Development of a Cooling Process to Allow Production of an Aluminium Cylinder Head without Heat Treatment

1. Introduction

Aluminum alloy cylinder heads are commonly heat-treated to a T5, T6 or T7 temper. These processes are energy-intensive and expensive.

Nissan’s UK casting plant was tasked with developing a Low Pressure Die Cast cylinder head without any heat treatment process, but with sufficient strength and durability, and with an acceptable level of residual stress. This was to be achieved by developing an ‘air-quenching’ system to rapidly cool the parts immediately after casting.

The system was to be integrated into existing LPDC machines in order to minimise investment, and maximise the cooling impact and use of space.

2. Development process

The focus of the development process was on finding a way to deliver the cooling air that consistently achieved the required mechanical properties and minimised manufacturing cost.

Validation of different cooling systems and conditions was performed on parts cast in AS7U3G0.35 alloy, using prototype and series tool steel dies.

The main validation method was tensile testing of test pieces cut from several Head Bolt pillars of the cylinder head. Other checks performed included hardness, residual stress, thermography measurements and testing of permanent growth.

3. Results and discussion

Different initial prototype systems were tested, delivering air from a different combinations of a fan and directed compressed air. All provided some level of success.

A system using only a fan and no compressed air was judged to be both low-cost and easiest to assure in production. However, it did not achieve the specified mechanical properties in all areas of the cylinder head.

Analysis showed two causes for this lack of strength: some areas of low strength lacked exposure to the air flow, and some had casting defects such as porosity or a high level of eutectic material.

A permanent facility was installed, and a number of trials were made to set key parameters such as volumetric flow rate, exposure, duration and start time. In parallel the metallurgical quality of the alloy and the casting conditions were improved to minimise the presence of porosity, oxide films and eutectic material.

This combination of good part quality and optimised cooling condition, shown in Fig. 1, produced a process that consistently achieved all mechanical properties targets whilst generating little residual stress.

UTS and yield strength are lower than that obtained through the T7 process, but within specification. Elongation at break is at a comparable level, but with greater plastic deformation. Test results are shown in Fig. 2.

Engine durability tests confirmed the suitability of the part and process for use in production vehicles.

The cylinder head is now in production, with a first-year volume of approximately 4,000 cylinder heads per week expected to grow to more than 9,000 per week in the next year.

4. Conclusions

Cylinder heads for modern engines can be made without heat treatment, provided that a suitable cooling process is employed directly after casting.

This process is already in high volume production use at Nissan’s UK casting plant.