
Summary of Honda Third-Era Formula One Chassis Development

Akio TONOMURA*

Shun KAWABE*

Nobuhisa NAKAYOKU*

ABSTRACT

The third era of Honda's Formula One participation started in 1998 with a stage of preparation for the return to actual racing, which began in 2000 and extended up to their withdrawal in 2008. A summary view of the Honda Formula One cars that were developed every year during this period of participation in competition is presented from the perspective of chassis technology. An overview will be given of each year's aims regarding the chassis and the technology that was required for third-era Formula One racing, accompanied by photographs of the chassis. Each year's regulations and the aims of chassis development will also be surveyed from the separate perspectives of aerodynamics, the chassis, and the like. The points on which development was successful will be discussed on the basis of racing results, and points calling for rethinking will also be examined.

1. Introduction

The Formula One cars of recent years cannot succeed just by one prominent performance capability, but have to achieve a high-level balance of all factors in order to win. Even if one car has the most powerful engine, if it is heavy it will damage the rear tires. If efforts to perfect an aerodynamic advantage limit the space available for the suspension, the chassis will be lacking in stiffness and will become unstable. Going too far in reducing the weight of parts will detract from rigidity and reliability. The question of how to discern the points of optimal balance as a whole for conflicting approaches like these is the key to chassis development.

The team conducts actual driving tests in order to search out the optimal balance points. However, testing on a slow car will only yield low-level balance points. For example, when a car has unstable braking, the brakes cannot be applied hard, and since the brakes cannot be applied, the tire temperature will not rise to the working range, and the cornering grip will be reduced. Low grip on corners means that the corner exit speed will be lower, which reduces the top speed on the straight-end. In this way, a sequence of various different factors can fall into a vicious cycle. A team that has a fast car faces the opposite situation, and the difference cannot readily be overcome. These are the reasons that a new team finds it so challenging to come into its own, and it takes a considerable number of years to raise all the factors to a high level. This is because there are various constraints placed on the development environment.

Formula One vehicle testing is carried on with a variety of different limitations, including the funding for team operations as well as limitations on the distance of test drives, limitations on the number of tires, and so on, in addition to which the circuit conditions are constantly changing due to weather, dirt, and tire rubber deposits. When determining the sensitivity contribution of a single factor on vehicle performance, it is necessary to test it with all the other factors held constant. Under these conditions, however, it always seems as though either nothing more than a very rough evaluation or a mistaken evaluation can be done. Therefore, every team competes fiercely on the development of evaluation methods, using bench tests in a stable environment that also includes inexpensive simulations and wind tunnel testing. One might say that the determining factor lies in these evaluation methods. However, it is in the nature of simulations and bench tests that the results may diverge from what is obtained using the actual machine. In order to compensate more or less correctly for this divergence and to decide the direction for development, it is essential to obtain correlation with the results of repeated testing with the actual machine. This means that tests run with the actual machine are necessary, and so the development is caught in a dilemma. This is what makes Formula One development such a challenge: it is a race to overcome dilemmas like these, to find reliable evaluation methods and evaluation criteria, and to quickly discover the car's balance points.

This article will relate how the Honda team dealt with this development race.

* Automobile R&D Center

2. The RA099: 1998-1999



The RA099 came into being in late 1998 when Dr. Harvey Postlethwaite, who had been working with Tyrrell until 1998, came to Honda Racing Development as technical director. The chassis fabrication and simulation analyses were carried out on contract by the Dallara Automobili company in Italy.

Honda was aiming toward entry into Formula One competition from 2000, and the RA099 was intended as a prototype to be test-driven the year before that. The engine was a Mugen-Honda V10. The concept was true to the basics: to build up a proven system by driving it steadily as a dedicated test car and gathering definitive tire data, aerodynamic characteristics, and directions to take in vehicle setup so as to develop a car for actual racing in 2000. The primary focus in this was the aerodynamic concept that there was little variation in the downforce (hereafter referred to as the aerodynamic pitch sensitivity) due to changes in the chassis pitch angle. If this sensitivity was excessive, then changes in the chassis attitude when braking and accelerating would result in excessive aerodynamic changes, causing instability. This effect could not be mitigated through other tuning elements such as the suspension springs or the weight distribution, and the result was that the tire characteristics could not be employed to full advantage. Ascertaining the tire characteristics required raising the tire temperature to the working range of approximately 70°C and maintaining a speed that would keep the temperature at that level. It was therefore crucial to assure the car's aerodynamic stability.

