Accelerating global production through upgraded manufacturing capabilities

Kawasaki is taking active steps in emerging markets to implement a global strategy that covers from production to sales, while seeking to upgrade its manufacturing capabilities by handling production back home in Japan.

This paper discusses the development of a cylinder that contributed to the production of a lighter engine with higher output while improving production capacity. It also introduces readers to cases in which robots were employed to automate welding and finishing processes in order to achieve superior quality.

Preface

In emerging countries, demand for motorcycles is growing year after year, accompanying remarkable economic development. In response, the market is being supplied by high-quality products from existing motorcycle manufacturers and low-cost products from new manufacturers in countries such as India and China. In recent years, the existing manufacturers have had to work to keep improving their competitiveness against the new manufacturers, which keep improving their quality every year. In such conditions, Kawasaki is working in various ways to provide emerging countries with products that have high quality on the level of developed nations and yet are cost-competitive.

1 Strategic global models: Aluminum die cast sleeveless cylinders

(1) Background and aims of development

In developing the new Ninja 300 model, Kawasaki has gathered its powers of product development and manufacturing technology to supply a higher-performance model in a more timely manner to meet market needs. It is a strategic global model aiming to suit both emerging and developed markets.

Since the Ninja 300 has greater engine power than the previous model, the Ninja 250R, the temperature in the engine tends to rise, and the cylinders which hold the reciprocal motion of the pistons also heat up. Therefore, the efficiency of heat release to the coolant passage needs to be improved (Fig. 1).

