, which enables the engine to handle operation at low rpms. Extensive testing has been performed to ensure the oil pump and water pump can deliver the proper pressure and flow at this engine speed.* [5]
- *Next January, the Detroit division of Daimler Trucks North America will offer the Freightliner Cascadia Evolution Class 8 tractor with a DD15 engine that features a new downspeed rating of 400 hp and 1750 lb.-ft. of torque.* [6, 7]

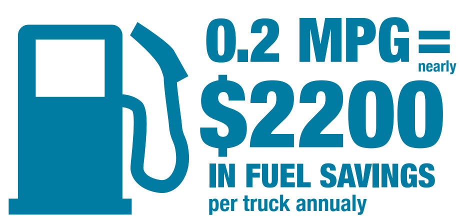
The Movement Toward Engine Downspeeding

Engine downspeeding is rapidly picking up momentum in the market. Volvo and Kenworth are showing markedly increased sales of their engine downspeeding packages, with Kenworth, sales expected to double in the next three years.[1] Numerous engine downspeeding packages from OEMs and Tier 1 suppliers have been tailored to take advantage of the increased efficiencies associated with engine downspeeding.

Running at a lower rpm provides numerous advantages. The most obvious of these is reduced fuel consumption, since the engine can spend more time running within its optimum efficiency range. Other advantages include reduced engine friction from lower piston speeds, reduced relative heat transfer, and increased thermodynamic efficiency.

Figure 1 shows how fuel efficiency increases by approximately one percent for every 100 rpm reduction in engine rpm at highway cruise speeds, and the savings are even more impressive for light loads or empty returns.

Current technology allows downsped engines to reduce fuel consumption by about 550 gallons and carbon dioxide emissions by about 12,000 lbs. per truck annually. Translated into dollars and cents, this increased efficiency delivers a fuel savings of nearly $2,200 per truck every year.



High-Torque Challenges

With most engineering advances, however, there are also challenges that must be overcome, and engine downspeeding is no different.

An engine running at lower rpms requires faster axle ratios to maintain the same vehicle speed and performance in all driving conditions, and it generates significantly higher torque stresses in the drivetrain. As shown in *Figure 2*, by decreasing an engine's rpm at cruise speed from 1450 rpm for the typical engine to 1125 rpm for a downsped engine, torque loads in the driveline increase by 57%. These higher torques place added stress on the axle, driveshaft, and inter-axle shaft, greatly reducing the life of these components, especially U-joints.

Figure 3 shows how the life of a conventional U-joint is impacted with the decrease in engine speed; and it demonstrates the pressing need for driveline suppliers to properly address the increase in torque and help keep trucks on the road.

A powertrain that takes advantage of the efficiency gains from engine downspeeding requires all elements – engine, transmission, axle ratio and tire size – to work in concert to deliver the power needed to get the job done with the maximum efficiency.

Competing Strategies for Managing Increased Torque

Today, there are two competing approaches for handling the problem of increased torques in the drivetrain. The first is to de-rate the engine by adjusting its electronic controls.

De-rating is generally performed by recalibrating the software that controls the engine. Engineers set a calibration that only allows so much torque to go through the engine at certain speeds or under

Fig. 1

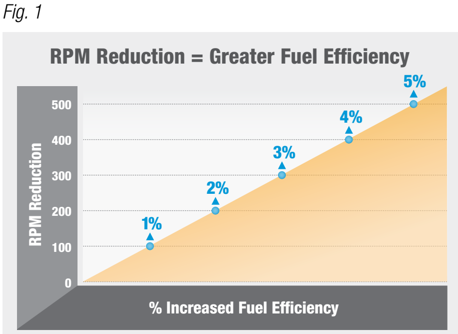


Fig. 2

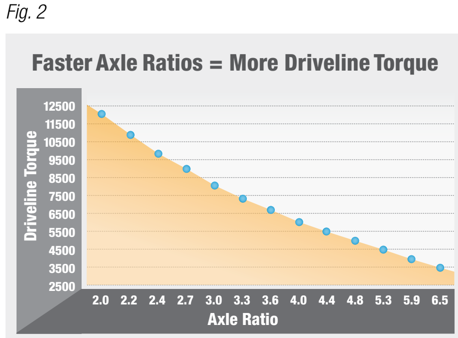
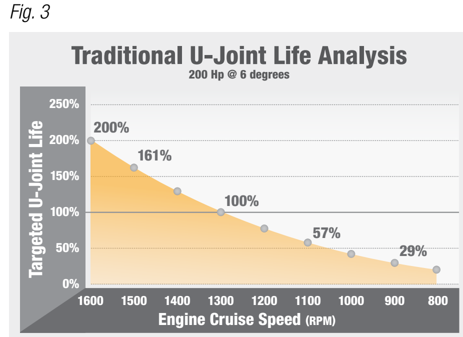


Fig. 3



particular circumstances, predominantly while the truck is in first gear.