The front suspension was largely like those of the other Formula One vehicles of recent years, in a double wishbone configuration that has torsion springs located in front of and behind the rocker arm shafts. The rear suspension employed a double wishbone with a coil spring coaxial damper positioned perpendicularly to the chassis and connected by a large rocker arm protruding from the aluminum cast gearbox. This layout of the rear suspension opened up space on the top surface of the gearbox, allowing a third damper to be added easily in later testing. The third damper consists of a spring and damper that expands and contracts when the chassis moves vertically with the wheels on either side in phase (i.e., heave). Its purpose is to control pitching.

The layout around the gearbox today, when the Coke-bottle shape and top exhaust represent the mainstream,

is designed for a gearbox made as narrow as possible. At that time, however, the mainstream type had exhaust pipes that passed between the top and bottom of the suspension to vent to the rear, and this was the form followed in the RA099.

The only adventuresome step taken amid this orthodox fabrication was in the top wishbone in front. The arms were made of Carbon Fiber Reinforced Plastic (CFRP), the fittings that attached them to the body were made of titanium, and they were bonded together with adhesive. Since that was the time when the use of CFRP for suspension arms was just getting started in the Formula One world, one arm was selected as an example to begin development. The other suspension arms were all made of steel.

The weight distribution on the front axle of the chassis (hereafter referred to as the weight distribution) was designed using calculations based on tire characteristics data. The objective was 45%, and the design faithfully achieved this. The wheel-base was 3020 mm. The height of the center of gravity was 250 mm above the floor, which was lower than that of the following year's car, the BAR002. A crucial issue in race car design is how to assure traction when cornering. This was addressed by an effort to bring the jack-up power that arises from the suspension link mechanism down toward zero by locating the rear roll center more or less on the rear floor. The RA099 was built in an orthodox manner without any remarkable measures to reduce its weight, but even so it turned in a series of good lap times in 1999 tests. The car looked promising for the next year's races, but Dr. Postlethwaite suddenly passed away in April. That May, the project was put back on the drawing board, and RA099 development was brought to a halt.

3. The BAR002: 2000



In 1998, Tyrrell was bought up and British American Racing (hereafter BAR) was founded. The BAR001 was built starting in 1999, and was entered in Formula One competition. The BAR002 was the model from the second year of BAR.

Honda contracted with BAR in 1999 to supply engines and conduct joint development of the chassis from 2000. The work on the BAR002 therefore represented Honda's debut in the third era. The BAR001 from the previous fiscal year had repeatedly experienced

trouble every time it raced, and with two cars in a total of 16 races, it had 22 retires. The reliability was therefore upgraded, but even though the BAR002 placed fourth and sixth in the opening competition, it experienced mechanical trouble that resulted in Jacques Villeneuve retiring from the race five times and Ricardo Zonta two times out of 17 races. There was no choice for the development effort throughout 2000, therefore, but to focus on upgrading reliability, and weight reduction was sacrificed accordingly. The fact is that the car was able to load 27.5 kg of ballast in the opening race, but the amount was down to 3 kg in the final race. The Formula One rule is that the car must be driven at a weight of 600 kg or more, including the driver, and considering the weight of the driver's equipments, the maximum-target weight for the chassis would be approximately 500 kg. The chassis is made as light as possible, and then ballast is loaded to bring the total weight up to 600 kg. As much ballast as possible is loaded, and it is placed in as low a position as possible. This lowers the center of gravity and allows adjustment of the weight distribution, and explains why the amount of ballast is directly tied to chassis performance. By the end of the season, the BAR002 had almost no ballast loaded.

Another issue was the 42% weight distribution. It is not known why this weight distribution became a starting specification. Considering that the RA099 had a figure of 45% using the same Bridgestone tires, this means there was a difference of as much as 3%. A weight distribution that is skewed to the rear is advantageous for acceleration but becomes unstable in the deceleration range. To control that, the rear wing is turned up to increase the downforce. The higher up the rear wing is turned, the more the aerodynamic efficiency is degraded and the drag increases. It is also necessary to suppress fluctuations in the aerodynamics in order to limit the vehicle's instability, and there was no choice but to stiffen the springs in order to limit fluctuations in vehicle height. The actual spring wheel rate was 25 kg/mm, which was stiffer than the vertical spring rate (24 kg/mm) of the tires themselves. In the lower speed range, therefore, the vehicle would bounce and lose its grip. Having the weight distribution skewed to the rear also placed a burden on the driving wheels and caused the tires to rapidly deteriorate. When the situation progressed, the tires would generate excessive heat, causing blisters to form.

