Residual Stress Mapping in Solution Heat Treated Al Engine Blocks

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Materials Science

Lightweighting has become an important aspect in the design and production of automobiles due to strict government legislation on fuel economy. This has led to the implementation of light weight Al alloys for automotive applications such as engine blocks. However, Al alloy engine blocks are prone to the development of high tensile residual stress during production due to the interaction between Al and the gray cast iron cylinder liners. Heat treatment is an effective method of relieving tensile residual stress. As such, the development of an optimized heat treatment schedule is important to prevent potential problems such as in-service cylinder distortion. However, to effectively optimize the engine block heat treatment schedule, the current solutionizing parameters must be analyzed to establish a baseline for residual stress relief.

In this study, 319 Al alloy V6 engine blocks were analyzed. The engine blocks were initially cast using the Nemak-Cosworth process in conjunction with precision sand mould. Following casting, the engine blocks were subjected to a thermal sand reclamation treatment at 495 ºC for 1 hour and a solution heat treatment at 470 ºC for 8 hours, followed by forced air quenching. Residual stresses were measured from top to bottom along the Al cylinder bridge and the adjacent gray cast iron liner using neutron diffraction. The residual stresses were measured in the hoop, radial and axial orientations by utilizing the peak-shift method and generalized Hooke’s law.

The results for the Al cylinder bridge, shown in Figure 1 (a), indicate that the hoop and axial stress components were mainly tensile while the radial stress component was compressive. The hoop component had a residual stress magnitude of approximately 110 MPa at the top of the cylinder (depth of 10 mm), which increased to approximately 130 MPa at a cylinder depth of 60 mm and then gradually decreased to approximately zero at the bottom of the cylinder (depth of 120 mm). Similarly, the axial component had a stress magnitude of approximately 40 MPa at the top of the cylinder, which increased to 100 MPa at a depth of 60 mm and then decreased to approximately 10 MPa at the bottom of the cylinder. Finally, the compressive radial stress magnitude ranged from approximately zero at the top of the cylinder to 110 MPa at the bottom.

Similarly, for the gray cast iron cylinder liners (Figure 1 (b)), the residual stresses were tensile for all cylindrical orientations. The hoop stress magnitude varied between 50 and 100 MPa along the depth of the cylinder, while the radial stress was relatively constant with a magnitude of 100 MPa. In contrast, the axial stress profile had high stress magnitude at the top of the cylinder (~240 MPa), which decreased to and remained at 130 MPa between depths of 30-100 mm and then increased to approximately 190 MPa at the bottom of the cylinder.

When compared to the as-cast condition (examined in a previous study), the results indicate that solution heat treatment using the current production parameters partially relieved tensile residual stress in the Al cylinder bridge, with stress relief being more effective near the bottom of the cylinder. In addition, solution heat treatment did not relieve residual stress in the gray cast iron cylinder liners.

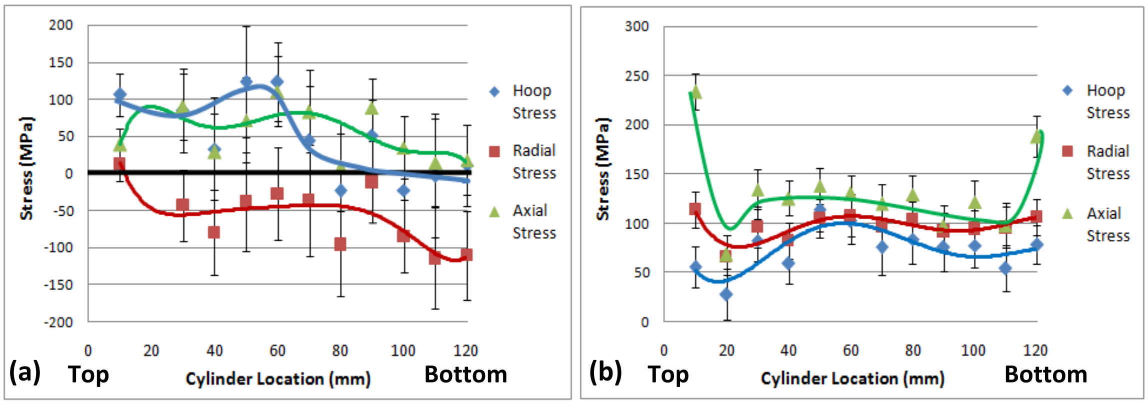

Figure 1: Residual Stress profiles along the: (a) Al cylinder bridge, (b) gray cast iron cylinder liner of T4 treated engine block.