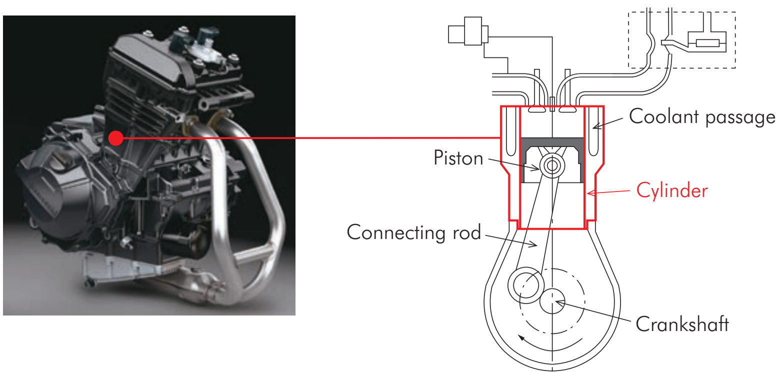


Fig. 1 Cylinder constituting an engine

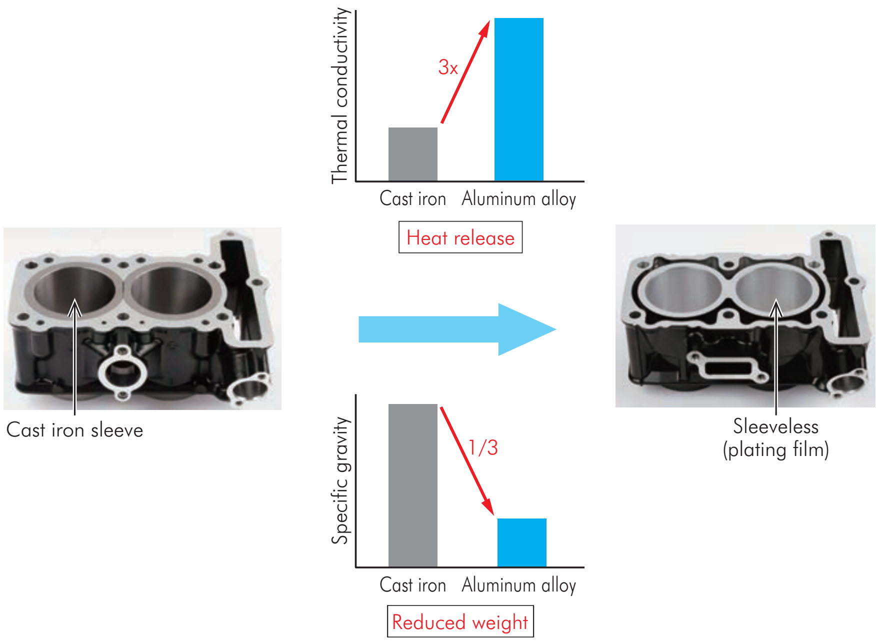


Fig. 2 Advantages of sleeveless cylinders

In the previous model, the Ninja 250R, the cylinders were structured with cast iron sleeves embedded in the aluminum alloy body for sliding performance. However, if cast iron sleeves were used likewise for the Ninja 300, there could be overheating or knocking from the rise in temperature due to the low thermal conductivity of cast iron sleeves. Also, since the specific gravity of cast iron is approximately three times that of aluminum alloy, it would increase weight.

To answer these challenges, with the Ninja 300 cylinders we improved productivity by changing the production method from gravity die casting to die casting, and we achieved excellent sliding performance, heat release, and reduced weight by applying a thin plating film to the aluminum alloy body instead of using cast iron sleeves (Fig. 2).

(2) Development of manufacturing technology

(i) Switch to aluminum die casting

To adapt production capacity to the increase in demand in emerging countries, we changed the production method of aluminum cylinders from gravity die casting, which we used to use, to die casting, which makes production five times faster. Since die casting fills dies at high speed, both high precision and high productivity can be achieved. However, high fill speed can cause casting defects due to such factors as gas entrapment and non-uniform solidification rate. This makes it challenging to apply to cylinders that require high performance (Table 1). We answered this challenge by using casting simulation to optimize the production method, including the runner and gating system and the die's internal cooling structure. Thus, we were able to achieve high quality (Fig. 3).

Table 1 Advantages and challenges of the die-casting method for gravity die casting

Advantages	• Short cycle time allows fast production • High dimensional precision, low surface roughness • Enables thin-wall molding
Challenges	• High fill speed can cause defects due to gas entrapment at the inner cylinder surface • Shrinkage cavities can form at thick walls and bolt bearing surfaces, which require strength • Mold easily damaged due to high fill speed

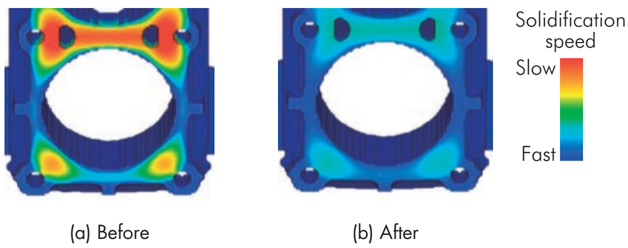


Fig. 3 Equalization of the solidification speed by the casting simulation

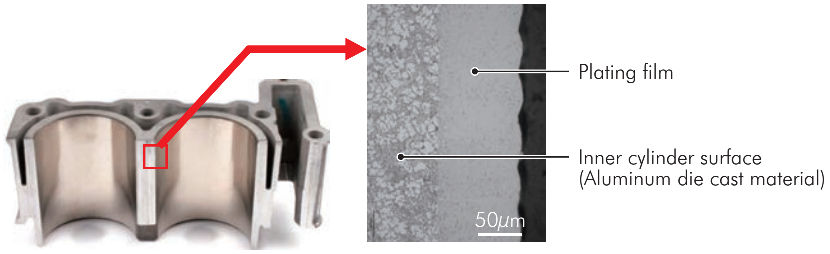


Fig. 4 Cross-section of a composite plated cylinder

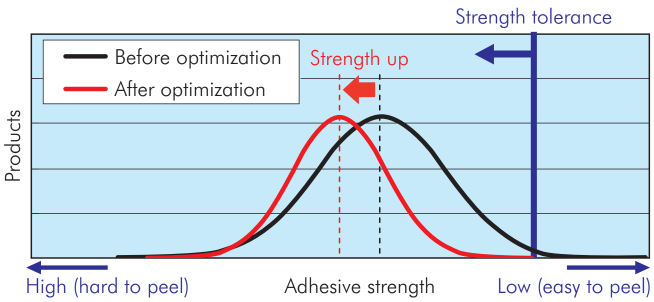


Fig. 5 Distribution of adhesive strength of plating film

Fig. 6 Ninja 300 featuring sleeveless cylinders

(ii) Replacing sleeves with composite plating
Instead of using cast iron sleeves as before, we applied composite plating to the aluminum cylinder.