The way that races developed for the BAR002 was to do a rocket start and pass two or three cars before the first corner. After that, the rear tires would degenerate, and the car would drag back and lose its position. This pattern was repeated. The weight distribution was gradually enhanced toward the final races of the season, reaching 44%. In conjunction with this, the distribution of the aerodynamic downforce exerted on the front wheels (hereafter the aero balance) changed from 33% to 38%, but the aerodynamic efficiency ended up decreasing. The reason for this was that the aero balance target value served as a reference

in promoting the development of all the aerodynamic parts so as to raise the aerodynamic efficiency to a maximum at the balance point, and making mid-season changes to the target value therefore would cause a fatal delay in aerodynamic development. Similarly, the weight distribution target values that are calculated from the gripping force of the front and rear tires should also be decided initially when beginning chassis development. The reason is that the weight distribution target values end up determining the dimensions, weight, and positioning of the monocoque, fuel tank, engine, transmission, and suspension, so that trying to make changes later causes the yaw inertia moment and the height of the center of gravity to increase.

Another notable development topic was electric power steering (EPS), which was used starting with the Hungary Grand Prix in August, ahead of the other teams. No one doubts its effect any more, but when it was initially developed, people wondered whether power steering really would reduce the lap time. This was because the increase in lap time due to the addition of 2.6 kg to the system weight was clear, but the enhanced stability caused by reduction of the burden on the driver could not be quantified. At that time, however, a self-alignment effort of 40-50 Nm was considered to be necessary for the steering on the high-speed corners in Barcelona and the USA. This means that drivers would have to exert fine control on a 10-inch diameter steering wheel while supporting a 20-kg load on it with their arms extended. The drivers were in a situation where keeping the steering aligned was all they could manage without exerting further control, and it was therefore decided to adopt the EPS. The size of the motor was a constraint on the EPS, and it was developed to be capable of a maximum assist of 15 Nm.

The issues faced with the car during that year were the inability to optimize the height of the center of gravity and the weight distribution because of the weight increase caused by reliability upgrades. With the following year in mind, therefore, weight reduction of the various parts was given priority in order to properly establish those parameters.

4. The BAR003: 2001



Making use of lessons learned in the previous fiscal year, a weight reduction of 33 kg was accomplished and a weight distribution of 45% achieved. Typical weight

reductions are as follow:

- (1) Use of CFRP in suspension: 13 kg
- (2) Overhaul of gearbox structure: 6.5 kg
- (3) Hydraulic systems: 1.5 kg
- (4) Thinner walls for tubes in aluminum radiator and enhancements to fins: 3.0 kg
- (5) Optimization of orientation and number of monocoque laminates as well as of honeycomb thickness using computer-aided engineering (CAE): 3.0 kg
- (6) Achieving a balance of collision performance and weight reduction by using CAE to optimize nose cone, front wings, and rear wings: 4.4 kg
- (7) EPS motor enhancement to increase assist torque from 15 Nm to 27 Nm while reducing weight: 0.2 kg
- (8) Use of titanium for seatbelt buckle: 0.5 kg

These are some of the ways in which the parts were overhauled and refined.

The aerodynamic performance achieved the lift/drag ratio (L/D) of 3.0 under the aerodynamic conditions of a downforce of 12500 N at a speed of 250 km/h, which was the initial objective when the BAR003 was first raced. Development was pursued with the aero balance objective of 42%.

The wheel spring rate came out at 14 kg/mm, finally bringing the car's basic characteristics and specifications to appropriate values, and making this a year in which development could raise the car to a whole new level. The weaknesses of the BAR003 were its instability from braking up to the point when the steering wheel started to be turned, understeering (US) at the cornering apex, and the kind of sudden oversteering (OS) called snap-oversteering that occurs when the accelerator is pressed and the car is building up speed coming out of a corner. In other words, the steering characteristics during cornering were inconsistent, requiring constant corrective steering. This was addressed by altering the control in the electronically controlled differential to increase stability by directly linking the left and right wheels when the brakes were applied, then freeing the wheels after that, which was effective in resolving US in the middle of a curve as well as snap-OS when the car was coming back up to speed. It was necessary to develop optimal control, and even before that it was necessary to enhance the basic characteristics of the suspension. In other words, the camber angle-change characteristic (hereafter suspension compliance steer) and the toe angle obtained by input from the tires became the toe out when lateral force was input to the rear suspension. Measurements made after the season showed that these were in the direction of instability. Carrying out measurements with a suspension tester reveals these clearly, and it is taken as the accepted wisdom that new cars should ordinarily be tested once they have been built and before they are driven. Under pressure from the testing and racing schedules, however, there was no choice but to give priority to circuit testing over bench testing, so that practice could not be implemented. As result, however, the discovery of an essential issue was delayed, and the development ended up taking a detour.

