Engineering 24 (2023) 10–12

Contents lists available at ScienceDirect

Engineering

journal homepage: www.elsevier.com/locate/eng

News & Highlights

Electric Racers Hit the Track, but still Catching Up

Mitch Leslie

Senior Technology Writer

John Metric was shocked the first time he drove his electric dragster, a modified 1984 Pontiac Fiero (Fig. 1). Metric had swapped the car's gasoline engine for two electric motors that could generate 1830 N·m of torque. When he hit the accelerator "it threw me back in my seat so hard," he said. Reaching 97 km·h^{-1} in just over 2 s, the car produced such strong *g*-forces as it accelerated that "I had tunnel vision" and almost blacked out, said Metric, who owns Lonestar EV Performance (Lake Jackson, TX, USA), a company that makes batteries for electric racing vehicles. The experience, he said, was like being in "a roller coaster."

That was in 2010, and it was just the beginning for Metric. Since then, he has converted three other dragsters to electric, one of which he got up to 300 km·h^{-1}, and he is now building an electric car he hopes will be capable of 480 km·h^{-1}. Metric is one of the drivers showing that electric vehicles (EVs) can be fast and exciting on the racetrack. Like many electric racing enthusiasts, he performs and pays for the conversions himself, using "my retirement fund," he said. In the last decade or so, however, electric motorsport has taken off, drawing multimillion dollar investments from major manufacturers, corporate sponsorships, celebrity owners, and larger audiences. Fans can now tune in to professional electric competitions for almost every type of racing vehicle, including Grand Prix motorcycles, off-road sport utility vehicles (SUVs), and rallycross cars [1–3]. Formula E, the all-electric equivalent of the prestigious Formula One series, is now in its ninth season and in 2023 will hold races in 11 countries [4].

Fig. 1. John Metric upgraded this Pontiac Fiero by adding two electric motors where the gas tank had been and installing a 375 V lithium-polymer battery pack. The vehicle set an electric racing record for its class by covering the 1/4 mile (0.4 km) in 9.898 s. Credit: John Metric, with permission.

Most electric race vehicles are still slower than their internal combustion counterparts, but their performance is improving rapidly [2]. In less than a decade, for instance, the top speed of Formula E cars has increased by more than 40% [2]. In a few events, EVs now vie with internal combustion rivals—and sometimes win [5]. But whether electric racing can catch up to traditional motorsports in popularity or have the same technological impact on the design of passenger vehicles remains to be seen [6].

Although the first electric race cars hit the tracks in the 1890s [7], internal combustion vehicles dominated the sport for more than century. But as traditional automobile and motorcycle makers have gradually begun shifting to EVs, many of them have jumped into electric racing, including BMW, Mercedes, Nissan, Audi, Porsche, and Jaguar [2,8]. These companies saw electric racing as a way to hone their consumer models, said Arthur Hyde, an associate professor of practice and automotive engineering at the University of Michigan, Ann Arbor, MI, USA. "Motorsport is a place where technologies are developed and proven out," said Hyde, who worked for Ford for 40 years and was chief program engineer for the company's Mustang program.

Like consumer EVs, electric race vehicles have shown dramatic improvements in just a few years [9]. Formula E illustrates this rapid pace of engineering innovation—as well as some of the remaining limitations on performance. The first generation of Formula E cars featured a rear-mounted electric motor that delivered 200 kW of power, allowing them to reach a top speed of 225 km·h^{-1} [2,10]. However, an EV's range depends on its battery capacity [11], and the cars' battery delivered a modest 28 kW·h [10], not enough to keep them moving for an entire 45 min race. As a result, drivers had to switch cars midway through a race [9].

With their higher capacity batteries, the second generation of Formula E cars could complete their races, and the third generation, which began competing in 2023, is even better (Fig. 2). Now, a 51 kW·h battery drives an electric motor that provides 350 kW of power, yielding a top speed of 322 km·h^{-1} [2,10]. All three generations of Formula E cars have been able to partially recharge their batteries through regenerative braking, a system

https://doi.org/10.1016/j.eng.2023.03.003

(a)

(b)

Fig. 2. The third-generation Formula E racers from (a) Porsche and (b) Nissan look alike because all cars in the competition have the same body design, maximum power, and battery capacity. What sets Formula E teams apart is the design of their powertrains, their strategies for managing battery power, and the skill of their drivers. Credit: (a) Porsche (public domain); (b) Nissan (public domain).

also found in hybrid cars and consumer EVs in which the electric motor helps to slow the car, generating electricity in the process [1,12]. The third-generation cars take this capability a step further—they carry a second electric motor only for braking and electricity generation [13]. As a result, they can gain 600 kW through regenerative braking, producing 40% of the electricity they require during a race [6,10]. In comparison, the first-generation cars could only generate 100 kW [10].

