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Research in the field of electric and hybrid mobility at the university of pitesti - the 4x4 electric duster project

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Abstract. The paper presents the electric concept 4WD type, DUSTER Z.E.RO 4WD developed within the Alternative Propulsion Systems for Electric and Hybrid Vehicles laboratory, from Automotive Engineering Research Centre, University of Pitesti, in order to create a green and versatile electric all-wheel drive. This concept car was built on the platform DACIA DUSTER 4WD by implementing a new electric equipment that contains Renault ZE components already launched on the market for commercialized vehicles: Renault Kangoo Z.E and Renault Fluence Z.E. The electric drive, mono-motor type includes a synchronous electric motor type placed transversely, 44 kW, a gears' reducer with two speeds: L- Low for all terrain and H- High for the road and a mechanical all-wheel drive system. The driver to choose from three different driving modes: 2WD front-wheel drive, Auto, in which the rear-wheel drive is engaged automatically and Lock, whereby 50 % of torque is consistently fed through the rear axle. The traction battery is lithium-ion, Lithium ion Manganese Oxide (LMO) type, 400 V, 22 kWh. The estimated performances are: maximum speed: 130 km/h; autonomy NEDC (New European Driving Cycle): 130 km; standard charging: 6 to 8 hrs with home WALL BOX.
Keywords: Dacia DUSTER 4WD, Electric Vehicle, Full Electric 4WD Powertrain
INTRODUCTION

INTRODUCTION

DUSTER Z.E.$_{RO}$ 4WD (ZERO- Zero Emission ROmanian concept) (Figure 1) is a full electric 4WD concept developed between 2013-2014 within the *Automotive Engineering* Research Centre, University of Pitesti, Romania.
This new concept is developed on the mechanical platform of the Dacia DUSTER 4WD, the low cost crossover car made by the Automobile Dacia- Group Renault, at their plant located near Pitesti city, Romania.

Figure 1. DUSTER Z.E.$_{RO}$ (ZERO- Zero Emission ROmanian concept) a full electric 4WD vehicle developed within the Automotive Engineering Research Centre, University of Pitesti [1, 2, 3]

This study is an academic project and has no connection with the projects or future car models of Dacia-Group Renault.
Unlike the previous concept DUSTER Hybrid E4WD, named Grand Hamster Electricway 4WD [2], where only the rear axle was driven in electric mode. the DUSTER Z.E.$_{RO}$ 4WD concept is an entirely battery electric vehicle, all-wheel drive. It is a light SUV (Sport Utility Vehicle) developed in order to create a green and versatile Dacia all-wheel drive for the special applications usable in areas with restrictions on pollution.
The electric version of Dacia DUSTER 4WD features the same practical functions as the internal combustion- engine version, i.e. the same carrying capacity and the same high standard of comfort. On top of that, it delivers a silent ride, responsive performance, immediate availability of torque as soon as its starts, automatic transmission, low running costs and, of course, the satisfaction of owning a zero-emissions vehicle in the areas of use.

DUSTER Z.E.$_{RO}$ 4WD will complete the panoply of concepts realized within the *Alternative Propulsion Systems for Electric and Hybrid Vehicles* laboratory *Automotive Engineering* Research Centre, University of Pitesti: NOVA Matic Hybrid developed on Dacia NovaMatic CVT (2002-2004) [4], Grand Sandero developed on Dacia Logan MCV (2007-2009) [5], Electra developed on Logan Sedan (2008- 2009) [6], Hamster developed on Dacia Sandero (2009-2010) [7, 8], Grand Hamster developed on Dacia DUSTER (2011-2013) [9, 10].

Figure 2. Concept vehicles made within the Alternative Propulsion Systems for Electric and Hybrid Vehicles laboratory, Automotive Engineering Research Centre, University of Pitesti

DUSTER ZERO 4WD ARCHITECTURE

The electric drive system 4WD concept is a mono-motor type and it includes an electric powertrain placed in front side of the vehicle and a transmission all-wheel drive type.
The traction battery assembly with three stacks is located in the central and rear sides.

The architecture of the DUSTER Z.E.$_{RO}$ 4WD is presented in Figure 3.