5. The BAR004: 2002



This car represented a further evolution with a weight reduction of as much as 14 kg, as well as increased stability achieved by having control play a larger role. While traction control during acceleration was a matter of course, over-run control was adopted to transfer torque from the engine when the rear wheels were detected as locked during braking. Having the rear wheels lock during braking is ordinarily very likely to result in a spin. In order to avoid this, the brake force distribution to the front and rear brakes must allow an extra margin of distribution to the front, but this over-run control now allows the rear-wheel brakes to be applied even closer to their limit.

Efforts were also made in this year to enhance the analysis of maneuverability. One rather basic matter was to enable quantitative evaluation of driver comments about the degree of OS and US from the chassis data. Tools for evaluating stability by means of simulations that take suspension compliance steer characteristics into account were also adopted. All of these originated in chassis performance evaluation technology for mass-production vehicles.

The weight reduction measures included the development of materials for disks and pads in carbon disk brakes. Friction material made with carbon is subject to progressive wear when they are oxidized due to heat, so they are made thick enough to last through the running distance of a race. Curbing that oxidation and thereby reducing the amount of wear enabled reductions from 24 mm to 20 mm in the thickness of disks and from 18 mm to 15 mm in pads made to Suzuka Grand Prix specifications. This also led to reduction in the total width of the calipers themselves, achieving a total weight reduction of 1.6 kg in the system. Weight reduction was pursued by going so far as to implement proprietary development of parts that ordinarily must be purchased from the brake manufacturers. Efforts were also begun to reduce the weight of the materials employed in many different CFRP applications in the chassis. Carbon laminates are made up of carbon fiber and resin, and in order to raise the fiber volume fraction (VF), extra-thin prepregs were applied. These were made from carbon fibers that had been opened up and crushed and then lined up side-by-side without any gaps between them. Their use in the engine cover achieved a weight reduction of 3.1 kg.

New attempts were also made regarding chassis stiffness. Air intake to the engine passes through holes in the roll hoop above the driver's head to the air box where it is conducted to each cylinder. The air box was treated as more than just an air vent, however, by making it a structural member that fastens the top of the engine to the monocoque in order to provide a dramatic increase in chassis stiffness. This measure enhances torsional stiffness 8%, vertical bending stiffness 55%, and lateral bending stiffness 6%. When tested in actual driving for comparison with and without this air box, however, the results showed no difference, and the regular air box was returned to use partway through the season. This led to the formulation of a rule of thumb that driving stability is insensitive to chassis bending stiffness in the vertical direction, and this provided an excellent reference point for implementation of weight reduction the following year. Advances were made in weight reduction and control development during this year. Although the car was balanced, however, it was slow. The balance that had formed was still at too low a level, and it would be necessary to upgrade performance in all directions.

6. The BAR005: 2003



During the previous fiscal year, every element had been reviewed from the ground up under the guidance of technical director Geoffrey Willis, who had moved over from Williams. Dramatic progress was made in the quality control of carbon parts and the reliability of bonded parts in particular. Faults in carbon parts occurred much less frequently after that. Rigorous quality control of other parts was implemented, as well.

Measures to reduce weight also extended beyond simple weight reduction. The effort to reduce weight above the rear axle, to take a particular example, expedited selective weight reduction in the chassis rear end in order to lower the rear center of gravity, making the gearbox lighter and more compact and the engine 16 kg lighter, which was expected to promote stability. These measures had a significant effect in reducing the yaw inertia moment, and even though the wheel-base was extended by 61 mm, from 3133 mm to 3194 mm, the yaw inertia moment remained largely the same at 688 kgm². The overall height of the center of gravity was lowered from 243.1 mm above the floor of the previous fiscal year's BAR004 to 226.6 mm above the floor,

making the BAR005 the lowest of all the third-era Formula One cars. Although further measures to reduce weight were also pursued in subsequent models, changes in the collision safety regulations turned the focus toward how to reduce the resulting weight increases. Consequently, the year-to-year changes in the height of the center of gravity tended to show either leveling off or slight increases.

