Micro-Joining of Shaped Stainless Steel Sheets for Fuel Injection Orifice with High Misting Capability

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Abstract. A fuel injection orifice for most of passenger cars was made of the formed stainless steel sheet with small holes to mist the liquid fuel into fine droplets. Since the mist-capability increases with decreasing the diameter of holes, these orifice holes had to be as small as possible. The precise micro-piercing with use of the WC (Co) slender punches has been successfully employed to form the orifice circular holes with the diameter of 80 μm. There were huge engineering issues to decrease this hole diameter down to 55 to 60 μm when using the conventional piercing process in the above. One of most effective solutions to save these difficulties might be micro-joining of two stainless sheets with pierced small holes in different geometry and dimension. For an example, the first and second sheets were pierced to have a circular hole with the diameter of 80 μm and to have a regularly triangular hole with its inscribed circle diameter of 50 μm, respectively. The effective hole diameter enough to generate fine mists could reach down to 60 to 55 μm. In order to put this solution into practice, the micro-joining process must satisfy the following two conditions; 1) The heating temperature might well be lowered as possible to be free from thermal distortion during diffusion bonding process, and, 2) The residual pores must be decreased on the joined interface to increase the structural integrity of fuel injection orifice. In the present study, the low temperature diffusion bonding system was employed for this micro-joining of two dissimilar stainless steel sheets. This system consisted of the argon and hydrogen plasma activation unit to reduce the oxide passive films on the stainless steel sheets as well as the high frequency induction heating unit to make fast-rate and uniform temperature distribution.

In the experiments, the stainless steel sheets were laser drilled to have circular hole with the diameter of 80 μm and regularly triangular hole with the inscribed circle diameter of 50 μm by using the femto-second machining. After ultrasonic cleaning, these stainless steel sheets were micro-joined by the present system at 1073 K (or 800 °C) lower than the diffusion bonding temperature needed for bare stainless steels by 100 K for 900 s. Both the high resolution optical microscopy and scanning electron microscopy revealed that the residual porosity became less than 10 % on the interface between two stainless steel sheets. Owing to this high joinability, the peeling strength exceeded 100 N. Standing on this success in micro-joining of two dissimilar stainless steel sheets into orifice, the fuel injection experiment was performed to investigate the effect of controlled orifice hole diameter on the misting behavior.