MOBILITY DISCUSSION ON EFFICIENT FUTURE HEAVY HYBRID VEHICLES

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ABSTRACT

Mobility in future should be efficient, neutral in emission and flexible in use. So it ‘s time to discuss the most important systems for transportation and working machines.

Heavy duty vehicles on street, on railways and working areas have in case of efficiency to be analyzed in respect to their efficiency, traction structure. These have respectively to be seen in saving energy on several construction details and material saving overall. New alternative traction structures on energy efficiency and future traction opportunities forces therefore the discussions around heavy duty vehicles and juggernauts.

The questions are, which structures of power trains have the best chances to be the primary future drive train in respect to the hot topics of the mobility challenges.

This paper shows a smart overview on ideas in personal sight of the author about future aspects and ready developed solutions in the field of heavy duty vehicles, well seen in quality, efficiency and performances on traction structures and material saving.

1. INTRODUCTION

Trucks and heavy vehicles for transportation are that vehicles on road and off road, which have the most weight, the longest running time over year and system life for much more than 1 million km (1 million for wood trucks, 2 million for street runner trucks). Further their forcing diesel engines in Europe consume diesel energy by 40 liters for 100 km on asphalt road and 80 liters off road per km, in US with their super gasoline trucks e.g. Mack needs 50 liter per 100 km by speed up to 90 km/h (50 miles per hour).

In respect to that gasoline and diesel effort it makes sense to discuss new ways of power train structures for more efficient driving.

Fig.1. Knafl Transportation with a 560 HP forced MAN Woodliner

This must be seen by the most important fact that the classic mechanical power train has a very bad efficiency from fuel energy (11 kWh energy per liter) well to street under 9 % by trucks. This is represented by the sum up from losses of serial mechanical rotating parts from primary and secondary gears, clutches, hydraulic systems, retarder, differential gears, multi parts on heavy axles and heavy rotation systems.

The next important fact is the engine itself, because the effort on mechanical controls and electronics controls to run an engine fully over their full speed range is very big and the mean efficiency is there by only in mean 27% - only the engine itself.

But what's the alternative: New highest power packs on power electronic converters, inverters and utilities, high efficient water cooled PM synchronous electrical machines, best multilevel control units, high energy storage units e.g. gives us the possibility to think about new power train structures on heavy duty vehicles by use of finest electric controlled drives.

Therefore the main questions for new heavy vehicle power train in all modern trucks and heavy duty applications are:

How can they utilize the stored energy!
How can tires more prevent from abrasion for longer using?
How the exhausting emission could be clearer?
How to reduce losses on power train?
How to reduce weight over all?
Which will be that primary energy in future!

Answering this questions will be done in this paper, well in respect to very modular system functionality groups with clear interfaces, to be fine in production, service and recycling.

2. VERIFICATION OF HIGH EFFICIENT POWER TRAIN DEVELOPMENT

To solve above mentioned facts transforming into high efficient drives, we have to verify the basic parts of trucks. And that are the components discussion and the wheel to street combination.

2.1 Energy Saving and Exhausting Efficiency of Combustion Engines

Using diesel engines the only answer for best efficient use could be to run this combustion systems only in the best and efficient working points. If we look to their common diagrams of CO2, NOx emission and fuel consumption (so called shell diagrams for efficiency, torque and speed) and it is clear to see, that these engines have the best efficiency in this small "shell-areas" by specified speed seen at the engine characteristics.

That means when primary diesel energy should be used in future, their highest efficiency could only be reached by running this engine in superior working points in constant running mode. F.e. this is today given by electric power generators.

