F2008-SC-029

ALL-WHEEL DRIVE HEAVY VEHICLE WITH HYBRID DIESEL-ELECTRIC POWERTRAIN

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KEYWORDS – Hybrid Electric Vehicle, Diesel Electric Vehicle, Powertrain Control, Torque Distribution, Electric Motor Drive

ABSTRACT - This work concerns a project of a heavy multipurpose all-wheel drive vehicle. The modern vehicle should meet road safety and mobility requirements, use environmentally friendly techniques. This project follows all modern trends. The vehicle's transmission enables dependent on road conditions torque distribution through axes and wheels. The system of torque distribution uses individual motors for every wheel getting power from both the diesel-electric unit and batteries or separately according to control program. The vehicle uses a 4-axis chassis which provides the highest level of floatation. The hybrid drive provides enhanced fuel efficiency and increases the vehicle's environmental safety keeping high road performance. All the project's features make the vehicle up-to-date and useful in various fields where advanced transport is needed.

Multiaxis off-road vehicles present a quite sparse class of automotive transport. They were always detached from other vehicles as their concept goes contrary to ordinary cars for most people. They are being created for areas without roads and well-developed infrastructure. Their mission cannot be overstated.

The vehicle class we are talking about is in great demand generally for mining operations, emergency situations and for transportation in conditions of lack of roads. Usually the main requirements for such a vehicle are simplicity, unpretentiousness to service and road conditions, reliability and ease of possible repair. To meet these demands the vehicles have remained unchanged and had their out-dated design over a long period.

Now the situation is being changed. The customer is no longer satisfied with just simplicity of a vehicle. One requires versatility and comfort, high performance and environmentally friendly operation.

One of today’s most expected technologies is hybrid drive application.

HYBRID DRIVE

What are the features of our project? The basis of powertrain is a diesel-electric powerplant which includes a 320 kW diesel engine and a 250 kW generator. The 8-wheel drive vehicle system includes asynchronous motors per each wheel, an energy conversion unit, a control board, a power switching unit, an electric machine mode control unit and a battery unit.

The diesel engine always rotates the generator shaft and it is not able to rotate wheels directly. The diesel-electric powerplant combined with the energy storage unit allows to provide optimal engine speed. The optimal speed is the revolutions of minimal fuel consumption. So

the engine runs at a constant speed. The diesel's work goes for motion itself and for accumulating energy in battery unit.

Mechanical Parts of the System

Using the hybrid electrical drive and individual motors for every wheel allows to reduce parts for mechanical torque transmission. Therefore we use fewer parts which could fail during operation. We may refuse a differential and a transfer case as the torque distribution function now lies on electronic devices.

Eight electric motors are installed on the frame along the longitudinal axis (see Figure 1). It offers several advantages over the motor-in-wheel technology. Taking the motor out of the wheel reduces weight concentrated at outer suspension parts i.e. unsprung weight. Smaller unsprung weight provides better stability and safety on the road. Another advantage of the individual-motor drive design is ability to better protect a motor and its connections from mud and water than being installed directly on a wheel. This feature is highly important for the vehicle designed to move through the rough terrain and adverse conditions. Maneuverability is provided by the chassis with the full steerable system. Wheels of the front pair of axes rotate against the rear pair. It gives the minimal turning radius for a large truck.

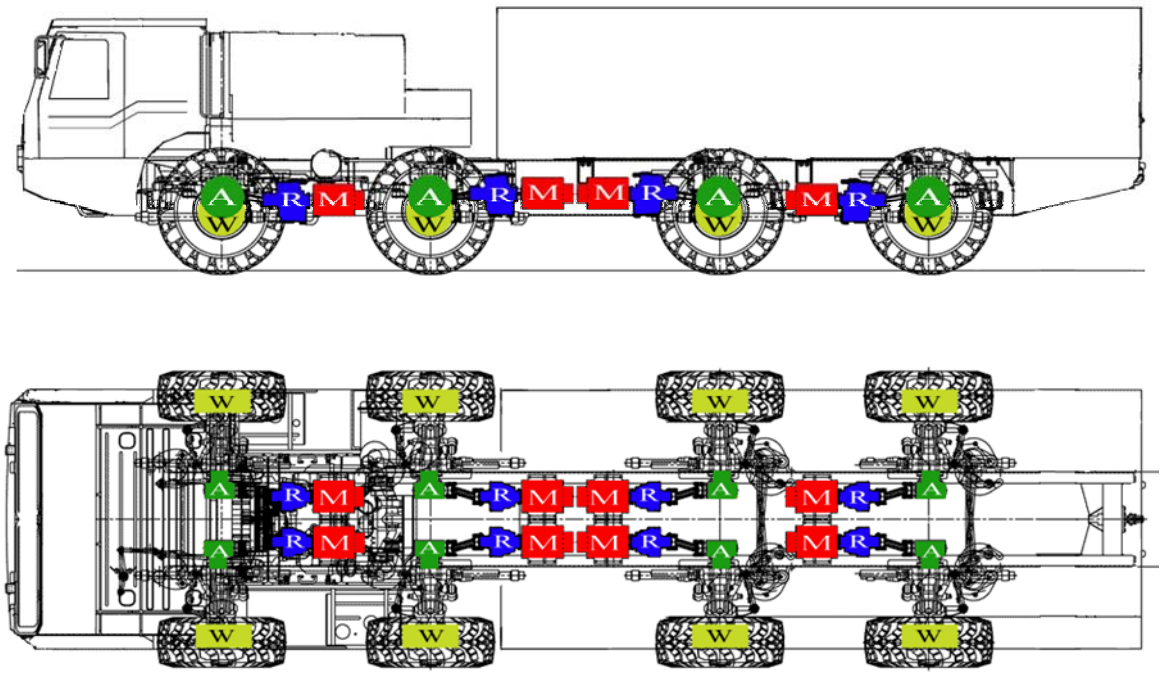

Figure 1: Scheme of multipurpose tetraaxial all-wheel drive hybrid vehicle.
M — electric motor, R — 2-speed reducer, A — angle drive, W — wheel reducer

The truck uses 60 kW motors providing motion (see engine performance in Figure 2). Each electric motor gives 300 Nm torque. The drivetrain also includes:

- 2-speed reducer;
- angle drive;
- wheel reducer.