With this machine, the basic elements of chassis performance, such as the height of the center of gravity, the weight distribution, and the moment of inertia, as well as the aerodynamic performance, reached the highest level standard. Even though the BAR005 showed signs of being fast during winter testing before the season, weight reduction had resulted in diminished reliability in the gearbox and hydraulic systems, so that Jacques Villeneuve retired eight times out of 16 races while Jenson Button retired five times. The car ended up with fifth place in the constructor's standings. This was the result of pressing hard in development, and taking drastically aggressive measures, in order to catch up with and overtake the top team, and the reliability of the points in question was steadily upgraded in the following year.

7. The BAR006: 2004



Of all the third-era Formula One cars, this was the most competitive machine throughout its season. Of the 18 races, Jenson Button finished with points in 15 races and went to the victory stand 10 times, while Takuma Sato finished with points in 10 races and went to the victory stand once, with the BAR racing team placing second in the constructor's standings. The reasons for this breakthrough were the way in which the BAR005, which had great potential, matured through evolution along normal lines to secure its reliability, and the change in evaluation methods used in aerodynamic development. Target values were set for the variation range so that the aero balance could be maintained constant as much as possible during cornering. The aero balance change from braking to corner exit can increase by as much as 10% in some cars, and these measures were part of an attempt to bring that figure down to zero. The conventional approach was to evaluate aerodynamic pitch sensitivity by mimicking the changes in vehicle height at the front and rear during cornering. This was now augmented with a crosswind mode that subjected

the car to a diagonal wind from the front, taking the actual vehicle slip angle during cornering into consideration, and also adding a mode in which the tires are steered. These efforts placed the wind tunnel evaluation modes on a well-established basis. The establishment of these aerodynamic evaluation methods held an important meaning: making the aero balance stable meant that drivers could attack corners with confidence, and this is a key to building fast racing cars. It would be ideal, essentially, if the degree of confidence with which a driver can attack a corner could be expressed in quantitative terms, and if it could then be predicted how many seconds of lap time that would be equivalent to. This quantification, however, is no easy matter, so it is necessary to ascertain and evaluate the causal relationship between the aero balance change and the driver's confidence.

Advances in methods for analyzing tire characteristics also enabled a better understanding of how to use Michelin tires with the weight distribution configured at 48%. This was another major factor in the upgraded competitiveness of the BAR006.

Another gain in competitiveness came from the front clutch pack. When the driver begins turning the steering wheel while braking, the normal load on the inside front wheel is reduced, and that tire tends to lock up. Once it has locked, the braking distance increases, and not only is lap time lost, but flat spots form on the tire surface, vibrations are generated, and subsequent driving is impeded. The front clutch pack is a system that avoids the above by transferring torque from the outside wheel to the inside wheel in order to prevent locking. It connects the left and right front wheels by means of the clutch. The results for this year were achieved because the basic elements of chassis performance reached their highest level, reliability was upgraded, and on top of that, the car possessed another powerful advantage. Unfortunately, the front clutch pack ended up being prohibited in the following year's regulations.

8. The BAR007: 2005



Measures were taken with the aim of further increasing the range of adjustment of the weight distribution toward the front by 1% (to a maximum of 48.9%) compared to the previous year's BAR006, and to reduce the yaw inertia moment (-9%). The result was a packaging layout that moved the front axle 46 mm to

