Development of the Most Powerful Racing Motocrosser KX450

With an uncompromising attitude toward winning races, we have been continuously engaged in development with the aim of creating the fastest motocrosser in the world.

KX450, which has undergone a full model change, provides improved engine performance with finger-follower rocker arms and improved chassis performance with modified chassis stiffness balance.

Introduction

Motocross is a motor sport in which riders compete in speed races on an unpaved loop course of dirt and sand (motocross race track). Motocrossers start at the same time standing side by side and rush into the first corner, which creates a very powerful scene. The course includes huge jump ramps and a series of bumps as well as straight and curved sections, and figuring out how to best run these sections is the key to victory.

Many motocrossers used to have a two-stroke (2st) engine but four-stroke (4st) engine models were released in early 2000. Since then, because of their easy-to-handle torque characteristics, not only experienced riders but also beginner riders have been replacing their 2st models with 4st models, leading to the expansion of the entire motocrosser market.

1 Background

In response to such market trends, Kawasaki changed the engine of the KX, which is Kawasaki's flagship model, from a 2st 250-cm^3 engine to a 4st 450-cm^3 engine in 2005 and has been working to improve the engine power. In addition, we are required to continuously produce competitive products, and so have been continuing technological development.

2 Development concept

We set "Most powerful racing motocrosser" as the development concept. To win the title in a race every year, it is important to improve the machine's fighting power and provide the equipment necessary to constantly earn points.

To improve the fighting power, we decided to improve the engine power, steering stability, and cornering performance, and to constantly earn points, we decided to reduce the operation burden of the clutch lever and improve startability.

3 Improving the engine power

After a manufacturer releases a motocrosser, they continuously work to improve its engine power, so engine power is still increasing each year. Improving the engine power does not merely mean improving the peak power but the engine is required to have torque characteristics that can easily be handled by the rider as well. In racing, all the motocrossers start at the same time standing side by side. In order to be the first motocrosser (holeshot) that reaches the first corner, the engine is required to have excellent acceleration at high engine speeds. In addition, the engine is required to have good response in the low speed range to make a jump immediately after a corner.

In this model change, we adopted the finger-follower rocker arm mechanism shown in **Fig. 1**, instead of the tappet-type direct-hitting valve mechanism, thereby achieving significantly improved engine performance.

The greatest advantage of the finger rocker arm mechanism is that the mass of the moving parts in the valve train can be reduced. This is because the rocker arm has an oscillating motion and has much lighter moving parts than the tappet, which has a reciprocating motion. With the reduced mass, the following performance

Fig. 1 Finger-follower rocker arm

improvements have been achieved:

① Increasing the intake and exhaust valve sizes

We increased the intake valve size from 36 mm to 40 mm in diameter, and the exhaust valve size from 31 mm to 33 mm in diameter, thereby achieving high power with enhanced intake efficiency at high engine speeds.

② Reducing the valve overlap

We adopted a cam profile that provides high maximum lift and acceleration to decrease both the intake and exhaust operating angles and decrease the overlap shown in **Fig. 2** from 76 degrees to 68 degrees, thereby improving the low speed range performance with improved scavenging efficiency in the low speed range.

③ Increasing the maximum engine speed

Thanks to the reduced mass, the maximum speed has been increased by 200 min^{-1} from 11,500 min^{-1} to 11,700 min^{-1}, and the engine speed after an upshift made after the maximum engine speed is reached has also increased further, enabling smooth acceleration. This is a great advantage both at the start of a race and during the race.

For the final engine performance, we port matched the intake and exhaust parts and achieved torque characteristics that have a wide power band with a flat torque curve as shown in **Fig. 3** and can easily be handled by the rider.