De-rating the engine is a common, reasonable strategy for addressing certain issues, and it is an effective short-term workaround for reducing the likelihood of a catastrophic driveshaft failure during vehicle launches from zero speed and sudden acceleration.

However, it does nothing to address the high-cycle fatigue that results from long-term torque stresses on the drivetrain. No matter what is done to re-program the engine to reduce spikes in torque, a downsped engine at cruise speeds still increases torque in the driveline by 57%.

Figure 4 shows the torque loads exerted on the drivetrain from a de-rated, low-rpm ISX 400 engine in an International ProStar linehaul truck. In this particular test, we simulated a real-world wintertime scenario where a driver is operating the truck in first gear to hook up a trailer that has frozen brakes and wheels.

Through this test, we sought to determine the maximum torque that could be generated with the engine at idle. Engine rpm was elevated at launch, with the driver loading the throttle while releasing the clutch. The clutch was not fully engaged, but the engine rpm dropped to a point where it stalled. The maximum torque value recorded was 18,953 lb-ft (25,696 Nm), which is more than enough to break a traditional truck driveshaft at idle speed.

This test demonstrated that engine de-rating is not a sufficient standalone strategy for reducing torque loads and increasing the life of driveline components in a downsped engine configuration. It reinforces the notion that a second method for handling increased torques is required; one that takes a systems' approach and acknowledges that when the engine changes, the other parts of the powertrain need to be upgraded to match.

This solution requires an axle and driveshaft system engineered from the start that works together to support engine downspeeding. This includes an efficient, lighter weight tandem axle that offers the fast ratios required to fully leverage the efficiency benefits and a driveshaft that can withstand higher torques – both in the short- and long-term.

Spec'ing the Right Way

We've always held that the best way to spec a driveline is by selecting components that have been carefully engineered, thoroughly tested, and proven to deliver the performance and durability you need, mile after mile.

The tandem axle selected for an engine downspeeding package should incorporate numerous innovations to improve performance in a high-torque environment, including:

- *More capable primary gear*
  - *Wider face gearing with longer tooth length for lower contact and bend stress*
  - *Rigid ring gear mounting that eliminates joint loosening*
- *More capable input shaft and pinion splines*
- *More capable input and pinion bearings*
- *Faster ratios to match intended operating speeds*

The other piece of a driveline solution for engine downspeeding is a driveshaft and inter-axle shaft engineered to maximize the efficiency and durability of the tandem axle. The driveshaft should feature numerous engineering innovations designed to manage the higher torque stresses associated with engine downspeeding, including:

- *Larger U-joint cross engineered for high strength*
- *Larger bearings with greater capacity*
- *A high-density package to fit within existing design envelope*

Figure 5 illustrates how a properly engineered driveline – including an advanced axle, driveshaft, and inter-axle shaft – can manage increased torque stresses better than a traditional driveline system.

The proper driveshaft designed for longevity can improve life by 57% at the 1125 rpm typical of today's low-speed engines, and by 77% for the 900-rpm engines on the immediate horizon.

Figure 6 shows the comparative strength of U-joints in recent benchtesting. On the left are the average results of tests on two driveshafts that have traditionally been used on trucks, and on the right is an advanced driveshaft design specially engineered for use with downsped engines. You can see that the driveshaft optimized for engine downspeeding is about 50% stronger than the two traditional models.

The Dana Solution for Engine Downspeeding

The Dana system optimized for engine down-speeding includes the Spicer® AdvanTEK® 40 tandem axle, the SPL® 350 driveshaft, and the SPL 250 inter-axle shaft.

The Spicer AdvanTEK 40 axle is offered in five ratios that support the engine downspeeding efforts of truck manufacturers, including the industry's fastest axle ratio of 2.26:1. Weighing an average of 21 pounds lighter than competitive 40,000-lb. tandem axles on the market today, the Spicer AdvanTEK 40 tandem axle was developed with faster axle ratios to handle the higher axle input torques that result from lowering engine rpm at highway cruise speed; thus enabling increased overall vehicle efficiency by up to 2 percent.

