Abstract

In variable nozzle geometry turbines (VNT), opening of the nozzles is used to control turbine mass flow and expansion ratio, allowing more turbine power to be generated over wider operating conditions. In turbocharged vehicles, the nozzles are 'closed' to provide high boosts for engine and vehicle acceleration and for engine braking assistance. At the both conditions, high nozzle expansion ratios are created, and shockwaves may generate from the nozzles. These shocks reduces turbine efficiency and they can cause high cycle fatigue (HCF) damage to the downstream rotor blades. Design of high expansion ratio radial nozzles is difficult for VNT because transonic flows are very sensitive to small geometry changes, and the large semi-vaneless space created by the nozzles makes the design a tricky business. Shock minimised nozzle designs are therefore often achieved by auto-optimisation technique. While design targets may be achieved, this technique does not offer sufficient insights into how the optimal flow field has been derived, so the same optimisation procedure has to apply to every new designs. In this paper, a new design method that overcomes this problem is proposed. The method first uses a conformal mapping to transfer a radial nozzle from the r-θ plane into the x-y plane. Mapped nozzle displays amplification of supersonic acceleration and diffusion. This is explained by the curvature changes brought about by the mapping, and a link between the shock strength and the flatness of the suction surface of the mapped nozzle is found. The amplification and the link can be utilised to design nozzles with reduced shock loss in the x-y plane first and then mapped back to the r-θ plane. Two nozzles for 6:1 expansion ratio were designed in this way and CFD results show a significant reduction of nozzle loss. The nozzles were also checked for fully open condition and no performance penalty was found.