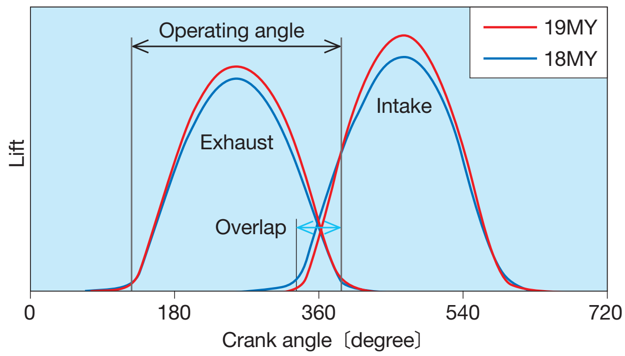

Fig. 2 Cam profile

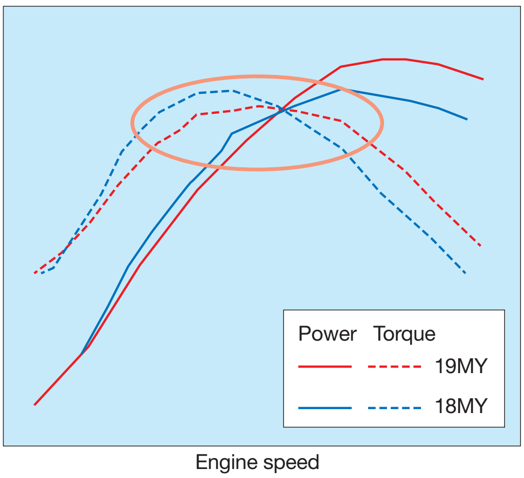

Fig. 3 Engine performance curve

4 Improving steering stability and cornering performance

On rough roads, like motocross race tracks (bumpy, unpaved roads), stable acceleration and deceleration and cornering cannot be achieved merely by increasing the frame stiffness. If it is too stiff, it causes the frame to be subject to direct shocks from bumpy roads and bounce, but if it is not stiff enough, it causes the frame to deform significantly, both of which may cause unstable frame behavior. For stable frame behavior, it is extremely important to allow the frame to bow moderately and absorb the shock with the suspension.

Therefore, we analyzed the strength and stiffness of the frame components, such as the main frame and swing arm and selected appropriate combinations of forged materials, cast materials, and extruded materials for these components, thereby achieving well-balanced stiffness.

(1) Main frame

To improve shock absorption and front and rear traction, we changed the stiffness balance of the main frame, which can be likened to the bone structure of the vehicle. **Figure 4** shows the results of the stiffness analysis.

We repeatedly conducted this stiffness analysis and changed the manufacturing method, shape, and material and clearly distinguished the areas where force is absorbed and where stiffness should be increased as shown in **Fig. 5**, thereby achieving improved shock