The electric drive system 4WD include: Traction battery packs (1), HV Conductors (2), Connexion box/Charger (3), Inverter/DC/DC 14V (4), Electric motor (5), Coupling (6), Reducer with two speed (7), Front differential (8), Front drive shafts (9), Transfer gear box (10), Propeller shaft (11), Electric Controlled Coupling (12), Conical gear (13), Rear differential (14), Rear drive shafts (15).

When the driver presses the accelerator pedal, the lithium-ion battery (1) send energy to the electric machine (5) via the high voltage conductors (2), the connexion box (3) and the inverter (4). The front reduction gears have two forward speeds, L- Low, for all terrain and H- High for the good roads. The reverse mode is realized by the electric machine.
The battery charges whenever the vehicle decelerates. When the driver lifts his foot from the accelerator pedal, the vehicle's kinetic energy is recovered by the electric machine (5) (generator mode) which converts it into electric current. The current generated is stored in the traction battery (1).

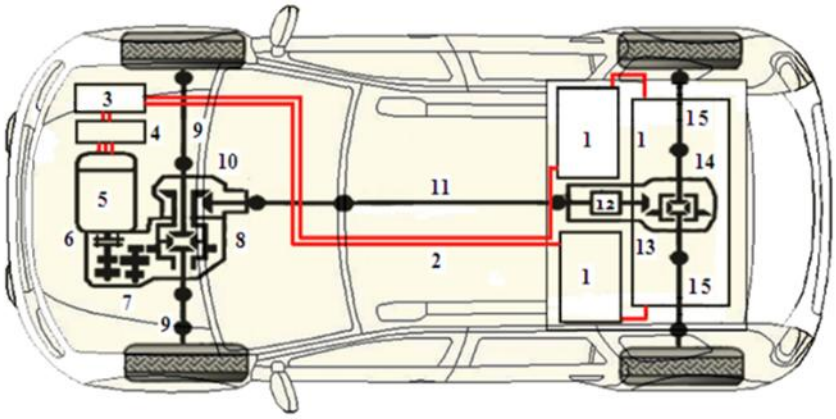

Figure 3. Architecture of the DUSTER Z.E.RO 4WD, full electric vehicle, all- wheel drive [1, 2, 3]

ELECTRIC DRIVE SYSTEM 4WD

The diagram of the electrical propulsion equipment from the *DUSTER Z.E.RO 4WD* concept is presented in the Figure 4.

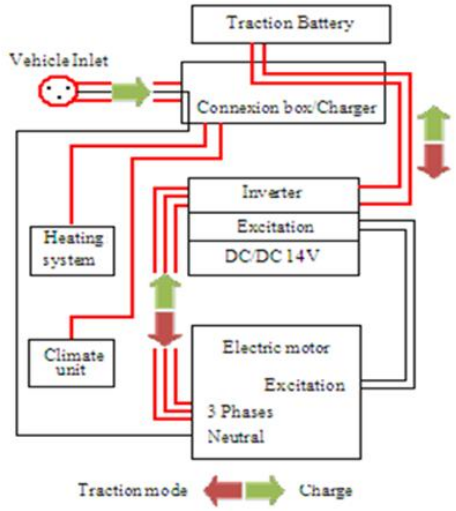

Figure 4. Diagram of the electrical propulsion equipment from the DUSTER Z.E.$_{RO}$ 4WD concept

The electric motor is powered by the inverter from the traction battery. Charging the traction battery from the vehicle inlet is carried out by the on-board charger. Charging the 12 V auxiliary battery is carried out from the traction battery via the DC/DC converter 14 V.

The electric power-train

The electric equipment of the power-train assembly consists of:

- the electrical system (Figure 5) that includes the connexion box (1) and charger (2), the power electronic box with the inverter box and DC/DC converter (3), the electric machine (4) (the electric motor) fixed on a specific frame;
- the adaptation flange for coupling electric motor - transmission;
- the transmission (Figure 5) that includes the vibration damping coupling, the modified TL8 transmission with the gearbox with two forward speeds, the final transmission and the front differential (5);
- the transfer case (6);
- the final transmission (7).