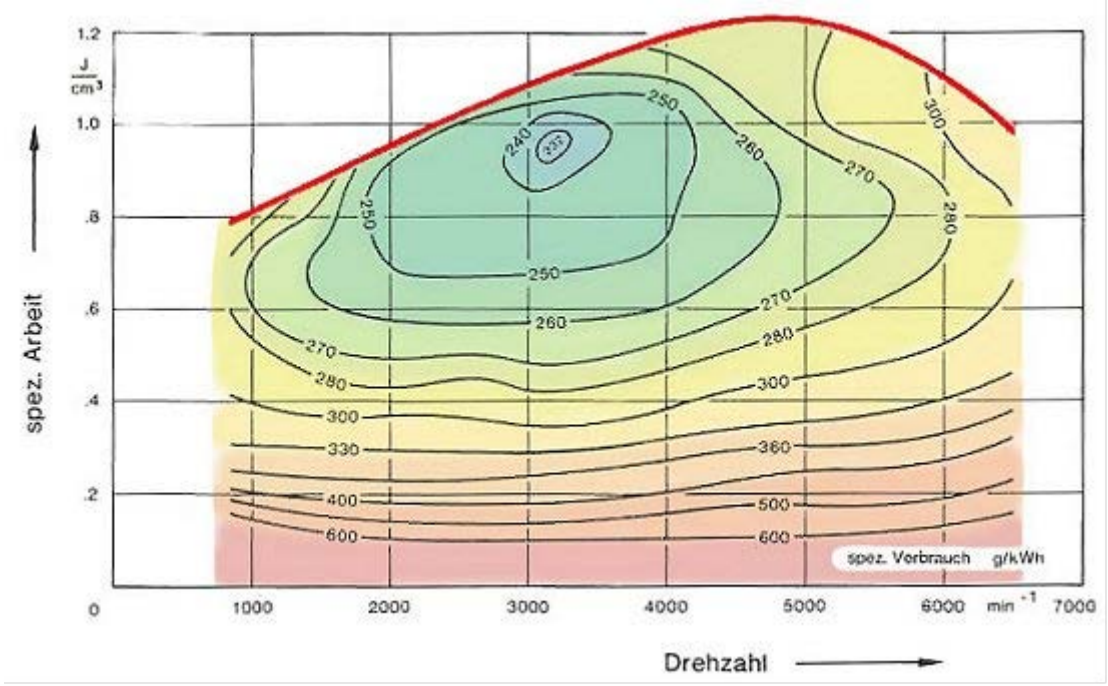

Fig.2. Typical Shell Diagramm for spezific Fuel Consumption in g/kWh over Speed for Gasoline golf Class Vehicles by Rico Klein , www.spritmonitor.de

2.2 Reducing losses on Power Trains

To reduce mechanical thermal losses means in wide view to reduce components of the traction line. Each not used gear, shaft, clutches or differential parts saves and reduces energy, weight, production amount and costs.

2.3 Efficient Single Tire Drives!

The discussion of „well to street efficiency“ has to begin by forcing the tires in a fine abrasion minimizing way. To „torque“ the tires in the best possible way means, to control each tire „personally“ in that own straight running behavior at each time and track conditions.

Mono wheel control is the game. That means each tire has so his own anti slip control and roll resistance control. Alteration from slipping and grabbing is the main abrasion point. That has to prevent. The tire should roll on his best friction to street contact quality without severing.

In contrast by differential gear units of hard standard power train all wheels are fully direct coupled, each wheel has now freedom in respect to the necessity of its street coupling.

So in future the full mono wheel control can maybe only be done on high efficient self anti slip controlled electric drives.

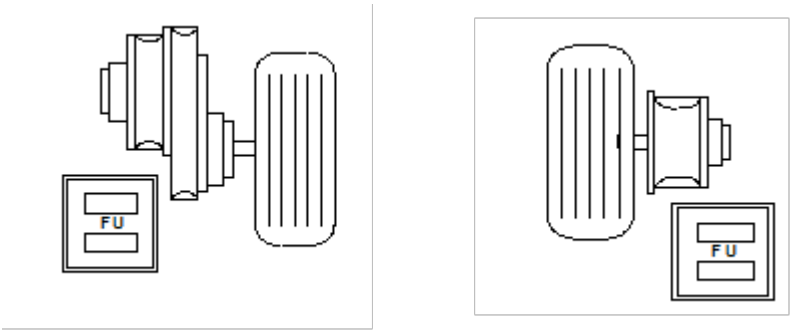

Fig.3. Optimized geared Single Wheel drive with Converter controlled embedded E-Machine and direct e-machine in direct shaft coupling by W.Egger

Hub e-machine embedded in wheels are not the optimum, because the big swinging weight in action makes many troubles in the tire itself and heating them up.