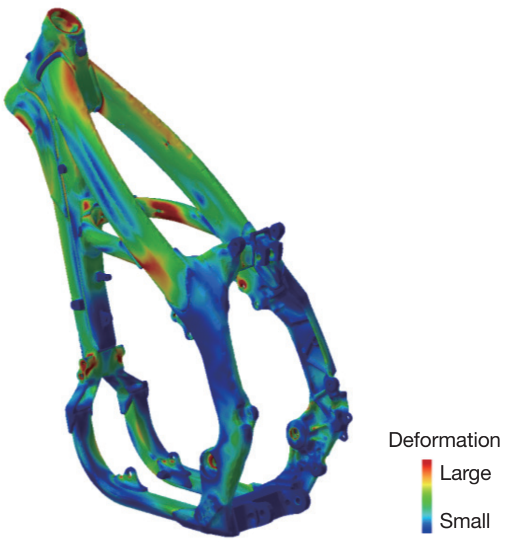

Fig. 4 Stiffness analysis results for main frame

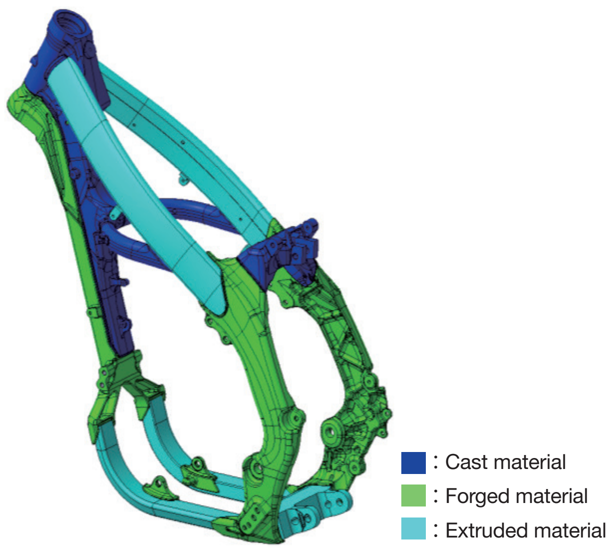

Fig. 5 Manufacturing methods for main frame components

absorbance and front and rear traction.

(2) Swing arm

To improve the rear traction, we changed the stiffness balance of the swing arm that connects the rear wheel and main frame. **Figure 6** shows an example of the stiffness analysis results.

We repeatedly conducted this stiffness analysis and changed the manufacturing method, shape, and material to increase the height of the widest section of the pipe as shown in **Fig. 7**, thereby increasing the longitudinal stiffness. At this time, the torsional stiffness increased, so we decreased the stiffness of the axle bracket, which supports the axle, thereby maintaining the cornering performance with a reduced increase in torsional stiffness. With these improvements, the rear traction has been improved both when the vehicle is traveling straight and turning.

In addition to the main frame and swing arm, we changed the stiffness of other components, such as the rear frame, engine mount, front fork, triple clamp, axle, and axle shaft to develop a frame that has both acceleration, deceleration, and cornering stability and light vehicle handling.

5 Reducing the operational burden of the clutch lever

In motocross, depending on the condition of the track, the clutch is operated frequently, not only when the engine is started and when the gears are changed but also for

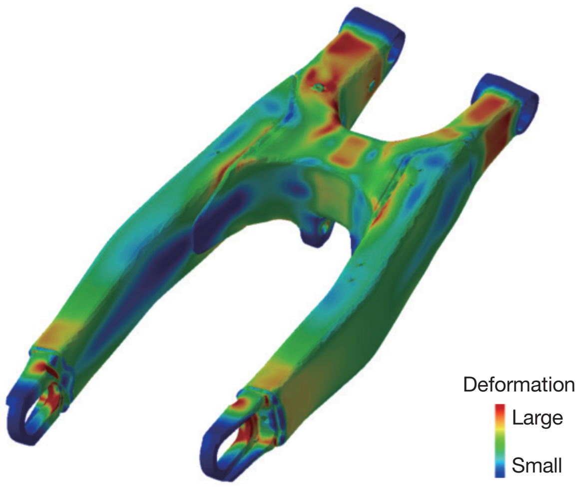

Fig. 6 Stiffness analysis results for swing arm

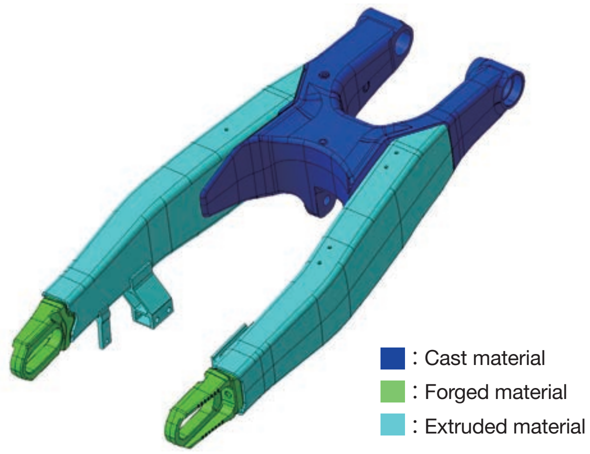

Fig. 7 Manufacturing methods for swing arm components

machine control while running. Especially in racing on sandy tracks and muddy tracks, the clutch is operated more frequently. Frequent clutch operation causes the clutch to get hot and expand in the axial direction, and as a result, the push rod pushing position changes, and the lever play changes accordingly. For a conventional cable clutch, which has been adopted because it is lightweight and can be serviced easily, a play adjustment mechanism is provided around the lever to address this problem. However, adjusting the lever play during a race adds to the burden of the rider.

