Article citation info:
Golebiowski W. Concept of the construction of electric go-kart (eKart). The Archives of Automotive Engineering – Archiwum Motoryzacji. 2018; 80(2): 53-63. http://dx.doi.org/10.14669/AM.VOL80.ART4

CONCEPT OF THE CONSTRUCTION OF ELECTRIC GO-KART (EKART)

KONCEPCJA KONSTRUKCJI GOKARTA ELEKTRYCZNEGO (EKARTA)

WŁODZIMIERZ GOŁĘBIOWSKI[1]
Technical University of Lodz

Summary

Today electric vehicles are becoming increasingly popular in our lives. Especially in motorsport. However, they are not as widely used. Formula E, which was created to boost electric motorsport, is not enough to popularize it. Every driver who wants to advance to F1 (highest rank racing series) has to start from karting between the ages of 5 and 8. But today go-karts are only powered by internal combustion engines.
In order to provide young drivers with the possibility of racing small electric vehicles called eKarts, internal combustion engines have to be replaced with electric motors. eKarts should offer similar performance to combustion engine go-karts.
It was proven by the author in previous papers that current technology enables to construct eKarts for children's and juniors` categories. In this paper concept of the construction of eKart uses advantages of electric motors which are presented. The proposed construction concept assumes the introduction of an in-dependent wheel drive of the rear axle allowing the so-called torque vectoring.

Keywords: eKart, electric motorsport, formula-e, electric go-karts, construction of electric drive train, electric differential

Streszczenie

Pojazdy elektryczne stają się coraz bardziej popularne w naszym życiu. Nie są jednak tak szeroko stosowane w sporcie motorowym. Formuła E, stworzona w celu zwiększenia popularności

[1] Technical University of Lodz, Faculty of Mechanical Engineering, Department of Vehicles and Fundamentals of Machine Design, ul. Żeromskiego 116, 90-924 Lodz, Poland; e-mail: golebiowskiw@wp.pl

napędu elektrycznego w sporcie motorowym, nie wystarczy. Każdy kierowca, który chce awansować do Formuły 1 (seria wyścigów o najwyższej randze), powinien swą przygodę ze sportem motorowym rozpocząć od kartingu najlepiej w wieku 5 lat. Obecnie gokarty są napędzane tylko silnikami spalinowymi.
W celu zapewnienia młodym kierowcom możliwości ścigania się małymi pojazdami elektrycznymi zwanymi eKarts, silniki spalinowe powinny zostać zastąpione silnikami elektrycznymi. Jednocześnie, eKart powinien oferować osiągi podobne do gokartów spalinowych.
W artykule podsumowano efekty analiz możliwości budowy eKarta dla różnych kategorii wiekowych. Udowodniono, że obecna technologia umożliwia tworzenie eKartów dla kategorii dzieci i juniorów.
W publikacji zaproponowano również koncepcję budowy eKarta wykorzystującego zalety silników elektrycznych. Zaproponowana koncepcja budowy zakłada wprowadzenie niezależnego napędu kół osi tylnej pozwalającą na tzw. torque vectoring.

Słowa kluczowe: eKart, elektryczny motorsport, formuła-e, elektryczne gokarty, budowa elektrycznego układu napędowego, elektryczny dyferencjał

1. Introduction

The history of the electric car has been started at the beginning of the automobile era, i.e. in the 19th century. At that time, electric vehicles competed with combustion and steam engine ones not only in the streets but also on race tracks. The world land speed record of 105.88 km/h was established by the Belgian Camille Jenats in 1899 in an electric vehicle and was unbeaten for another 3 years [1] [2]. The Paris-Bordeaux-Paris race was attended by the French electric constructor Charles Jeantud. His car offered great performance, but its 950-kg batteries had to be replaced 15 times during the race [3]. The problem with storing electricity was the reason why electric vehicles have long disappeared from the streets and from motorsport as well.

Rising awareness of ecology and the search for new fields of experiments in motorsport have led to the development of hybrid technology, which was the first sign of a return to electricity. In the F1 racing series, fuel efficiency regulations have been intensified and the share of hybrid energy recovery systems has increased. In 2006 regulations were announced and in 2009 a kinetic energy recovery system was introduced in the F1 racing series. The system called KERS (Kinetic Energy Recovery System) allowed the release of energy up to 400 kJ on one lap [4,5] and no more than 60 kW. In long-distance races the importance of the hybrid system has been confirmed in the most prestigious race. In the LeMans race on 16–17 June 2012 two Audi hybrid cars were classified in the first two places. This was the first long-distance race for hybrid vehicles, as apart from the Audi LMP1 e-tron, Toyota also entered its TS030 hybrid vehicle.