the rear while keeping the location of the rear axle unchanged and placing the differential center 5 mm farther to the front. The wheel-base was 3085 mm, and the gearbox was changed from a 3-speed to a 7-speed with seamless shift to reduce the time loss when shifting gears to zero. As the speed of the cars increased year after year, the FIA had adopted a policy of placing limits on it, so that the regulations this year aimed at reducing the downforce by raising the height of the front wings 50 mm and moving the rear upper wing 150 mm forward, new regulations were introduced for the diffuser area, and so on. The FIA was eying a 20% reduction in the downforce, whereas the Honda team decided to limit the reduction target to 10%. Although the target was met, the other cars achieved smaller reductions than anticipated, so there was a considerable gap at the start of the season. Every effort was made in the subsequent development, and a 13% increase in the downforce was achieved in the course of the season, while the year-round figure had usually been 7%. However, the other cars achieved similar advances, and the gap was not closed. The drag had also increased to a maximum, and enhancement of the L/D remained an issue. The lack of downforce resulted in excessive deterioration of the rear tires, which also had an impact on traction and braking performance. In combination with insufficient warm-up of the front tires, this caused conspicuous delays due to OS in high-speed corners and US in low-speed corners. In the later competitions, "push rod on upright" was introduced as a front suspension measure to achieve better weight-shift distribution, and this provided a better grip in low-speed corners. In "push rod on upright," the push rod is attached to the upright instead of the lower arm, where it is conventionally, and also offset from the kingpin, so as to control the vehicle height and weight shift during steering. Although this measure yielded its effect, it did not increase performance enough to overtake the top team, and this was a year that left unresolved issues in tire handling.

The fourth competition at the San Marino Grand Prix would have been a double victory, the first time in the season for both drivers to earn championship points (Jenson Button in third place and Takuma Sato in fifth). The car inspection after the race, however, found a violation: when all the fuel in the fuel collector tank was removed, the cars came in under the regulation minimum weight (600 kg). The team responded by disclosing their data and insisting as follows: the fuel tank is not a special item, and the car did not go under the regulation minimum weight of 600 kg under any conditions whatsoever while running in the race. The FIA responded that data can be altered and cannot be recognized as evidence. They took the view that, structurally, there was a possibility that the cars fell below the minimum weight, and they deemed the cars to have infringed the regulations. The race results were forfeited, the team was suspended from entering the fifth and sixth competitions – the Spain and Monaco Grand Prix – and the team was suspended from racing for six months, with a probation period of one year. This year,

therefore, was also one in which severe rulings were imposed.

9. The RA106 (BAR008): 2006



Honda bought up all the BAR shares during this year, so that it was 100% Honda-owned. The chassis designated BAR008 was renamed during the development stage as RA106. Since regulations required that the engine be changed to a 2.4 L V8, the total engine length was reduced by 90.5 mm, affecting the chassis package. In order to maintain stability, the monocoque and gearbox case alone were lengthened, and a driveshaft with lightweight constant velocity joints was adopted. The wheel-base retained the same 3085 mm length as in the previous year.

With the new engine, the lateral mounting points were spaced with a larger pitch and the chassis lateral stiffness was increased 33% to heighten the stability. In the gearbox, the seamless shift that had been introduced the previous year was expanded to all the gear shifting stages. A direct-push clutch was adopted with the aim of stabilizing the clutch friction performance necessary to control tire slipping at the start, which came with the reduced engine displacement, and this measure also increased acceleration from a standing start. Aerodynamic measures were taken in light of the reduced power with the change to a V8 engine, and a policy change from emphasis on downforce to emphasis on efficiency aimed to enhance efficiency by 13%. In order to obtain downforce without increasing the drag, steps were implemented to increase the rate of flow across the bottom surface of the floor, and the nose was raised higher and the keel was eliminated in order to heighten performance. This setup sought to overcome the excessive wear of the rear tires that had been an issue the previous year by taking steps to maximize the traction performance of the tires, and the front-rear ratio of the weight-shift distribution, which was caused by the lateral force generated when building up speed coming out of a corner, was changed to give it a forward shift. This allowed the temperature of the front tires to be brought up to the working range of 70°C or higher.

The RA106 (BAR008) produced top-level times in the early qualification rounds when the season was beginning, but the car was not producing winning times in the actual races, and this became a conspicuous issue. The effects of aerodynamic enhancement brought out

turning performance that exceeded the other cars', but delays in developing technology to reduce rear wing drag at high speeds meant that this machine was far outstripped by the top teams at maximum speed. In the area of tires, the excessive deterioration of the rear tires was resolved. However, warm-up became an issue on certain circuits, making it necessary to further upgrade tire temperature management. Although it was helped by the dropout of the top teams in the 13th race, this year the RA106 did achieve Honda's first win (with Jenson Button) of the third era of Formula One racing. Various measures were taken to upgrade the car's competitiveness even from the 14th race, such as extending the wheel-base by 50 mm at the front axle to enhance its braking stability, and these yielded positive effects, but not enough to put its performance on a par with that of the top teams.