A hydraulic clutch pushes the push rod via oil and automatically compensates for changes in the push rod pushing position because the amount of oil is automatically adjusted in response to lever operation. This eliminates the need to adjust the lever play while racing, which is the greatest advantage of the hydraulic clutch. However, because of the characteristics of a hydraulic clutch, it has a smaller engagement width than the cable clutch. This makes it difficult to control the clutch engagement at the start of a race, which means stable and quick start is impossible. Therefore, we adopted a judder spring in the clutch to ensure an adequate clutch engagement width.

The hydraulic clutch, which was adopted for the first time on the KX, has provided an adequate engagement width and eliminated the need to adjust the lever play, so it can easily be handled by the rider.

6 Improving startability

In motocross racing, even top-class riders with high-level skills cannot avoid falling. Riders often fall due to contact with another rider immediately after they start at the same time standing side by side. Even while solo, they may fall because the road conditions change every lap. What is most important when a rider falls is returning to the race in the shortest amount of time. Once a rider falls, he or she is required to pick up the machine and restart the engine to return to the race. In such a situation, an electric starter, which only requires pushing the button to start the engine, is much more advantageous than a kick starter, which is lightweight but requires more time to start the engine.

For this model, we adopted a lithium-ion battery for the first time in a Kawasaki motorcycles and improved the main power circuit, thereby achieving safety and excellent startability while minimizing the increase in mass.

(i) Lithium-ion battery

Lithium-ion batteries, which are compact and lightweight, are already in use in many electrical appliances, such as mobile phones. However, not many motorcycles have adopted lithium-ion batteries, but Kawasaki adopted a lithium-ion battery on this model for the first time among its motorcycles. Therefore, careful specification selection was required. We verified the startability and mechanical reliability in the same manner as for conventional motorcycle development, and in addition, tested the following three items specific to lithium-ion batteries:

① Overcharge test

In the event of overcharge, the protection circuit provided with the battery must detect the overvoltage and break the circuit to stop charging.

② Over-discharge/recharge test

The protection circuit provided with the battery must prevent over-discharge and ensure safe recharge.

③ External short circuit

The protection circuit provided with the battery must be partially broken to safely make the battery unusable.

(ii) Main power supply circuit

Unlike most motorcycles, the KX, which is a racing vehicle, does not have a main switch function. For this model, we developed a system to hold the main power supply circuit with the main relay when the user presses the starter button, instead of turning on the main switch. When the engine is stopped, the main power supply circuit is broken after a certain amount of time by the self-shutdown control of the ECU (Electric Control Unit), instead of turning off the main switch. In addition, this self-shutdown control can instantaneously reset the ECU in case of a fall, so even when the engine stops due to a fall, the rider can restart the engine while picking up the machine. With the main switch type, the ECU must be reset manually but with this relay type, the ECU is reset automatically, allowing the rider to return to the race more quickly.

Conclusion

Kawasaki has been continuously developing the KX with the aim of developing an unbeatable motorcycle on motocross race tracks[1)]. The KX has won many titles in the main classes, contributing to enhancing Kawasaki's brand image. With the KX, Kawasaki's rider became the second person to win four consecutive championships in the AMA Supercross and the KX boasts an overwhelming number of wins (the numbers of wins and podiums in Supercross between 2006 and 2018 are 84 and 148, respectively). We are confident that the number of wins will increase further with the technologies we adopted this time.

We will be actively developing new technologies without compromise and developing motorcycles that outdo competitors' on our mission to create motocrosser trends with the KX.

Reference

1) Takasu, Matsushita, et al.: “Overwhelming performance motocrosser KX250F,” Kawasaki Technical Review, No. 174, p. 39-44 (2014)

Ryosuke Atsumi
Design Department 1,
Research & Development Division,
Motorcycle & Engine Company

Mitsuru Matsushita
Design Department 1,
Research & Development Division,
Motorcycle & Engine Company