Better are e-machine direct coupling on wheels with short shafts and independent wheel suspension. So the “swinging masses from wheels” are smaller, the tire material has lower stress.

2.4 Weight Reducing over All

Weight reduction of truck chassis and power train is beside the single control drive that action field for saving energy. To reduce mass is that engineering assignment for future all over moving vehicles.

Lightweight machinery construction, alternative compound materials and energy solving production lines with energy recovering is the future.

And this minimization and optimization has to be done at all details from chassis, over wheels to engine and motor constructions.

Oil will further be needed well for products and interior, but with a grade of 87% recycling factor (VW) it will be calculable in future and only on energy supply gas will be the main energy carrier. Without oil ever – the only movements will be done on horses.

Save material and save energy.

2.5 Minimizing Exhausting Emission and primary Energies in future!

To reduce emission losses the discussion leads us from combustion engine to alternative drives.

Hydrogen H2, diesel, gasoline, Gas, methanol, electricity e.g. – are that the primary energies in future?

Well this discussion cannot be solved here – but that is the primary discussion and needs intelligent decisions on political side.

3. NEW EFFICIENT HEAVY TRUCKS STRUCTURES

3.1 Sum up of high efficient Development Task for Future

By summing up all above mentioned ideas, we recognize following facts:

Combustion engines has do be only driven on the most efficient running point. Mono wheel full control units for each wheel is saving tire characteristics. Full modular unit construction with strictly defined interfaces saves production, service and recycling costs.

Material savings and minimizing weight is the leading consequence.

3.2 New Power Train Structures on Heavy Duty Vehicles

The discussion of results for heavy duty power train structures leads us to hybrid structures.

Pure electric driven trucks are possible, but only on special using. See down under. With the question: how many expensive battery makes sense to be used in trucks?

Battery stacks on trucks are not cost effective for normal use of trucks. Maybe in smaller stack packages for special energy braking savings they are useful – only for maximal 15 seconds. This breaking energy can be re-used in generation way for acceleration on electric wheel drives.

Better because much more lighter in weight are super capacitor stacks for that short acceleration jump.

If there will be new batteries on market with much higher capacity, the prices for them will stay high, so pure electric trucks over all are further unthinkable.

3.3 The Future Heavy Truck System: The Serial Hybrid Power Train

All over discussion that system for heavy duty vehicles in future could be the serial hybrid power train.

This systems includes all positive aspects as we mentioned above.

Well in defined modular units with clear interfaces, self controlled wheels and without any gears it is that scenario of energy saving.

Without any mechanical gears, clutches and the whole mechanical line – the hot spots in energy thermal losses and weights have been canceled.

Well good for future efficiency, bad for Germans gear and mechanical power train lobby.

