Effects of Horn Connected with Gas Tunnel Type Plasma Spraying Torch†

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The alumina coating deposit by means of a gas tunnel type plasma spraying apparatus is very hard and less porous.[1)] In this work, for the purpose of improving the quality of coatings, the special horn is connected with the gas tunnel type plasma spraying torch. This horn aids the elimination of unmelted powder and prevents the decrease of the plasma jet temperature. In this experiment the composition of the powder is 99.5% Al_2O_3 and its particle size is $10-40\mu m$. The substrate is SUS 304 blasted plate. The working gas of this torch is argon and its flow rate Q is adjusted to 150 l/min.

Figure 1 shows this type of spraying apparatus with a horn. The horn is attached to the exit of the gas tunnel type torch. The distance l_h between this horn and the plasma torch can be changed easily. In operation argon gas is blown on the surface of substrate for cooling and the substrate moves. **Figure 2** schematically shows the cross section of a horn. The horn made of brass is water cooled. The upper part of the horn is easily damaged by the plasma jet, so its part is made of ceramics (boron nitride). Some types of a horn were prepared and examined, by the arrangement of the upper diameter "d_a" and the under diameter "d_b". The length of a horn is 50 mm. Each type of a horn simply shows as "d_a-d_b" after this.

For the horn of d_a = 10 mm it was so severe to adjust its axis to the center of the torch that good result wasn't obtained: The deviation of the axis resulted that the plasma jet touched the horn at the upper edge of the nozzle, so the born nitride was apt to be damaged. The "12-20" horn which has larger upper diameter had another problem on spraying. As the under diameter d_b was too small in this case, the melted spraying powder adhered inside the horn.

On the other hand, the "12-25" horn which has larger under diameter d_a had a good result. For this reason, the effect of the "12-25" horn connected with a gas tunnel type plasma torch are reported as follows.

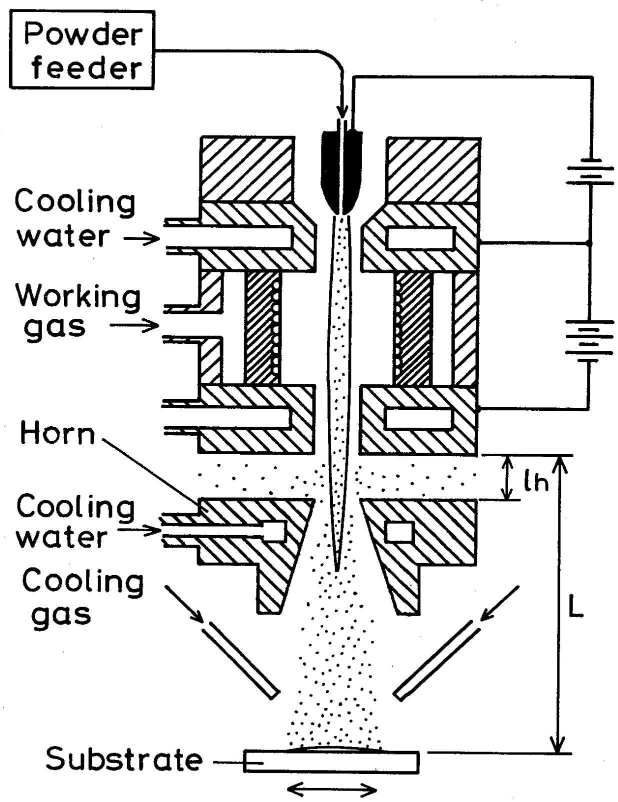

Fig. 1 Experimental apparatus of gas tunnel type plasma spraying torch with horn.

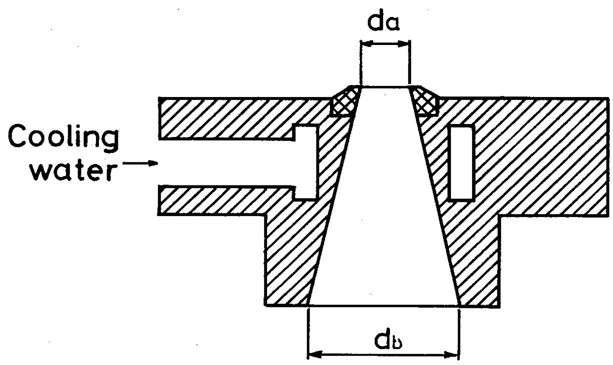

Fig. 2 Schematic illustration of horn.

