

Development of Hollow Crankshaft

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ABSTRACT

A hollow crankshaft of light weight and high quality was realized through the use of friction welding. The oil passage in the journal was made a hollow structure, and this had the effect of increasing average oil pressure by 500 kPa (reducing the pressure drop), reducing the pulsation amplitude by 400 kPa, and raising the minimum oil pressure by 600 kPa. The connecting rod bearing clearance was also adjusted and confirmed to yield 1 kW of performance enhancement and over 1200 km of durability as well as curbing bearing friction. Although this new crankshaft was never used in a race, this developed technology has provided the prospect of the first hollow crankshaft of 10 kg or less for practical use in the Honda Formula One.

1. Introduction

The durable reliability of the crankshaft is essential in the high speed and high power development of Formula One engines. Accordingly, this part is also considered to require lower friction and lighter weight in the pin and journal rotating portions as well as higher stiffness with respect to torsion resonance. The development of a lightweight, high stiffness hollow crankshaft has been underway since the end of 2003 as a horizontal deployment of the hollow structure of the connecting rod in other parts. Meanwhile, the International Automobile Federation (FIA) included a provision in its regulations that no welding would be permitted between the front and rear main bearing journals from 2006. This would make it impossible to use a welded hollow crankshaft in cars entered in FIA races. Honda therefore established the structure manufacturing technology for a hollow crankshaft in 2005, and set out to install it in a racing vehicle for use that year.

The creation of a hollow crankshaft required joining technology capable of providing stable strength and precision in the junctions that are of greatest importance. It also required manufacturing technology capable of assuring quality by enhancing the accuracy of machining on junctions as well as by removing burrs and the like.

2. Establishment of Hollow Structure Joining Technology and Quality Assurance

In order to create this hollow structure, the joining locations and strength feasibility were verified and

joining methods were selected. The manufacture of a high-quality, high-precision V10 hollow crankshaft involved enhancing the accuracy of friction welding (hereafter FW) on five journals and implementing quality assurance regarding residual burrs at joins, and deformation from machining and nitriding. Figure 1 shows the hollow structure and an external view of it.

2.1. Hollow Structure Specifications

The location and optimum shape of joins in the hollow were subjected to CAE verification, from which the joins at the center of the journal, as shown in Fig. 2, were selected.

The hollow pin with a diameter of 34 mm (journal wall thickness: 6 mm) opened the way to satisfying the strength requirements.

The bending stress, caused by explosion force, is

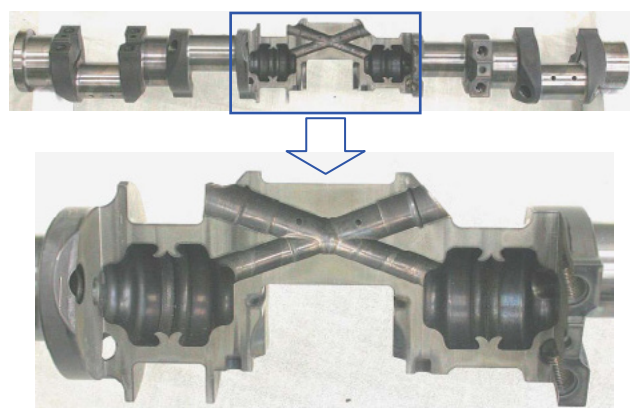


Fig. 1 Section of hollow crankshaft

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mitigated by the hollow structure, so that the stress was lower than in a solid. Furthermore, the inertial force was little influenced by the hollow structure, and the hollow pin with 34 mm diameter had lower stress than the solid pin with 33 mm diameter.

2.2. Joining Technology and Strength Verification

The three manufacturing techniques of electron beam welding (EBW), diffusion bonding, and FW were subjected to comparative evaluation by rig testing of fatigue strength. FW, which yielded joint strength equal to the strength of the base material, was decided on for the specifications.

2.3. FW of Five Journals

The basic conditions were set at a speed of 1900 rpm, pre-force of 10 tons, a pre-heat time of 9.5 sec, an upset force of 30 tons, and upset length of 9 mm. The surface roughness of the join surfaces was enhanced and acetone degreasing was done during the cleaning prior to joining (Fig. 3).

Key points in determining the FW conditions included shaping the flash form to rise up as much as possible and ensuring that the media is kept from being worked in.