Another step towards ecological motorsport was the creation of the electric Formula E series. In Formula E the race takes about 50 minutes, and the problem of storing a sufficient amount of energy has been resolved by the obligatory pit-stop and car replacement. Formula E takes advantage of easy energy control and makes the sport more entertaining. In racing mode maximum power is limited to 170 kW. However, the three drivers who win a fan on-line vote can receive an additional 100 kJ increasing maximum power to 200 kW for couple of seconds.

Formula E has received credit from racing drivers. Former F1 driver and current Formula E driver, Nelson Piquet Jr, said that "If you care about the fame and flashes the F1 is the best racing series, but equally exciting for racing drivers is competing in Formula E. Formula E was created to boost electric motorsport, but still very few series are purely electric."

To get to F1 each driver has to start from karting between the ages of 5 and 8. But nowadays go-karts are only powered by combustion engines. In order to introduce for young drivers the possibility of racing small electric racing vehicles, the so called eKarts, combustion engines have to be replaced with electric motors. It was assumed that for eKarts to gain a foothold, they should provide similar parameters to those of combustion engine go-karts. In precious paper "Analysis of vehicle dynamics parameters for electric go-kart (eKart) design" of the author [12] it was proven that with existing Li-Ion battery technology, it is possible to construct eKarts for children's and junior categories (up to 15 year old). And there is an expectation than emerging battery technology with an energy density of at least 350 Wh/kg, which should take place within 3 years, will provide a solution for senior categories (15 and over). So then the question arises: what should be construction of eKarts uses advantages of electric motors, and being closed to construction of combustion engine go-karts?

2. Construction of go-kart with combustion engine

For the purpose of designing construction of electric go-karts, construction of internal combustion engine (ICE) gokarts have been analyzed, to find must haves and improvement areas.

Gokarts are a simple construction of racing cars. They are built on a frame without suspension, with a rear-wheel axle drive rigid, without a differential.

There are a lot of ICE gokarts constructions, but there are two types of homologated racing types, the first one – 950 mm wheelbase for children's category and the second one – 1045 mm wheelbase for youth and senior citizens. Shape of the frame and its main dimensions They are defined by CIK-FIA regulations [6].

Figure 1 shows the construction of Birel typ RY 30 construction under the CIK-FIA regulations. Its main components are:

1. Rear axle
2. Front axle
3. Adjustable steering pin, steering wheel saddle
4. Support, rear axle beaing

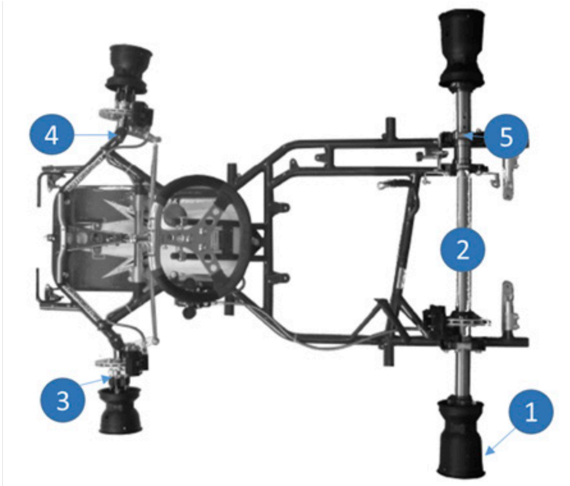

Fig. 1. ICE Gokart chassis Birel type RY 30 and its main component [7] [8]

Steering is a direct trapezoidal steering mechanism. The lack of differential and very high mechanical traction of the rear axle forced the steering system into a go-kart allowing Ackermann effect adjustment. Thanks to the adjustable position of lower and upper housing of the crossover pins, i.e possibility to change caster angle enable fully adjust the wheel-to-ground contact point. This design enable effect that when the front outer wheel is lowered and the front inner lift is raised, the center of mass is shifted, and the rear inner wheel is pulled off. Thanks to these effects, the resistance of the motion during cornering is reduced. [9]

For a 1045 mm gokart frame, there are two brake system configurations on disc on rear axle, and/or discs on front wheels, powered from separated hydraulic pumps (pedal, drivig wheel hinge):

The most popular motors in high-performance karting are two-cylinder single-cylinder units. Engine capacity varies from series to race category. There are two engine capacities of 60 cm^3, 125 cm^3, whose rotational speeds reach 20,000 revolutions per minute. In the junior and senior categories the 125cc units are dominant. The figure number 2 shows the 125cc Ro-tax Max engine with its equipment.