This involves forming plating film with dispersed SiC (silicon carbide) particles (Fig. 4) and using this thin film to bring out sliding performance and to grant strong heat dissipation. Kawasaki has been building up the technology for this composite plating method for over 10 years for high-output engines. However, the aluminum alloy used in this case has high silicon content, giving it poor metallurgical bonding strength with the plating film. So we broadened the binding site by plating pretreatment to accelerate surface roughness of the aluminum alloy, optimized the heat treatment performed after plating, and thus formed an adequate interdiffusion layer and improved adhesion (Fig. 5).

(3) Application to new models

The new sleeveless cylinders have given the high performance, light weight, and high productivity the Ninja 300 needed to achieve function and quality with power greater than that of the previous model, the Ninja 250R (Fig. 6). At the same time, they have been adopted for the new Ninja 250 and Z250 models as well, contributing greatly to improving production capacity for the increased demand in emerging countries. We intend to continue to apply them to more models.

2 Aluminum frame welding and finishing process automation

(1) Significance of development

Automation in global production is significant not only for saving labor to reduce costs, but also for securing quality on the same level as domestic products.

Below, we introduce welding automation technology and finishing automation technology for aluminum frames for motorcycles.

(2) Aluminum frame welding automation

Aluminum frame welding requires extremely high quality in many aspects, ranging from weld strength and dimensional precision to aesthetics.

Previously, quality was secured by the high skill of individual welders. However, the motto of the last decade has been deskilling. Various automation technologies have been developed, frames have been restructured to be easy to weld automatically, etc. Some current models achieve over 90% automation of welding (Fig. 7).

(i) ServoTorch

The ServoTorch uses a servomotor inside a welding torch to accurately control feeding of aluminum welding wire, which is prone to buckling. The ServoTorch has not only reduced feed problems, but also made it possible to achieve stable weld quality between different types of

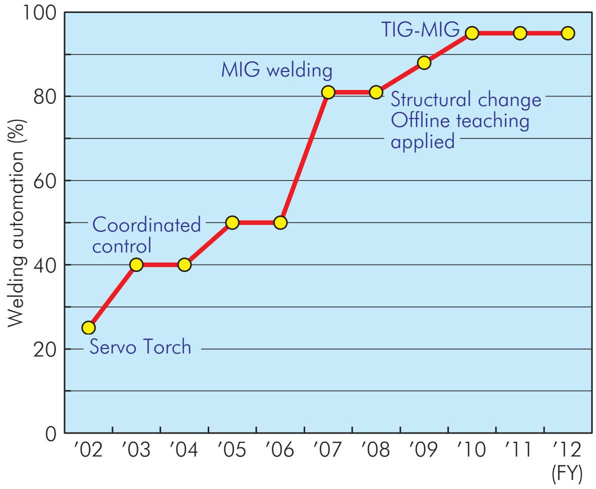


Fig. 7 Transition in rate of welding automation

materials, such as between sheet metal parts and cast metal parts with different melt forms.

(ii) Positioner-coordinated welding

To stabilize weld quality, flat-position welding is essential. Therefore, we have introduced coordinated welding technology allowing a welding torch and work positioner to work in harmony. This keeps the weld zone consistently in the flat position, even in continuous welding across the corners of a box structure, and has succeeded in stabilizing weld quality.

(iii) Offline teaching

We have sped up and deskilled work to teach welding robots with our own offline teaching software, KCONG. The challenge was applying offline teaching data to the actual robots, since discrepancies could arise between the offline teaching and the actual robot due to individual differences in robots. We minimized such discrepancies by correcting absolute position accuracy for the robots.

