RACING CIRCUITS

In Formula One racing, where reliability is everything, McLaren International counts on wire EDM to cut its gears.

William R. Stott

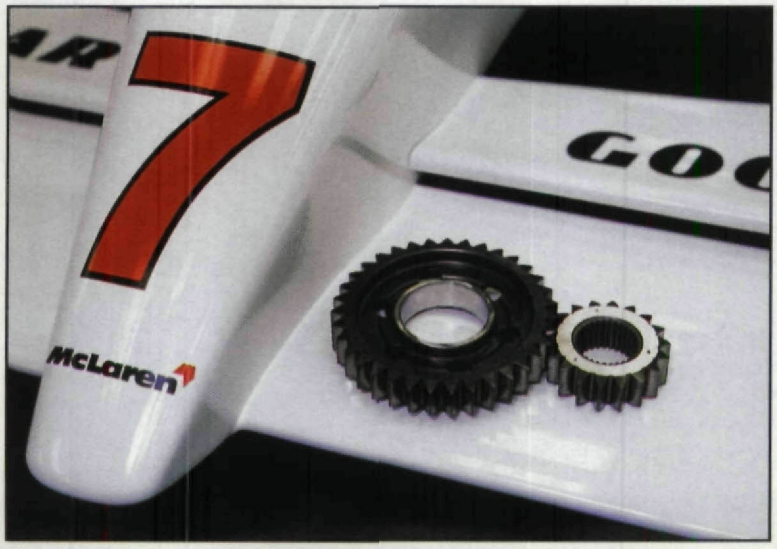
ZERO TO 125 MPH IN FIVE SECONDS. MAXIMUM SPEED OF 211 MPH. SEVEN-SECOND PIT STOPS.

Formula One racing is a high-adrenalin sport—one which demands peak performance from drivers and machines alike.

In their quest for speed, safety and performance, the racing teams are constantly pushing the boundaries of technology by testing new materials and manufacturing processes. McLaren International, one of the premier teams in the sport, has introduced a nontraditional gear manufacturing technique—wire erosion EDM—as a way to bring gear manufacturing in-house at a reasonable cost.

The transmission gears in a Formula One race car must be reliable. A single gear failure can mean the difference between the checkered flag and dropping out of the race. It is not uncommon for several cars in a 22-car field to drop out of a race because of gearbox failure. Because of this, each gearset is used only once for a race. Afterwards, the race team inspects the gears for damage and records the mileage. Then the gearsets are used for practice, qualifying and testing.

McLaren's cars use a semiautomatic six-speed (plus reverse) transmission, which means there are six change gear pairs in the gearbox. Before a race's practice session, the team chooses ratios based on previous experience at a circuit. Then, depending on weather and track conditions, they may have to adjust the ratios. Finally, on race day, they may have to make additional changes because of something as simple as the direction of the wind. If necessary, all six ratios can be changed in just 45 minutes.



Examples of change gears cut by wire EDM.

Overall, the team brings about 60 gear sets for each car at each race. With 3 race cars, 2 test cars, 16 races per year, and qualifying and practice sessions before each race, McLaren goes through as many as 1,000 change gears per year.

Traditionally, Formula One teams have used a handful of outside gear shops to design and manufacture their change gears, creating security problems. Because they already had a huge manufacturing facility in Woking, England, McLaren decided to bring the gear production in-house so they would have faster turnaround time, increased security and greater control over the design and manufacture. In addition, they could save money by not having to go through a subcontractor. But rather than purchase a dedicated hobbing machine, they looked to EDM as a more flexible, less costly alternative.

Wire erosion EDM uses a very thin wire to produce a high voltage charge that vaporizes material on the workpiece. By controlling the path of the wire, the machine can create a very complex form. Unlike a hobbing machine, the wire EDM machine requires no change in cutting tools for a change in gear design. You have only to change the program to generate a new part. There is no waiting for hobs to be designed, ordered or made—a process that could take as long as 12–14 weeks for a new design, says McLaren transmission designer Piet van Zyl.