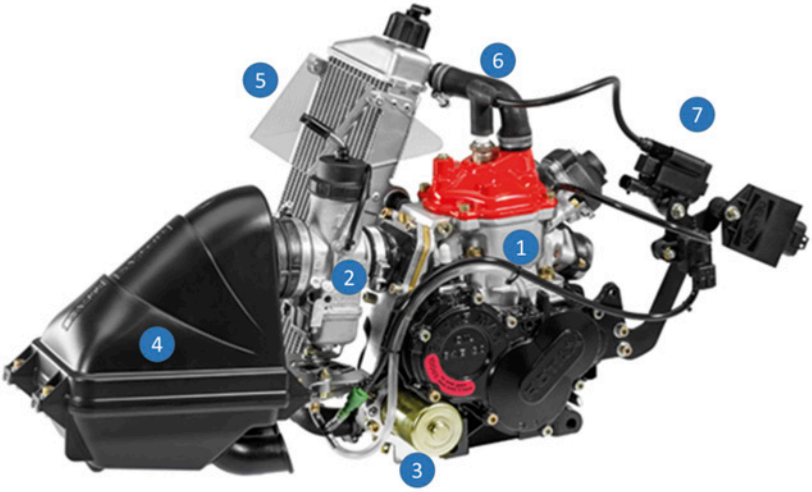

Fig. 2. 125 cm^3 Rotax Max engine for junior category with accessories [10]
1. Engine (cylinder); 2. Carburetorp; 3. Starter; 4. Resonance container of the intake;
5. Radiator (radiator air wheel); 6. Spark plug, spark plug pipe; 7. Ignition coil

Transmission ratio of the drive train is determined by the organizers for the selected track for each race and category according to CIK-FIA regulations. In advanced karting categories, drive train come with integrated gearbox.

The rear axle is supported at three points, one on the left and two on the right side near the drive train.

Go karts are equipped with aerodynamic elements while performing safety functions. The size of the aerodynamic elements and their fixation is determined by the CIK-FIA regulations.

3. Analysis of go-kart drive train

In order to determine assumption for eKart, analysis of powered used and traction parameters have been done based on Rotax Max Challenge 2016 Cup racings and official trainings on the following certified karting tracks:

- Speedworld in Bruck, Austria
- Goethe Stadium in Keckemet, Hungary
- Pann Ring in Ostffyasszonyfa, Hungary
- Autodromo Vysoke Myto in Vysoke Myto, Czech Republic
- Tor Radom, in Radom, Poland
- Bydgoszcz in the city of Bydgoszcz, Poland
- 7 Laghi Kart – International Circuit in Castelletto di Branduzzo, Italy

Obtained results were presented in the paper "Analysis of vehicle dynamics parameters for electric go-kart (eKart) design" [12].

It was proven that with existing Li-Ion battery technology, it is possible to construct eKarts for children's and juniors` categories, with the requirement that the current weight of the go-kart in each age category, see Fig 3. It was also stated that in order to provide a solution for senior categories, it would be necessary to change the regulations, for example: race time and vehicle weight, or waiting for emerging battery technology to provide an energy density of at least 350 Wh/kg, which should take place within 3 years.