The 2-speed reducer provides a variable ratio for the drivetrain. A 3.33 ratio is used to overcome heavy terrains while a direct drive is mainly for level road motion with high speed. The reducer has a planetary gear design, therefore it has a compact axial dimension. Gear changing is realized by the pneumatic drive to all units through the main air cylinder. This process can be operated without stopping as the reducer has a synchronizer.

The angle drive provides torque transfer at right angle. It is necessary as on-frame units are installed longitudinally and transmit torque perpendicularly to wheel axes. The angle drive has a bevel gear design, its ratio is 2.273.

And the final gear is the wheel reducer with a 3.357 ratio installed close to a wheel. The truck has an independent suspension system with high movement limits to provide off-road ability.

Totally we have a 7.63 ratio with direct drive enabled in the 2-speed reducer. It allows the vehicle to reach a maximum speed of 80 km/h. Enabling the lower gear we get a 25.4 ratio. The maximum speed decreases, but this mode is for severe driving conditions. In this mode the truck is able to climb a 45 % grade which is high level performance for the truck with laden mass of 18 tones.

Hybrid Drive Technology

As stated above, the engine rotate at a constant speed and charge the battery unit. Energy is also being stored during braking due to the function of regenerative braking. In this mode electric motor works as a generator. Accumulated energy is used for modes which need most of power and also it enables motion with stopped engine.

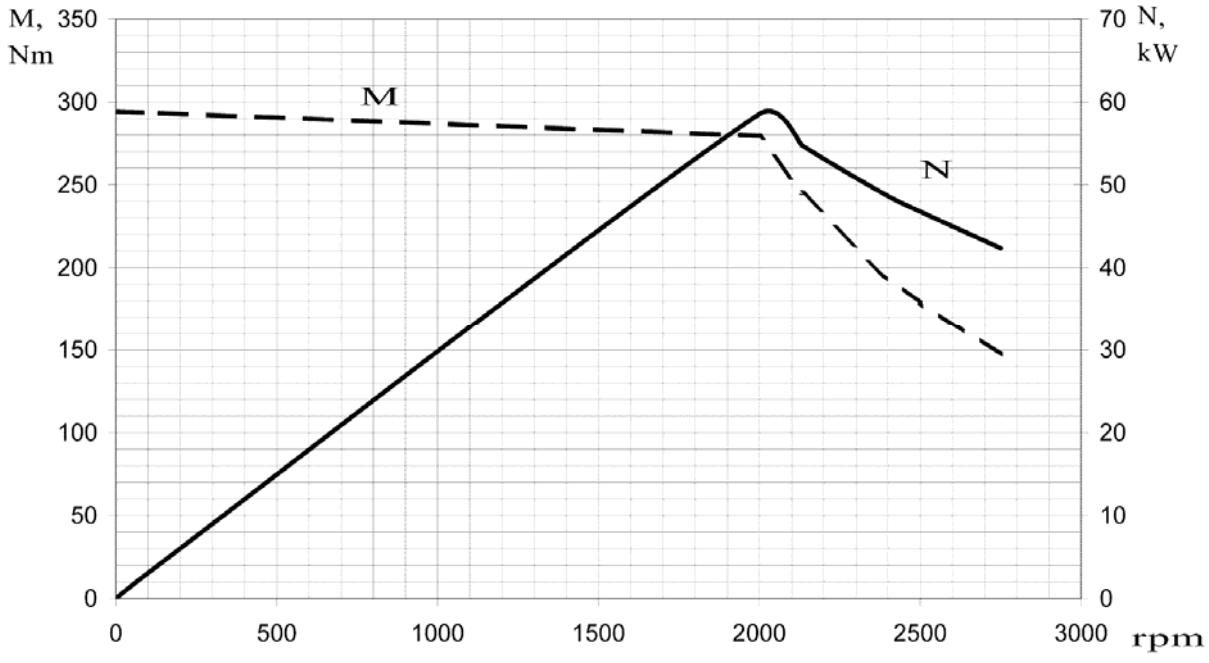

Figure 2: Full-load curve of electric motor.
M — torque, Nm; N — power, kW; rpm — engine's revolutions per minute

Individual-motor drive provides ability of flexible torque distribution. The system offers numerous modes for various motion conditions. A vehicle with mechanical transmission has

the only advanced mode. It is full lock of all differentials. Ability to overcome rough terrain is quite high but the essential fault of this system is difficulty or even impossibility to turn the vehicle as all wheels rotate at the same speed. Large ridges also make straight line motion hard. Driving in this mode on solid surface leads transmission to damage.

Our vehicle has no such shortages. Control unit sets parameters for every electric motor according to data from motion sensors. It provides a specific motor speed when a wheel goes through the longer distance on a ridged surface or when the vehicle moves on a bend.

CONCLUSION

Hybrid drive for heavy trucks is a new technology for the world automotive industry. Everybody understands their relevance but we need more time to find out what they are really capable of as the age of hybrids is just beginning. Tests will show how the vehicle behaves on a real road and it will allow to summarize all information and make corrections for future development.