Ultimately, the Spicer AdvanTEK 40 axle can help a truck operating in a typical linehaul duty cycle save

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Fig. 4

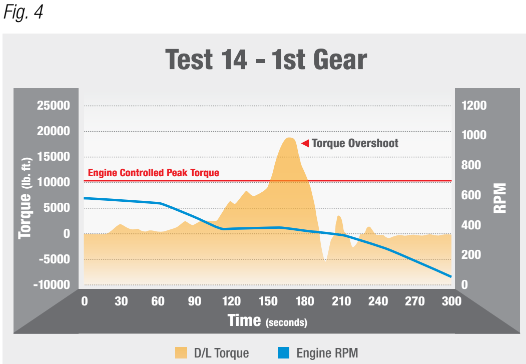


Fig. 5

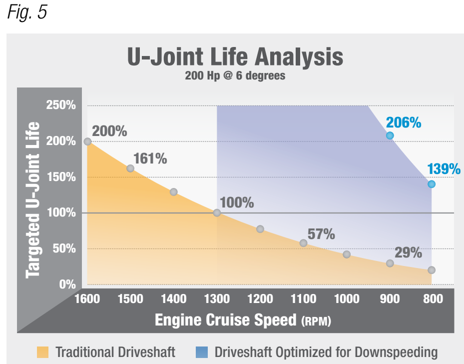
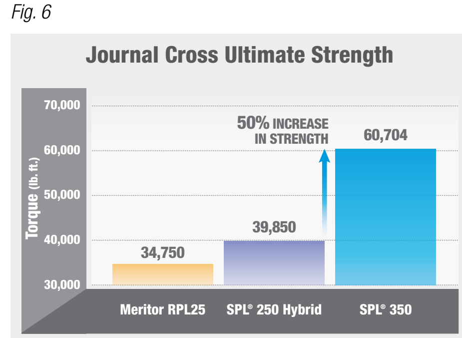


Fig. 6



more than 2,700 gallons of diesel fuel over a five-year time span. This translates into up to $10,000 in estimated operating savings with a reduction of over 60,000 lbs. in carbon dioxide output when compared to most tandem axle offerings on the road today.

The other piece of Dana's engine downspeeding solution is the SPL 350 driveshaft and SPL 250 inter-axle shaft, which have been engineered to maximize the efficiency and durability of the Spicer AdvanTEK 40 tandem axle and low rpm engines. The most robust heavy-duty driveshaft and inter-axle shaft in their class, the SPL 350 driveshaft and SPL 250 inter-axle shaft offer more power density, 40 percent more torque carrying capability, and double the bearing life over competitive designs. In fact, they are the only driveshaft and inter-axle shaft on the market today that can supply up to a million miles of life expectancy in a downsped engine powertrain.

Delivering up to 35,000 Nm (26,000 ft-lbs.) of torque capacity, the SPL 350 driveshaft and SPL 250 inter-axle shaft are equipped with High Power Density™ design features that extend product life and outperform competing driveshafts. Like all Spicer heavy-duty SPL U-joints, these products feature an optional service-free design for further maintenance and lifecycle benefits.

Higher Torques are Here to Stay

The trend toward engine downspeeding will continue to gain momentum as OEMs look for ways to further improve fuel economy. For example, Dana is currently collaborating with several truck manufacturers to engineer axle disconnect technology that will accommodate even further engine downspeeding to the 900 rpm range at highway cruise speeds.

The more you know about engine downspeeding, the more you realize that only Dana offers the most complete, most durable driveline solution to help you earn the greatest return on your investment. Dana has spent more than a century mastering the physics of the driveline, and we lead the industry today with a new generation of driveline innovations specifically engineered for the most fuel-efficient trucks you can buy.

Sources

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For more information

visit *www.danacv.com/advantek40*

View informative videos that showcase the advantages Dana offers for trucks that employ engine downspeeding strategies.

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With 37 years' experience in engineering and technology leadership, Nieman leads a team of more than 200 engineers deployed worldwide to produce innovations for the commercial-vehicle industry. Nieman earned a bachelor of science in mechanical engineering from the University of Michigan and a master's degree in engineering from the University of Toledo.

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Application Policy
Capacity ratings, features, and specifications vary depending upon the model and type of service. Application approvals must be obtained from Dana; contact your representative for application approval. We reserve the right to change or modify our product specifications, configurations, or dimensions at any time without notice.