Even with these technological advances, Formula E cars are not ready to take on their Formula One counterparts, which produce more than 780 kW of power and typically reach speeds of around 360 $km \cdot h^{-1}$ in races [2,14]. Range remains a limitation for consumer EVs, and it is also a handicap for Formula E, said Hyde. He noted that despite their higher-capacity batteries and regenerative braking, Formula E cars could not complete a Formula One race, in which the total driving time is up to two hours [15].

Nonetheless, EVs already best conventional racers on some performance measures. For one thing, "electric motors make a humongous amount of torque," said Metric. An electric motor only 23 cm in diameter "makes as much torque as a big block V8," he said. Moreover, electric motors can deliver maximum torque as soon as the driver steps on the accelerator, whereas internal combustion engines do not generate their peak torque until they reach higher rpms [16]. This capability is a boon for certain types of racing, such as hill climbs, drag racing, and off-roading, in which vehicles need to accelerate rapidly or power over obstacles. One electric racing series that capitalizes on these advantages is the two-year-old Extreme E, an off-road offshoot of Formula E that features modified SUVs [2]. And World Rallycross, in which cars negotiate paved and dirt roads, switched from internal combustion to electric engines in 2022 [3].

Most EVs do not race against their internal combustion equivalents, but the two types of vehicles sometimes go head-to-head. In 2018, for instance, an electric Volkswagen ID R set the world record in the Pikes Peak Hill Climb, a more than 100-year-old event that involves a 1300 m ascent to the top of a mountain in Colorado, USA [17]. The internal combustion engines of the Volkswagen's competitors produced less power at the race's high elevations, where oxygen levels are lower, but electric engines do not need oxygen [17]. The Volkswagen also held the record for the hill climb at the Goodwood Festival of Speed in the United Kingdom until 2022, when another electric racer dethroned it [18].

EV racing has boomed in recent years. Formula E, which did not exist ten years ago, now draws more than 300 million television viewers every year [9]. Still, it is not clear whether electric racing can have the same influence on vehicle technology or attract as many fans as traditional motorsport. Internal combustion racing, particularly Formula One, has driven innovation in passenger vehicles, said Hyde. Every week, a Formula One team completely redesigns its car, he said. "It is an engineering series, not a racing series." Many of the features that Formula One debuted have become standard on passenger vehicles, including adaptive suspensions, anti-lock brakes, paddle shifters, and traction control, he said.

But Hyde doubts that electric racing will be as important for the designs of consumer EVs. Instead, he contends that Formula One will have a greater impact because its cars have been hybrids since 2014. Their batteries are charged through regenerative braking and by a unit connected to the turbocharger, providing another source of power for cars that can carry only a limited amount of fuel [19]. The switch to hybrids means that Formula One engineering teams have been working to solve problems that also confront the designers of consumer EVs, including the tremendous amount of heat produced by batteries and electrical safety, he said. If anyone can come up with improved solutions for these problems, said Hyde, "I guarantee Formula One will drive that."

Ted Bohn, principal electrical engineer at the Argonne National Laboratory in Lemont, IL, USA, also doubts that many innovations from high-end professional racing series will trickle down to passenger EVs. Rather, he argues that another type of racing is more significant—amateur EV racing series for students. Dozens of universities in the United States and around the world, as well as secondary schools, participate in these competitions, in which students design, build, and drive their own EVs [20,21]. The races not only teach students key engineering skills, said Bohn, but they also serve as recruiting grounds for automotive companies. "Student competitions impact or enable far more people—engineers, managers, and innovators—than the higher level and higher budget Formula E and equivalent series," he said.

Whether electric racing can win as many fans as internal combustion racing is another unknown. Formula E's television audience is still only 20% the size of Formula One's [8]. And many race fans, including Hyde and Metric, agree that electric racing is less compelling. Formula E "does not have the drama," said Hyde. "Part of sport is seeing a human pushed to extremes," he said, and Formula E's slower, shorter races lack that ingredient. Metric and Hyde also say that they miss the roar produced by powerful internal combustion engines.

Still, Formula One's shift to hybrids made the cars much quieter, but its popularity has grown dramatically since [22,23]. And Metric notes that younger fans are less concerned that the cars are not as noisy. "There is still excitement if you listen for it," he said.

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