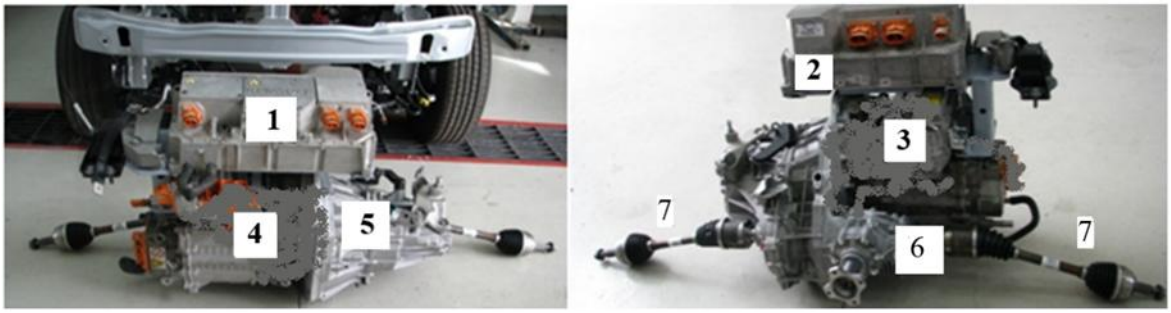

Figure 5. The electric power-train assembly [1, 2, 3]

Figure 6 presents the connexion box (1), the charger the (2), the power electronic box (3), the electric motor (4) and the adaptation flange (5), all made with Catia V5.

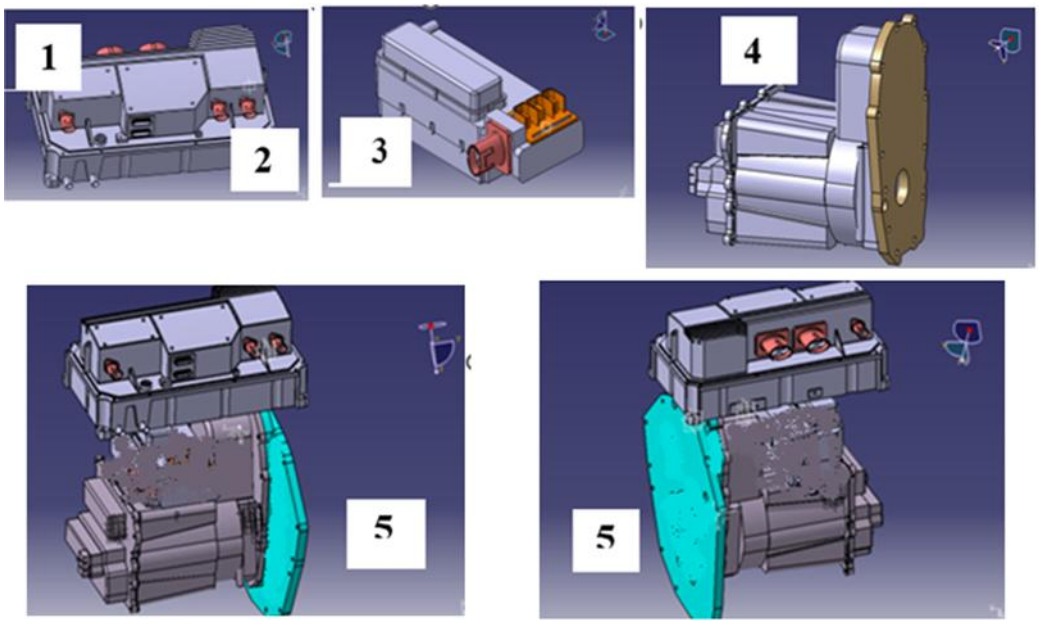

Figure 6. The parts of the electric assembly [1, 2]

Figure 7. DUSTER Z.E.$_{RO}$ 4WD motor compartment [1,2]

The main characteristics of electrical system equipment components are:

Electric motor:

- Manufacturer: 5AM40 Continental- Renault;
- Type: synchronous with wound rotor;
- Maximum power: 44 kW at 1856 - 10500 rpm (figure 8);
- Maximum torque 226 Nm at 480-1856 rpm (figure 8).

The external characteristic of the electric motor is presented in figure 8.