McLaren estimates that their wire EDM machine will pay for itself within 3–4 years. Also, the capital outlay for the EDM machine was far less than would have been necessary for a dedicated hobbing machine and all the tooling required for the various pitches and tooth numbers. In addition, the machine is used to make

parts other than gears, including titanium seat belt brackets, splines on differential drive gears, front and rear anti-roll bar arms and clamp brackets for electrical items.

But before McLaren could implement wire EDM gear manufacturing, they had to test it to make sure it could produce gears durable enough to withstand as many as 3,000 gearshifts in a single race. "In my view the most important aspect of the gearbox in a Formula One car currently is reliability," says van Zyl.

Toward the end of 1993, McLaren began testing wire-eroded gears made by a subcontractor. They tested these gears for several race distances without problem.

After deciding that the wire erosion process could produce gears of acceptable quality, McLaren evaluated equipment from several manufacturers and chose the Charmilles Robofill 4020 submerged wire erosion machine, which proved capable of cutting DIN 4 quality gears (roughly equivalent to AGMA 14) when the gears were single-stacked. Charmilles became an official supplier in the middle of 1994.

For production, gears are stacked on the machine two high with four stacks on a tooling plate. Gear quality is approximately DIN 6 (AGMA 12) under these conditions. Even though each batch of gears takes 18-24 hours to complete, bringing the gear cutting stage in-house has actually given McLaren faster turnaround than sending them out to be hobbed.

The real advantage to wire EDM comes when design changes are required in the middle of the racing season, says van Zyl. "Toward the end of the [1995] season we were requiring a new ratio to optimize engine performance in sixth gear. I designed a new ratio, which would have required new tooling if manufactured by a subcontractor, with the associated delay in getting hold of the tooling, but we had the new ratios ready in about three weeks time. If really stretched, we could probably do it in less than two weeks, bearing in mind the number of operations involved."

While EDM has proven successful for McLaren, the company has had to overcome some small hurdles. For example, one of the initial problems was developing the software required to convert gear designs into CNC programming.

McLaren uses Computervision CADD5 software to construct parametric models of parts, including gears. In addition, they have created a program using TK-Solver software to calculate points on standard or modified gear tooth profiles. Once a new gear is designed, the program can be downloaded to the machine. "Although there was a fair amount of work involved in creating the initial TK-Solver model and the parametric CAD model, it is now quick to produce data for a new design," van Zyl says.

Precision machines, both on and off the track, contribute to Formula One success. Above, the Marlboro-McLaren car with drivers. Below, the Charmilles wire EDM machine used to make transmission gears.

Another obstacle was dealing with a new machine and cutting process. "Since wire erosion was new to us, most of our initial problems stemmed from a lack of experience operating wire erosion machines," says van Zyl. For example, Charmilles had to develop tooling to hold the gears in place for cutting. Unlike hobbing machines, wire erosion machines don't allow you to mount the gears on an arbor. Instead, they have to be supported from the outside. This is achieved by having bigger blanks and supporting them in a tooling plate with holes cut into it to support the blanks, van Zyl says. The blanks have three starting holes drilled in them from where the gear tooth profile can be cut, leaving tags on three of the teeth to support the gear.

The 1994 and 1995 racing seasons have demonstrated that wire erosion EDM is a reliable gear manufacturing process. Driver Mika Hakkinen drove one of the first McLaren-made, wire-eroded gear pairs in the 1994 Japanese Grand Prix. In the 1994 Australian Grand Prix, both Hakkinen and teammate Martin Brundle had second gears produced in-house by wire erosion. McLaren went through 16 races without a single gear failure in 1995. "We had good reliability before wire eroding them, and now we are improving further on that with our own design and manufacture," van Zyl says.

Overall, the company produced 726 change gears with their machine. "At the end of the 1995 season, McLaren can now conclude that wire erosion has been successful in meeting the required manufacturing schedule for a season's change gears," says van Zyl. ✪

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