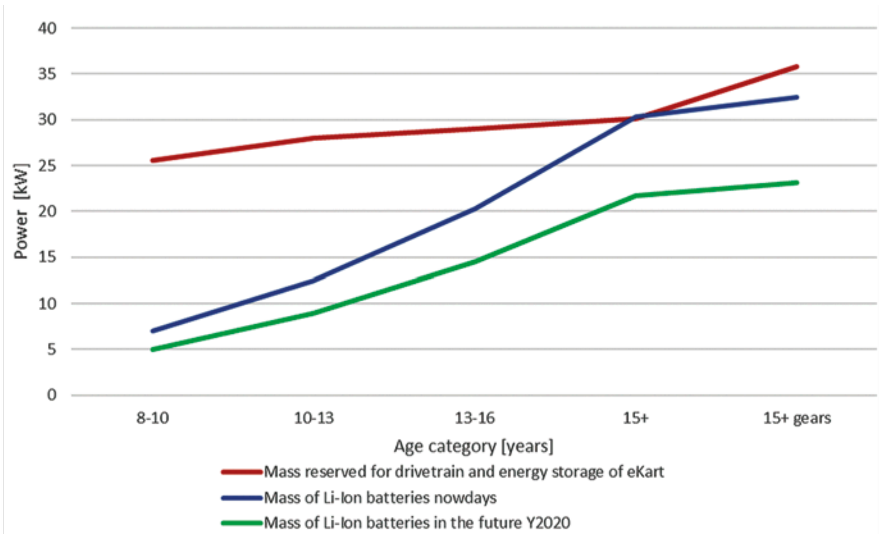

Fig 3 Maximum weight of drivetrain unit of eKart with batteries compared to potential mass of the batteries in Li-Ion technology nowadays and in 3 years' time for given age categories

4. The concept of electric go-kart

For working out creation of the concept, it was assumed that the eKart design should be a simple four-wheeled vehicle with rear-wheel drive, using advantages of an electric drive. The key advantages of the electric drive are the compact size, power to weight ratio, high torque of the drive and the ability to provide almost identical output parameters (speed, power, torque).

The ability to provide identical driving parameters like ICE gokart has also become the basis for vehicle chassis design. It was assumed that for the simplicity of the eKart, a tubular flat frame without suspension element will form the chassis.

In the eKarta project it was decided to use the compact dimensions of the electric motor. It was assumed that each wheel of the rear axle would be driven by a separate engine.

This solution will allow to vary the speed of the inner wheel and the outer rear axle while cornering. This will help to achieve better stability with a similar balance of eKart versus the ICE gokart.

Due to the fact that the construction of the karting sport is regulated it means that ICE gokart is regularly improved form the 50 years and standardized. That's why while creating the concept of eKart, the gokart was a comparison benchmark.

It was assumed that eKart will be made in the technology of ICE gokarts. eKart also has dimensions and weights similar to current cars to ensure the availability of the right track geometry, and to match the vehicle to the physical capabilities of drivers in different age groups.

eKart should share as many as possible standardized parts from the gokarting platform. Easy access to gokart parts should increase adoption hence of the vehicle. On the other hand, it was assumed to do not compromise the performance of the vehicles. So for example same steering and similar chassis are considered, while rear axle is assumed to be new construction with power vectoring. Electronic torque vectoring is distribution of driving force which corrects engine power when turning in turn. It is realized by so called an electronic differential.

The use of an electronic differential is an advantage of the electric motor to provide the same or better driving performance. In the case when the ICE gokart is moving in a bend with rigidly join left and right wheel by rear axle, forces a large understeer as the inner wheel moves at a higher speed than that vehicle trajectory and the outer wheel moves at a lower speed than the trajectory. Thanks to the torque vectoring correction of independent rear axle motors eKart handling will be neutral. Disconnection of rear axle wheels, and powering them by separate motors make possible to adjust its settings so that, depending on the track, the effect can be configured under or above the steering.

According to the assumptions, the following solution was proposed.

eKart chassis is ICE gokart chassis with two modifications shown in Figure 4.

The first modification marked 1 in Figure 4 is the additional rear axle support to the left side of the chassis. Support is symmetrical longitudinally to the existing double supports on the right side, in a way that the rear axle can be divided into two components.