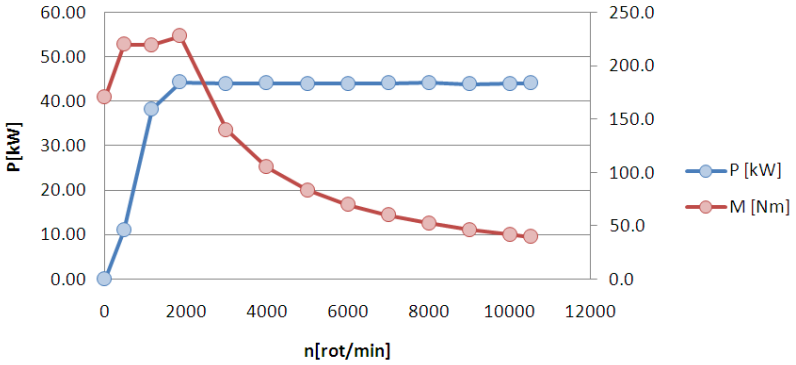

Figure 8. The external characteristic of the electric motor [2, 3]

DC/DC/Excitation inverter/converter

- Manufacturer: Continental;
- Converter power: 3 kW.

Connection box / traction battery charger

- Manufacturer: LEAR Company.

Traction battery

- Lithium-ion, Lithium-ion Manganese Oxide (LMO) type;
- Architecture: 48 modules, two modules of 24 L cells each;
- Maximum voltage 400V;
- The capacity of the traction battery is 22 kW/h;
- The weight is about 260 kg.

The transmission of the 4WD Type

The new transmission of the DUSTER Z.E.RO 4WD was made starting from the mechanical DUSTER 4WD TL8 transmission type of the internal combustion- engine version. Due to the favourable characteristics of the electric motor the new transmission does not require clutch, gearbox or reverse gear. In this case DUSTER Z.E.RO 4WD can be driven similarly to a vehicle with automatic transmission.

The selector lever (Figure 9) has four positions. P: parking; R: reverse; N: neutral; D: drive. The drive mode switch is given the command by a cable (for the forward, the neutral and the reverse mode) and the Parking Lock device. The display of the instrument panel (figure 9) shows these modes. However, to have similar performance as the thermal vehicle, a change was made for a reducer with two speeds. The architecture of this transmission (Figure 3) includes: a new coupling motor/gear input shaft (6), a new reducer with two speeds (7), and the classic components: front differential (8), front drive shafts (9), Transfer gear box (10), propeller shaft (11), electric controlled coupling (12), conical gear (13), rear differential (14), rear drive shafts (15).

The new Parking Lock device is mounted in the reducer housing.

The change of the speeds, L- Low, for all terrain and H- High for the roads, is made by a servo-motor controlled by the driver by a button.

Depending on the road conditions, similar as the internal combustion- engine version the mechanical all-wheel drive system can provide three different driving modes by another button:

- *2WD*, where the transmission is locked into front-wheel drive for maximum electric energy efficiency and maximum autonomy. This mode is used on dry roads with good grip. And the following is indicated on the new instrument panel;

- *Auto,* in which the rear-wheel drive is engaged automatically. The operating principle "AUTO" distributes the electric motor torque between the front and the rear axles, according to the road conditions and the vehicle speed. This position optimises the road holding. This mode is used on any type of road: dry, snow covered, slippery, etc. This mode is not indicated on the instrument panel and it is not available now;
- *4WD Lock*, whereby 50% of torque is consistently fed through the rear axle. The operating principle "4WD Lock" mode distributes the electric motor torque between the front and rear axles in order to optimise the performance capacity of the vehicle in off-road situations. This mode is used only in extreme driving conditions (mud, steep slopes, sand). This mode is indicated on the new instrument panel.

Figure 9. The DUSTER Z.E.$_{RO}$ 4WD cockpit and dashboard with the charge level of the traction battery (left); speed indicator (centre); econometer (right) [2, 3]

The traction battery

The traction battery, lithium-ion, passive air cooled contents two stacks of 24 modules each serial coupled: the first stacks are located in central position beneath the rear seats and the second one is located above the rear axle.
This new architecture was chosen to boast the same carrying capacity as the internal combustion-engine version.

The capacity of DUSTER Z.E.$_{RO}$ 4WD's traction battery is 22 kW/h and the weight is 260 kg. In addition to the modules package the battery box includes: the passive internal cooling system, the electrical circuit computer and connection box, the BMS box, the signal wiring "low voltage" and the general contactor.
An energy recovery system enables the battery to be charged when the car decelerates.
The modelling of the Traction battery - modelling in Catia V5 is presented in figure 9.