The chucks for gripping the workpieces for the series of five joints were bore-machined together to align their center lines, enhancing the accuracy of butting by the rotating side as well as the clamping stiffness on the fixed side. The equipment peculiarity was addressed using adjusting shims to correct for eccentricity of axis. With the join conditions established, the series of five FW joints (joints made while undergoing 180 degree phase reversal) was made, achieving an offset of 0.35 mm at the largest with respect to the target offset of 0.5 mm (Fig. 4).

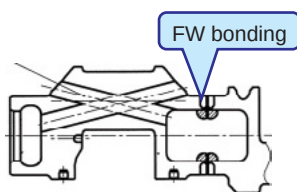


Fig. 2 Journal joint

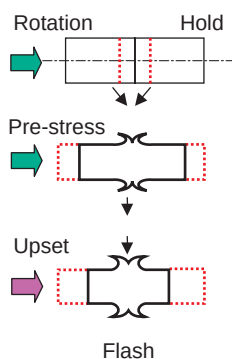


Fig. 3 FW bonding

2.4. Quality Assurance of Hollow Portion

The hollow portions joined by FW also serve as oil passages, making it necessary to conduct thoroughgoing quality assurance regarding the removal of burrs. First of all, the FW conditions were set so as to stabilize the flashes and control their shape. As shown in Fig. 5, scale, machining burrs, and spatter are removed after nitriding by barrel finishing with vibration using steel spheres and cleaning by cavitation. All were then checked by microscope and guaranteed. Figure 6 shows the nitriding quality of the hollow interior. Although the central portion of the flashes were not nitrided, the joints and the hollow portion were confirmed to be uniformly nitrided. Rig testing of the 2.5 cylinder joined items confirmed strength equal to the base material.

2.5. Heat Treatment and Manufacturing Completion Accuracy Assurance

Deformation from heat treatment was addressed by using crankshaft pin milling items as dedicated jigs and setting conditions by corrective hardening. When the offset exceeded 1.0 mm, the bend was trued up. For working accuracy, a base adjustment eccentricity center was used and uneven thicknesses in the finish of the hollow portion were minimized. The target for wall thickness of 6 ± 0.75 mm in the journal hollow portion was achieved with 6 ± 0.3 mm and a maximum uneven thickness of 0.55 mm.

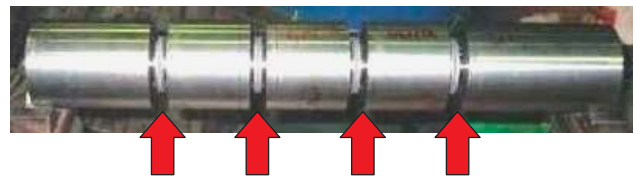


Fig. 4 Friction bonding



Fig. 5 After cleaning

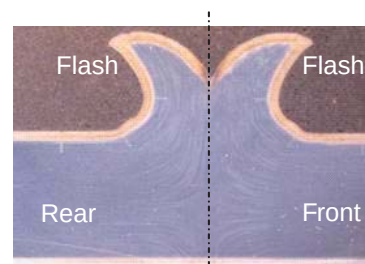


Fig. 6 Nitride of FW section

3. Results

A weight reduction of 0.8 kg was achieved, going from 6.55 kg (10.3 kg with counterweight) for the solid crankshaft to 5.75 kg (9.5 kg with counterweight) for the hollow, and making this the first Honda Formula One crankshaft to realize a weight of 10 kg or less. The effects of enhanced lubrication with the hollow crankshaft include recovery of 500 kPa in the instantaneous minimum oil pressure, which had shown negative pressure because of oil pressure pulsation, and prospects for durability.

4. Conclusions

The technology was established for manufacturing a hollow crankshaft that would satisfy the properties required for use in a high-speed, high-power Formula One racing engine.

The crankshaft was made hollow using a highly reliable FW technique, and production engineering capable of guaranteeing crankshaft accuracy as well as the cleanliness to use the hollow portion for oil passages was established.

It has been verified that the developed technology reduced weight 8% relative to the conventional crankshaft and had the effect of oil pressure pulsation reduction that could not be obtained with the conventional structure, yielding the prospect of durability for practical use. Regulations prohibiting welded crankshaft structures went into effect in 2006, and this hollow crankshaft was never used in actual competition.

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