(iv) TIG-MIG welding

TIG-MIG welding is the automation of the process to address inadequate penetration of parts at which MIG welding is started.

In frame welding, the perimeter of a cylindrical frame material is divided into front and back semicircles which are welded one at a time. When this is done by MIG welding*, often, the penetration of the part where welding is started is not deep enough, because the welding heat input at the start of welding disperses due to aluminum's high thermal conductivity. This phenomenon especially tends to arise where parts where welding is started are put on each other. Such parts cannot achieve the penetration required. Therefore, workers have been welding them together with TIG welding**.

Now we have developed the TIG-MIG welding method, in which parts at which welding is started are preheated with TIG welding, and then MIG welding is started.

The robot cell comprises two robots, a TIG preheat robot and an MIG final weld robot, and a work positioner (Fig. 8). Right after preheating by the TIG preheat robot, the MIG final weld robot, which has been waiting nearby, starts welding. In final welding, the frame is positioned for optimal welding position, for coordinated welding with the robot.

Thus, we have achieved automation even of the joint at the part where MIG welding is started. At the same time,

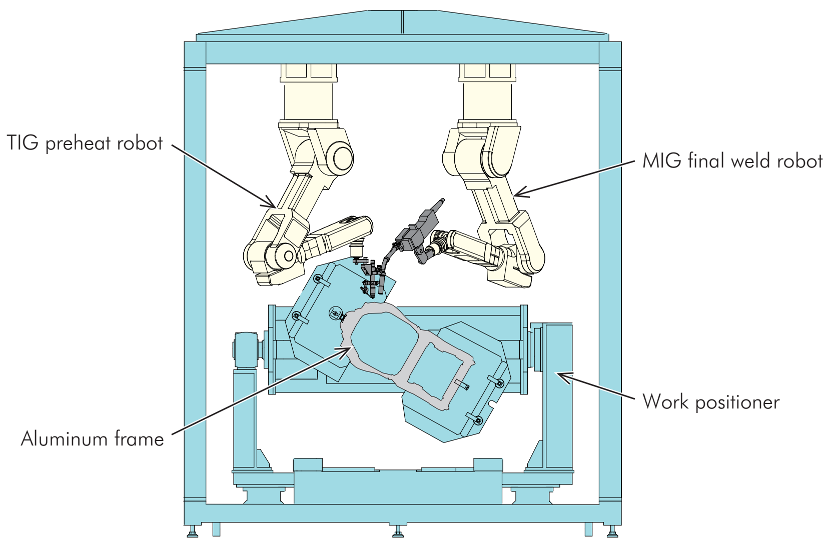
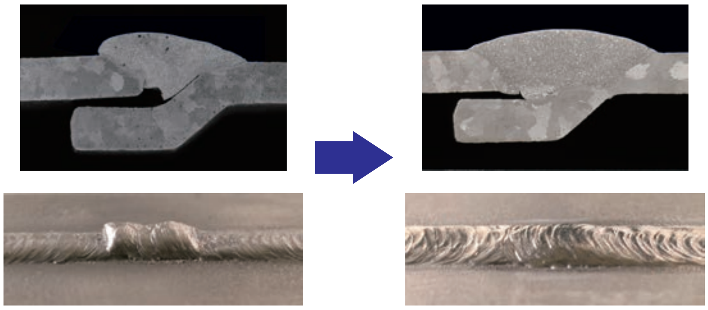


Fig. 8 TIG-MIG welding robot cell



(a) Defective MIG welding (b) TIG-MIG welding

Fig. 9 Improving penetration quality and controlling reinforcement height by TIG-MIG welding

we have secured the required weld penetration quality reliably, and we have managed to reduce the concentration of stress. In addition, we have obtained good weld bead appearance from an aesthetic perspective (Fig. 9).

*MIG (Metal Inert Gas) welding:
Inert gas arc welding using a consumable electrode. Weld beads are formed by melting welding wire as an electrode while melting the base material. An efficient welding method.