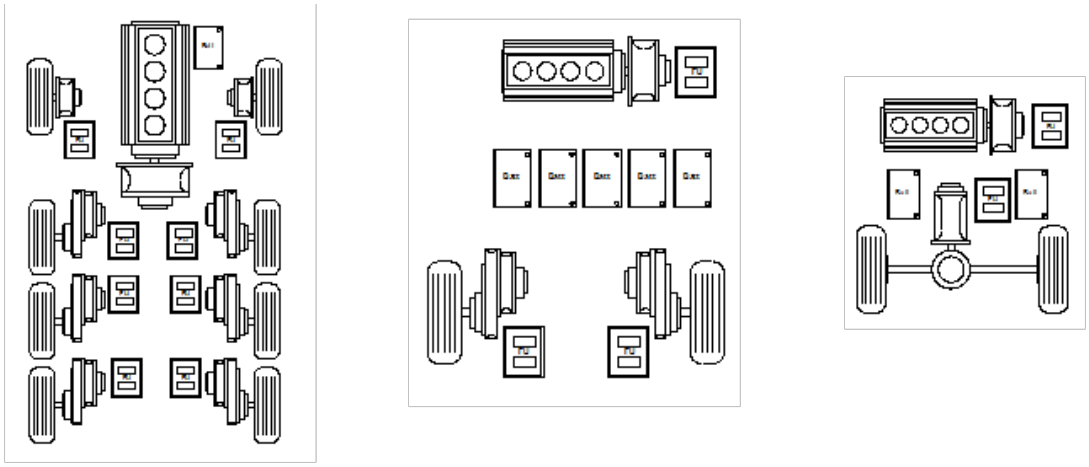

Fig.4. Multi role single wheel controlled serial hybrid traction modules by W.Egger well seen in modular structure with recovering braking energy storage

Seen from efficiency on a normal two wheel system the efficiency over all is only more than 10% per cent higher, but the biggest advantage is the high optimal control of the electric traction well to wheel and well to street.

Electric controlled power trains are the fullest optimized “CVT”- power lines ever.

That means Full torque from beginning and optimized high speed at the end by full field weakening range without gear steps and steady continuous speed variations.

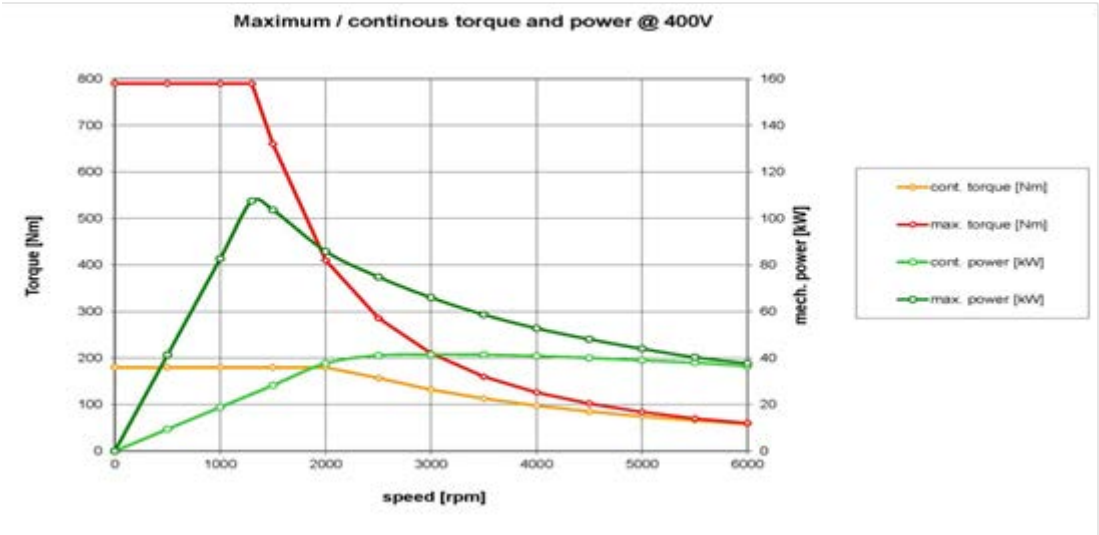

Fig.5. Brusa ASM Converter M-n-Diagram e.g.

3.4 Results on Serial Hybrids

With serial hybrid power trains, consisting of efficient diesel generator composition, well equipped with electric braking energy storage units and full dynamic single wheel control is that future power train structure, also for minimizing energy and for lowest friction rubber abrasion.

Drive assisting by a multi level vehicle control unit we will get full dynamic drive control in several levels from truck board computer.

Tab.1. Table for Control Levels by W.Egger

Level	Control
1	Trailer train control
2	Vehicle control
3	Group wheel control
4	Single wheel anti slip and friction control

So with this new construction structures we will get 15% more load volumes on frame, by 15% lower vehicle weight and 25% longer life period of tires!

