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Enhanced cooling performance of a ventilated brake disc

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ABSTRACT

This study provides new insights into the internal thermal/fluidic behaviour of rotating ventilated brake discs. For the first time, the local internal temperature and convective heat transfer distributions within ventilated brake disc channels have been experimentally measured. The measurements are made within the rotating frame of reference using the thermochromic liquid crystal (TLC's) heat transfer technique. The thermal/fluidic characteristics of different brake disc configurations (i.e., pin-fin, radial vane, curved-vane and novel wire-woven bulk diamond (WBD) cored brake discs) were characterized. For the radial vane configuration, the effect of the number of vanes on the internal thermal behaviour was investigated, providing insight into the radial, circumferential (vane-to-vane) and axial (inboard-to-outboard) convective heat transfer variations. In general, for a typical number of vanes used on automobiles (36-vanes), the overall thermal distributions are highly non-uniform, although uniformity improves as the number of vanes are increased. Significant thermal variation occurs between the inboard and outboard internal surfaces for all the brake disc configurations tested (18, 36 and 72-vanes), which possibly exacerbates thermal distortion (i.e., coning) of the brake disc when severe frictional heating occurs. For the maximum number of vanes, the end-wall thermal maps revealed distinct heat transfer behaviour attributed to the effects of enhanced secondary flow mixing that occurs above a critical rotational speed. The investigation of the pin-finned internal thermal/fluidics shows that the bulk flow within the ventilated channel of a rotating disc follows a predominantly backwards sweeping path between the pin-fin elements. The transient heat transfer measurements revealed that the internal local heat transfer distribution is highly non-uniform. A comparison of the heat transfer performance of the pin-finned and the radial vane brake discs showed that the pin-fin rotor has a substantially reduced pumping capacity relative to the radial vane rotors, yet still achieved increased overall convective heat transfer over the 18 and 36-radial vane rotor. Further detailed laboratory investigations and track testing of the novel WBD specimen showed that the highly porous core achieves a cooling advantage by greater utilization of the available end-wall and internal core surfaces for superior convective heat transfer in comparison with the pin-finned disc.