10. The RA107: 2007



Chassis development up to the RA106 had continuity, and consisted basically of carrying on with the previous year's development while adding refinements. In June 2006, however, technical director Geoffrey Willis left the team, and for this among other reasons, the RA107 represented a very challenging attempt to discard the preceding base and build instead from a new concept on up.

Development of the RA107 was begun with "top priority to aerodynamics" as its slogan. The wheel-base, made longer than in the RA106 by shifting the front axle 30 mm forward, was 3165 mm. In order to minimize the chassis inertia, the gearbox interior was shortened and the final gear center was moved approximately 50 mm forward. As a result, the sweepback angle of the driveshaft also became larger than in the RA106.

Significant changes were also made in the layout of the interior where they are not visible from the outside. For example, the oil and water radiators located on either side of the driver inside the engine cover were reshaped to be longer and more slender, slanted forward, and contained inside the side pontoons. A layout was also attempted that led the exhaust pipes from the engine forward from the left and right banks of four cylinders, gathered them together, then turned them outside at a point close behind the driver. While the purpose was to reduce the moment of inertia of the chassis by any amount possible, the increased vibration and noise from

the exhaust were not welcomed by the drivers.

Another major change made this year was the return to the use of Bridgestone tires, because Michelin, whose tires had been used for the preceding three years, withdrew from Formula One racing. The differences in the deformation of the Michelin and Bridgestone front tires when running had a greater effect on the aerodynamics than had been anticipated, and the time it took to understand it caused delays in development.

The aerodynamics of the RA107 were the first to be developed making use of the full-scale wind tunnel that entered operation in 2006. At the start of the design process, the objective was development to reduce movement of the aerodynamic center as much as possible, from the point of braking just before cornering up to the zone of acceleration at the exit. When testing began with the actual car, however, the amount of movement was greater than anticipated, counter to the plan, so that the chassis behavior showed unstable characteristics from the point of braking throughout the entire corner. Furthermore, the response emphasized downforce at the sacrifice of aerodynamic resistance, with the result that the car's straight-line speed fell short of the top teams' by 10 km/h or more. A number of changes were made partway through the season in order to enhance the aerodynamic characteristics, prominent among them a change in the shape of the side pods, and the aerodynamic performance did gradually enhance. The other teams, however, also advanced with similar rapidity, and the RA107 did not achieve superiority in performance.

The result was that the team did not mount the victory stand even once throughout the entire season, they earned points three times, and were eighth in the constructor's standings. Even in the Driver's Titles, Button was 15th and Barrichello was 20th. These were the poorest results since the start of the third era.

11. The RA108: 2008



One of the major causes of the lukewarm results achieved by the RA107 was its aerodynamic performance. Therefore, the RA108 also adopted the slogan of "top priority to aerodynamics" and development was begun with the goal of pursuing enhancement of L/D (20% better than the previous year) as well as yaw and pitch sensitivity reduction.

One major change in the development was the

introduction of the concept of "usable downforce" as an index for aerodynamic development. In this procedure, wind-tunnel test results conducted under various conditions, including front and rear vehicle heights, are multiplied by weighting factors according to importance. These are then integrated to obtain a single scalar value by which analysis is carried out. Setting up the factors requires expertise, but the method expresses performance using a single numerical value, and it has the advantage that, when further refined, it can be used to keep the development orientation in clear focus. Target usable downforce values were set for each update from the opening race and the major Grand Prix competitions, and development was carried out so as to realize those targets.

The monocoque was made more slender and longer (by 45 mm) to the external appearance, and the side pod locations were also moved toward the rear, largely due to aerodynamic requirements. As a result, the rear axle was shifted rearward while the sweepback angle of the driveshaft was maintained unchanged, and the wheel-base was increased 45 mm over the previous year's to 3210 mm. The nose was also raised and the bottom of the side pods narrowed, resulting in a chassis shape that takes the flow over the chassis bottom into consideration.

However, development that placed top priority on aerodynamics also had negative effects in some areas. For example, the overall width of the gearbox was narrowed out of concern for the flow along the side to the rear wing at the rear of the car. In the rear suspension, this caused a diminishment in the mounting stiffness and deterioration of the damper ratio. Traction control was forbidden starting in this year, and it emerged as an issue of driveability that the engine's low-speed torque did not increase smoothly when the throttle was applied. The RA108 was troubled throughout the season with unstable cornering and inadequate traction. During the last half of the season, in particular, graining of the tires (in which just the tire surface peels off as rubber grains, and these are rounded into roller-like shapes that cause the tire to lose its grip) caused by low-temperature road surfaces also became an issue.