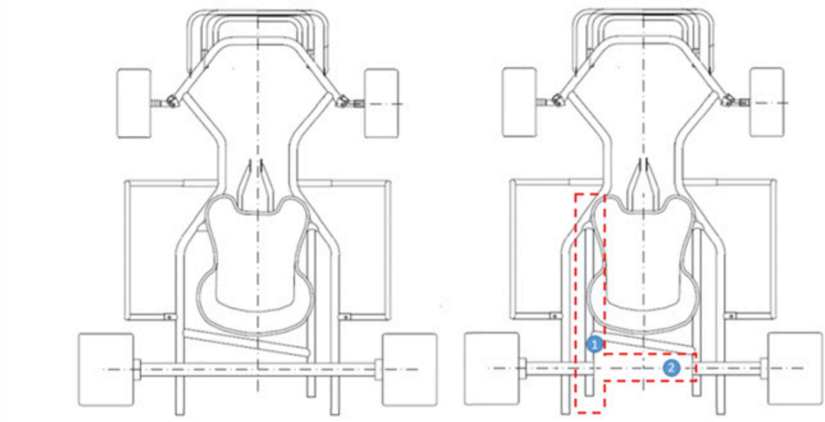

Fig. 4. Sketch of modification of the ICE gokart chassis for the eKarta construction

The second modification marked 2 in Figure 4 is the division of the rear axle into two independent elements. Because the rear axle in ICE gokarts connects its fulcrum points (shown in figure 5, marked 2), it is also the structural component of the rear frame of the vehicle. In the ICE gokarts, the rear axle has different stiffness parameters so allow to adjust the rear traction of the vehicle. The traction of the rear axle of the eKart will be adjusted by strut bar between the inner axle support points (not present ICE gokarts) and the spacer between the outer support points (solution in go-karts marked 2 in figure 5)

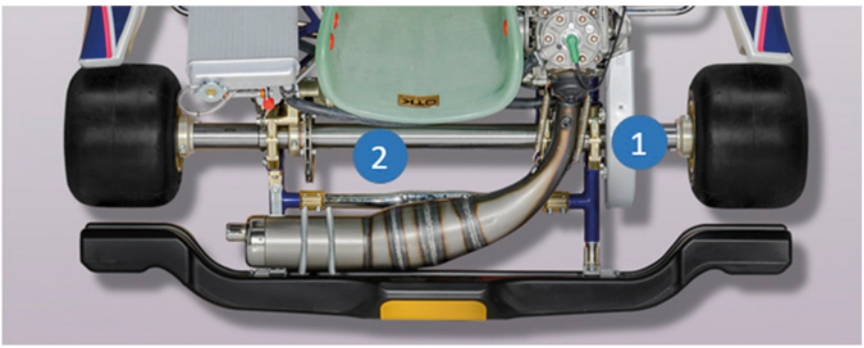

Fig. 5. Rear Suspension elements of Kosmic MERCURY MY15 [11]

Since in the ICE gokart support of the rear axle of the right-hand side are at the same time structural parts of the engine mounting, modification marked 1 in Figure 4 will allow the installation of separate motors for both wheels of the rear axles. At the design stage, it will be determined whether the motors are located ahead of or behind the rear axle of the vehicle, as illustrated in Figure 6 both variants are possible.

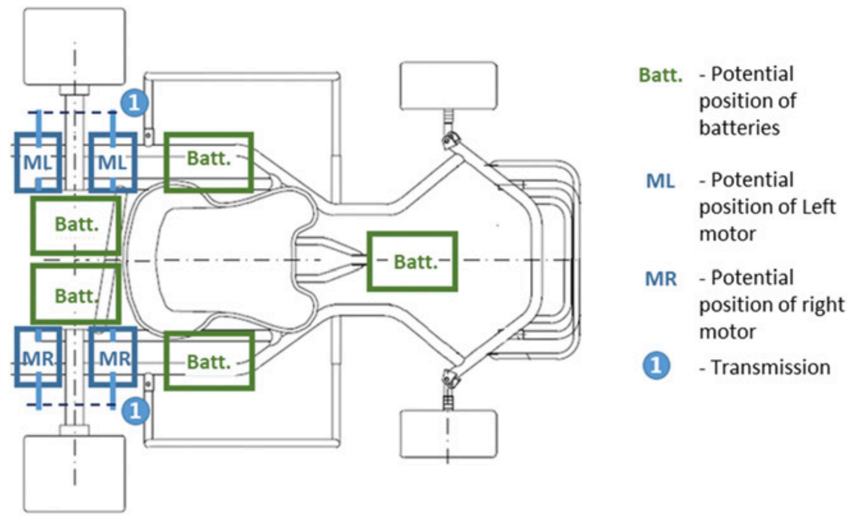

Fig. 6. Potential position of the main components of eKart

eKart will be equipped with Electric motors of different power depending on the age category. There can be also different kind of motor cooling, air cooled and liquid cooled, depending on its power.