**TIG (Tungsten Inert Gas) welding:
Inert gas arc welding using a non-consumable electrode. Allows control of heat input to the base material without forming a weld bead, since the electrode does not melt.

(3) Aluminum frame finishing automation

To visually inspect for welding defects common on the weld bead toe, including fracture and incomplete fusion, it is necessary to remove the smut (black soot) remaining on the weld zone of the aluminum frame in process.

Previously, this was done by an experienced welder placed at the end of the welding line. However, the work of removing smut with a toothbrush-like brush and checking weld quality was a heavy load. On top of this, the work environment was degraded by the dust arising from the finishing work, and, as pneumatic vibrating tools were used in addition to brush finishing in the process, it was truly a 3D job (dirty, dangerous, and demanding work).

By robotizing the finishing process, including such brush finishing work, we succeeded in not only reducing the worker load in the final process of the welding line, but also reducing the amount of dust around the welding line in general.

We realized the aluminum frame brush finishing robot system (Fig. 10) by adding function to arc welding robots, and we have equipped a pneumatic brush at the end of the arm to achieve ideal bead periphery finish (Fig. 11) and improve the appearance of the bead. Since the ideal contact force between the brush and the workpiece is

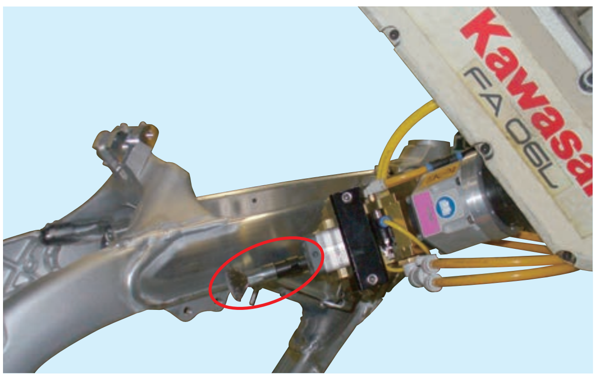
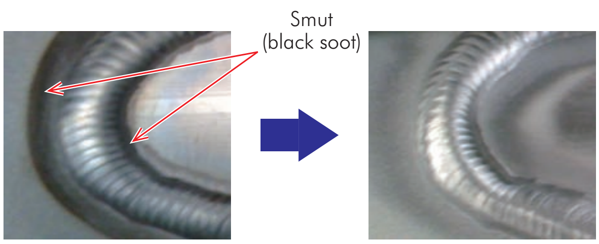


Fig. 10 Robotic system for brush finishing



(a) Before removing smut (b) After removing smut

Fig. 11 Weld bead finishing by robot

quite small relative to the mass of the pneumatic brush, we developed a suspension mechanism that resists influence from robot operation or position. Also, since the brush wears with processing time, and the wires get shorter, there was a need to modify the teaching path of the robot. Our system not only assures stable contact force using its suspension mechanism, but also applies a slight electric current between the workpiece and the brush to detect whether the current flows, to determine whether the brush and the workpiece are in contact, so that it can correct the robot arm path in real time.

In addition to this robot system for wire-brush finishing, Kawasaki has also developed and put onto the production line, for instance, a robot system that can finish aluminum frames to be shipped unpainted and give them hairlines as an appearance design feature.

It is easy for finishing processes for appearance design and quality verification to vary in work quality depending on the skill level of the workers. Automating this work allows us to stabilize its quality and to realize a production line capable of accommodating global production and drastic shifts in production volume.

Concluding remarks

This paper has introduced methods incorporating know-how in production and manufacturing technology that can be applied relatively easily even in emerging countries, but manufacturing sites in Japan have many processes that require more advanced manufacturing technology compared to overseas production bases.

We intend to respond to movement towards high-mix, variable-quantity production and to achieve better quality, timely production, and maximum cost reduction. Meanwhile, we shall push even further our multifaceted approach to improving production and manufacturing technology, including the creation of safe and comfortable workplaces and consideration for the environment.

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