4. PILOT IMPLEMENTATIONS AND APPLICATION OVERVIEW

4.1 New efficient heavy trucks

Examples for Hybrid high utility trucks are nowadays developed by all big global vehicle developers. MAN, Mercedes, DAF, VOLVO, Komatsu, Alstom, Siemens, eg. Never can stop the transforming traction world to energy saving hybrid systems.

Fig.6. DAF LF Hybrid medium duty truck system with storage

Fig. 7 Study of Technische Universität München TUM and Siemens, Design Colani

4.2 New electric powered Trailer for heavy Trailer Trains

Very important for high energy saving is to take a look on the whole juggernaut or trailer train.

When the tractive unit has engine generators itself with self powered and single controlled wheels so it makes sense to think over forcing systems for trailer wheels.

Embedded frequency converter driven e-machine wheels would bring an efficiency on traction special on hills and mountain tracks. On rising tracks the trailer itself pushes over his single wheel drives the whole train, brakes additive by downhill tracks. Further on the trailer stabilizes active wheel controlled the full wheel driven street train. That perfect power train.

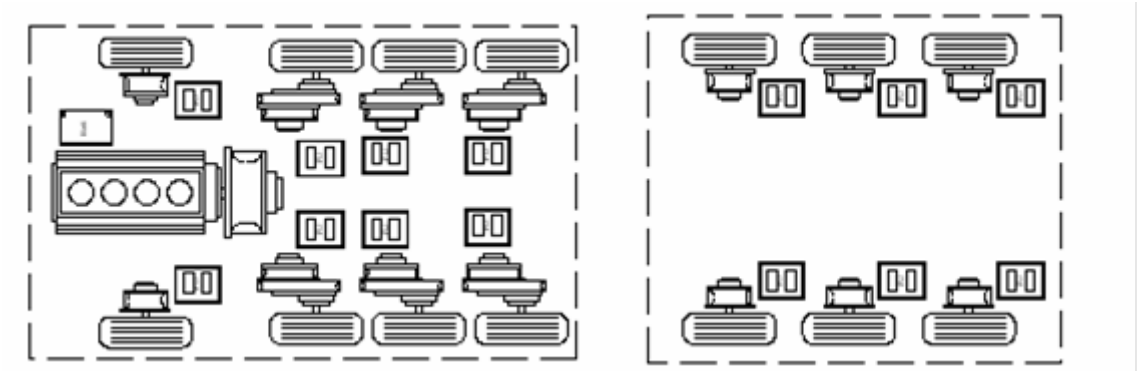

Fig.8. Full electric All Wheel forced Power Train by W. Egger
with trailer powering

Further In future a fully independent powered trailer could become interesting, when the trailer itself has his own efficient diesel generator. Not only for drive energy but also as general generator unit for cooling, hydraulic energy supporting and else.

In case of independent single trailer maneuver a trailer steering unit could be implemented in the self powered e-trailer.

So a new kind of trailer train modules would be the result and gives us new ideas for high efficient logistic possibilities.

4.3 Military Off Road heavy Vehicles

Fig.9. Oshkosh Hybrid heavy duty Military Trucks

Saving energy and high motion quality is essential for survival. Best conditions in driving, saving grip on tires and saving energy are the priorities.
Each saved gallon on sprit has not to be supported to the front of action.

4.4 eTrolley Bus – OBUS Salzburg

Trolley busses with full electric controlled drives are that center urban mobility vehicle, well equipped with frequency converter controlled high efficient electric PM-synchronous machines systems.

Their most important behavior is, that an optimized internal battery stack allows to drive disconnect from trolley line for about 6 to 10 km, for surrounding accident places or traffic jams.

Absolutely highlighted great.

Fig.10. OBUS SLB on Salzburg Town Tracks

Fig.11. E-Highway Study by Siemens

4.5 E-Powertrain for Safety Truck Applications

Fig.12. Electric safety Truck on Airports from Renault Z.E.