In order to enhance the damper ratio and the stiffness of the rear suspension, the damper was changed to a rotary type. This enhanced suspension was adopted starting with the 11th race – the Hungary Grand Prix – but it did not amount to a fundamental enhancement.

Another factor was that Ross Brawn, who joined as Team Principal in November 2007, adopted the policy of concentrating development resources on the 2009 car. Mid-season upgrades and enhancements to the RA108, therefore, tended to be omitted if they were not items that could be treated as advance tests for 2009.

As a result, the car scored points only five times, and the team came in eighth in the constructor's standings (McLaren was divested of its title due to a spying incident, so the actual ranking would have been ninth) with Rubens Barrichello the only third-place winner to mount the victory stand in the ninth competition, at Silverstone in the rain, when the pit strategy was

successful. The driver rankings had Rubens Barrichello at 14th and Jenson Button at 18th place, making this another year of low rankings to follow those of 2007.

12. Conclusion

The decade-long flow of Formula One chassis development in the third era can be generally summarized as follows. The years from 1998 to 1999 were the period of initial involvement with Formula One racing in recent years, with the fundamentals being learned from Dr. Postlethwaite and the Dallara engineers. The years from 2000 to 2001 were a time of working to get the cars at least up to a certain level by reducing the weight in every part in order to reduce the height of the center of gravity. The other main focus was assuring reliability. In 2002, an attempt was made to take a step forward from the fundamentals and address such issues as suspension stiffness and body stiffness. However, the vehicles that were the base for this effort had individual unit variations because of the manufacturing quality, the driving data evaluation methods and related matters did not evolve to match the effort, and the development stalled. The year 2003 brought advances in the manufacturing quality of CFRP and all other parts, as well as a new ability to engage in design while making limited predictions of how it would affect the maneuverability of the overall chassis package, including the engine. This became the year of transition from development of constituent technologies to development with a view to the balance of a single whole vehicle. The year 2004 represented a maturation and an evolution along normal lines from 2003, with new aerodynamic evaluation methods proving their worth. The car reached the top level. The second place in the constructor's ranking earned in this year, however, turned out to be a peak. In 2005 and thereafter, efforts were made to overcome the differences between phenomena in the actual machine and testing in a wind tunnel, and to determine techniques for obtaining the optimal performance from the tires, but these core technologies proved elusive, and the car slipped back in the rankings. It became apparent in 2007 that the regulations on aerodynamics would be changed significantly in 2009. This was taken as an opportunity to recover from a moribund situation, and work was begun on development of 2009 specification aerodynamics. The year 2008 turned out to be the final year of the third era. Although the car finished eighth in the rankings, the preparations for 2009 were steadily taking shape, and after Honda's withdrawal, that technology was inherited by the Brawn GP Formula One team and contributed to their finish in the two top places in the opening race.

Formula One development in recent years has been a puzzle about how to bring mutually antagonistic factors that govern car performance into balance with each other so that the level of the car as a whole can be raised. In order to achieve a high-level balance among complexly interrelated factors, it is necessary to evolve technology that can accurately grasp the degree of contribution made

by each individual factor, as well as the relative merits of different combinations of factors in terms of total performance. In the latter part of the third era, efforts were therefore concentrated on understanding of the gaps that exist between bench test results and simulations on the one hand and the actual machine on the other, as well as establishing methods of evaluation. Step-by-step tests and simulations had to be constantly repeated in order to obtain accurate tools and judgment criteria. Once these are in hand, a team will not lose sight of the direction of development, no matter how the regulations may change. Furthermore, any reduction in the necessity for tests using the actual machines enables a reduction in development costs, as well. As people increasingly call for the cost of Formula One development to be lowered, this style of development will no doubt continue to accelerate.

The movement to reduce development costs and to perform evaluation of cars as much as possible on the desktop and using bench tests is by no means limited to Formula One development. This is clearly a major trend in the development of mass-production vehicles, as well. It is a matter of firm belief, therefore, that the knowledge acquired during this 10-year period of development can definitely be used to advantage in the development of mass-production vehicles. All of that knowledge cannot be related in the pages of the Technical Review, but it will be fortunate indeed if some hints of it can be conveyed herein.

■ Author ■



Akio TONOMURA



Shun KAWABE



Nobuhisa NAKAYOKU