Traction battery (Figure 10), lithium-ion, consisting of two modules of 24 LG cells each mounted: one under the back seat (1) and other, above the rear deck (2). The rear module housing also includes the BMS (3) and relays with contacts (4) for coupling the battery to the propulsion system.
This architecture provides payload capacity similar to the internal combustion traction version.

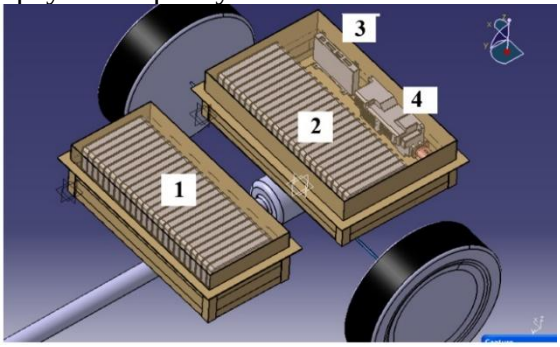

Figure 10. The traction battery [1, 2, 3]

The charging traction battery system for DUSTER Z.E.RO 4WD

The traction battery is connected to the charging station via a socket located in the front of the vehicle under the DACIA emblem (Figure 11, left).
The current version (without additional heating) has a secondary socket located at the rear side, behind the fuel filler cap (on classic vehicle) (Figure 11 right).
Household with WALL BOX type Schneider Electric: 10A or 16A, 220V in about 8 hours;
Rapid with terminal (public station): 32A, 400V in 30-60 minute.

Figure 11. The front socket (left) and rear socket (right) for DUSTER ZERO 4WD [2]

DUSTER ZERO 4WD's Steering

An important change to the vehicle was adapting an electric power steering system, variable rate, column-assist type. This system, a brushed DC motor was integrated in the steering column; the motor was located in the passenger compartment.
Compared with the traditional hydraulic steering systems, with hydraulic pump or electric motor and pump ("powerpack") mounted on the Dacia cars, the Electric Power Steering system offers the driver assistance directly and it has the advantages of energy economy, handiness, easy adjustment, less noise and waste, oil pollution and the working principle of ESP system.

DUSTER ZERO 4WD's Braking

The braking system is similar to the diesel version and includes: ventilated discs on the front axle with 280 mm disc diameter, drum in the rear axle 9 inches diameter, Anti-lock Braking System (ABS) Bosch 8.1, Electronic Brake force Distribution (EBD), Emergency Brake Assist (EBA) and ESC (Electronic Stability Control).
For the assist system a new vacuum pump HELLA, electric type was installed in the engine compartment behind the 12V auxiliary battery.

DUSTER ZERO 4WD's Climatization

Similar to the Renault electric vehicles, DUSTER Z.E.RO 4WD is equipped with a HVAC system with an electric compressor AC DENSO and an electric heating device.
The system with a specific architecture serves to cooling / heating the interior of the car and cooling /heating the traction battery. The liquid circuit is equipped with one radiator for the interior climatization and one radiator for the external battery climatization and the two pumps.
When the car is plugged in, the driver can programme pre-conditioning system, pre-heating or pre-cooling of the cabin.
In order to increase the cooling and heating efficiency, and cuts down on heat entering or leaving, thus also reducing the air-conditioning's power consumption the following measures were taken:

- The thermal insulation of the roof with aluminium foil and a hollow layer;

- The thermal insulation of the windows with anti UV foil, turquoise colour.

CONCUSIONS

The DUSTER Z.E.$_{RO}$ 4WD (ZERO- Zero Emission ROmanian concept) is an Electric Vehicle Concept developed within the *Automotive Engineering* Research Centre of the University of Pitesti in a partnership project between *Automotive Engineering* Research Centre and *Renault Technologie Roumanie*.
The full electric Dacia 4WD vehicle was built on the mechanical platform DACIA DUSTER 4WD, by implementing an electric drive with Renault ZE components already launched on the market for commercialized vehicles.

DUSTER Z.E.$_{RO}$ 4WD concept includes some innovative solutions: 4WD Electric Drive with two speeds; a specific dashboard display with specific EVs board computer; an electric power steering system with variable rate, column-assist type; a new HVAC system adapted for the passenger compartment and traction battery.

Acknowledgments

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