On closed and limited areas with central docking stations for charging or battery changing actions pure e-trucks will be common used.

So seen the solution from Renault for support action on the France airport Charles de Gaulle.

Fully explosion safety, no exhausting – well done!

4.6 eMobility Trucks for Standard Transportation

Fig.13. Sanyo study of PV-charged e-Truck

Told before on closed and limited areas with central docking stations for charging or battery changing actions pure e-trucks will be common used. PV-supplement is there fewer than a wish, but trails are accepted.

4.7 Hybrid Diggers

Diggers in each variation with are low running systems for digging and driving are representative for modular serial hybrid structures

4.8 Hybrid Chain Dredger

By chain diggers the biggest losses are by hydraulic motors to force the traction chains. Hydraulic motion drives with electric pump-machines, hydraulic regulated pump, long hydraulic lines with line losses and the hydraulic motors have well to ground only under 5% efficiency.

Therefore a main diesel generator supplies in future all necessary controlled e-machine for the systems and also PM-SM hub motor systems embedded in the chains.

4.9 Truck mounted Heavy Cranes

Truck mounted cranes may have one engine generator for all crane functions and do their crane functionality in serial way over electric controlled e-machines and the second serial drive is that from the truck. Both supplied from two different 1000 liter diesel tanks. The advantage are all over the high optimized controlled motions.

4.10 Truck with mounted hydraulic cranes

By wood truck vehicles further on the heavy duty hydraulic cranes will stay ever on the trucks with the same hydraulic system. Also the heavy oil pump with up to 300kW will be forced directly from the constant efficient running combustion generator, well mounted direct over an electric clutch to the crankshaft of the engine. Separation of the hydraulic system on electric way makes no sense.

4.11 Diesel Hybrid Locomotives

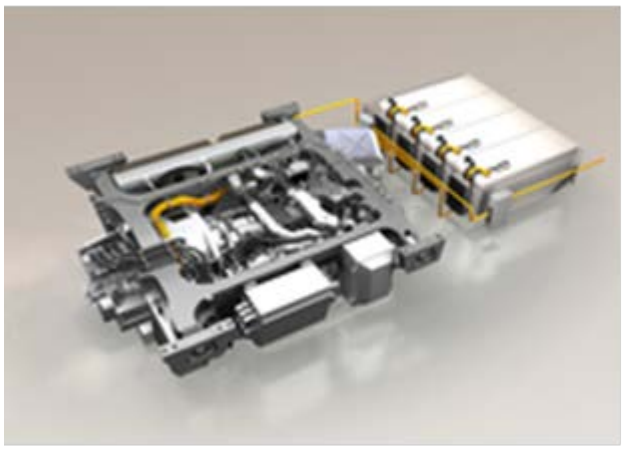

Fig.14 MTU Power pack for diesel electric trainset

Fig.15 Alstom Hbrid Diesel Power pack for diesel

Fig.16. Siemens Sitras recovering braking energy for diesel locomotives

Very special but great in efficiency is to store braking energy in super capacitor stacks in use by diesel electric locomotives.

So the acceleration energy to the running e-machines comes with up to 35% in the first 30 seconds from storage stack. Easy from thinking but great in action.

Pure electric locomotives are working with recuperation and new central control terminals steered the accelerations and breaking action over all running locomotives with time controls so, that every time 600 locomotives will be steady continuously supported by the same low energy level from Grids, so it's done by ÖBB Cargo.

5. CONCLUSION

Modern transportation seen under the priority of efficient energy utilization is the main development focus in future. Analyzing efficiency of power trains nowadays and combine

them with ideas of newest electric traction systems would lead to efficient serial hybrid truck structures. Combustion engines has do be only driven on the most efficient running point. Mono wheel full control units for each wheel is saving tire characteristics. Full modular unit construction with strictly defined interfaces saves production, service and recycling costs. Material savings and minimizing weight is the leading consequence.

Serial hybrids with diesel generator units running on constant working points with highest efficiency and variations of converter controlled electrical machines seems to be the standard truck traction for the next decade.

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