Potential position of batteries is also shown in Figure 6. It was indicated to ensure the best balance of eKarts. The position of the batteries must at the same time ensure maximum protection due to poisoning or burns in case of damage. The position of the batteries has been proposed in places least exposed to other eKarts and track elements (barriers) during the crash. The proposed battery position at the rear of the vehicle are located be-tween the rear axle and are protected by a rear bumper, lateral side seats are secured with side chassis, aerodynamic elements and a bumper. The front battery compartment is located at the fuel tank of ICE gokart. The advantage of rear or side mounts is the distance to the motor, while the advantage of the front position is a better eKart static balance.

Batteries will be additionally protected by shock absorbing housing so that the vehicle can be used safely in sporting events and in various weather conditions. Battery design must ensure that they are easy to replace and modular. Each of the batteries used must be of the same dimensions to be used interchangeably. Batteries should be able to quickly connect them to larger units.

In case of use of batteries generating large amounts of heat, the design of the cooling system will be determined at the design stage. Similarly to the engine, it is possible to use air or fluid cooling.

The most important component of eKart is motor controller. Motor controller will store program with algorithm of torque vectoring. Therefore it is assumed that the motor controller will be protected against unauthorized modifications and will be able to process information from following sensors:

- steering wheel position
- acceleration pedal
- brake pedal
- wheel speed
- roll, pitch, yaw accelerations
- data on Voltage, Current, and Resistance of motors
- data of rotor positioning

The controller location will be close to the motors and batteries, in the back of the vehicle behind the driver's seat.

Due to the characteristics of the electric motors, possible recuperation, it is assumed that the rear axle brake system will be provided by the electric drive system. For safety, reasons eKart will be equipped with an emergency brake system installed on the front axle. The emergency braking system will be based on the standard components of the ICE gokart.

5. Conclusions

In the paper "Analysis of vehicle dynamics parameters for electric go-kart (eKart) design" [12] author proves that with existing Li-Ion battery technology, it is possible to construct eKarts for children's and junior categories.

In this paper concept of eKart was presented which assume that eKart will be build based on ICE gokarts technology and components. It is expected that eKart thanks to electronic differential, can actively manage torque and power on each of rear wheels, called torque vectoring. Thanks to torque vectoring eKart is expected to have better performance, especially on cornering.

The full text of the article is available in Polish online on the website http://archiwummotoryzacji.pl.

Tekst artykułu w polskiej wersji językowej dostępny jest na stronie http://archiwummotoryzacji.pl.

References

[1] Renault S.A.S. The Electric Revolution, www.youtube.com (Available 2011).

[2] Jastrzębska G. Odnawialne źródła energii i pojazdy proekologiczne. Wydawnictwa Naukowo-Techniczne, Warszawa 2009.

[3] Węglarz A, Pleśniak M. Samochód Elektryczny Instytut na Rzecz Ekorozwoju. Warszawa 2011, Krajowa Agencja Poszanowania Energii S.A.

[4] FIA, Formula one technical regulations, ww.fia.com/regulations 2009

[5] Jacob J, Colin J A, Montemayor H, Sepac D, Trinh HD, Voorderhake SF, Zidkova P, Paulides JJH, Borisaljevic A, Lomonova EA. InMotion hybrid racecar: F1 performance with LeMans en-durance. The International Journal for Computation and Mathematics in Electrical and Electronic Engineering, 2015.

[6] Karting technical regulations, CIK-FIA.

[7] Technical drawing No. 1 Chassis frame and chassis main parts, CIK-FIA.

[8] Birel Homologation, CIK-FIA.

[9] William F. Milliken, Douglas L. Milliken. Race Car Vehicle Dynamics: Problems, Answers and Experiments, Publisher: Society of Automotive Engineers Inc, 2003.

[10] BRM http://www.rotax-kart.com/en/Products/MAX-Engines/ (cited January 2018).

[11] http://www.kosmickart.com (cited January 2018).

[12] Golebiowski W, Szosland A, Kubiak P. Analysis of vehicle dynamics parameters for electric go-kart (eKart) design, Mechanics and Mechanical Engineering International Journal (przyjęta do poblikacji), issn 1428-1511.