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The distance of a gap l_h between the plasma torch and the horn plays an important role for the separation of unmelted powder from the melted powder. The unmelted powder apart from a plasma jet flows in the radial direction through the gap by the centrifugal force of the strong vortex. The powder inside the plasma jet is enough melted, passes through the horn and deposits on the substrate. As the result, the good properties of a coating are obtained. The coating by means of the gas tunnel type plasma spraying torch with a horn is observed by a microscope and examined on the Vickers hardness H_v. The hardness is measured at the cross section of coatings. The load is applied at 300 g. The hardness Hv is shown by the average value and the deviation of more than 10 values.

Alumina powder was sprayed by changing the distance l_h, and the hardness of alumina coatings was measured. The result is shown in **Fig. 3**, when the electrical power of the plasma torch P is 21 kW and the spraying distance L is 100 mm. When the distance l_h is 0 mm (the horn is touched to the torch), the hardness with a horn is only as the same value as without a horn. In this case, any effects didn't appear on the separation of the unmelted powder. However, the distance l_h being increased, the hardness becomes higher. The increase of l_h affects to enhance the separation ratio of unmelted powder. On the contrary, when the distance l_h is enlarged more than 20 mm, it is difficult to put an axis of the horn on that of the torch, and the satisfied coatings couldn't be obtained.

Figure 4 shows the effect of hardness on the spraying distance L with the "12-25" horn, when the gap is l_h = 10 mm and the electrical power is P = 21 kW. As the spraying distance L is shorter, the hardness becomes higher. The Vickers hardness of the alumina coating reaches to 1200, when the spraying distance L is shorter, 80 mm. This coating obtained is very hard, compared with that by a conventional type plasma torch (usually the normal hardness in the average value is 700 – 900).

Figure 5 shows the photographs of a cross section of alumina coating by the gas tunnel type plasma spraying torch with a horn and without a horn, when the spraying distance is L = 100 mm and the gap is l_h = 10 mm. The photographs (a) and (a′) show the coating without a horn, and (b) and (b′) with a horn. Each below photograph shows the microstructure of the coating in a higher magnification. The hardness is 850 without a horn and 980 with a horn. The pore of with a horn is observed to be less than that of without a horn. The horn connected with the gas tunnel type plasma spraying torch makes it possible to produce high quality of coatings in a hardness and a porosity. This is induced by the fact that the horn is effective for the separation of melted and unmelted powder and for the maintaining the plasma temperature.

The coating by means of the gas tunnel type plasma spraying torch becomes very harder even at a lower power of 20 kW than by a conventional plasma torch (30–50 kW). Moreover the horn connected with this new type plasma spraying torch enhances the coating quality such as a hardness and a porosity. For example, the alumina

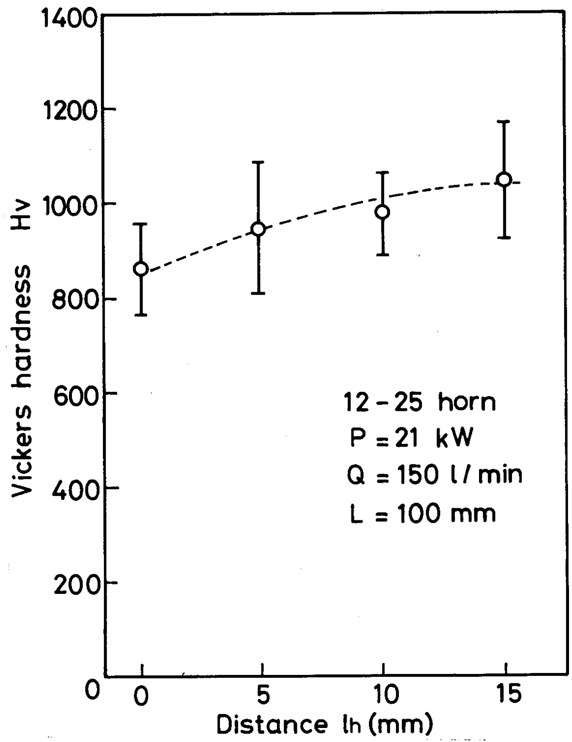

Fig. 3 Effects of distance between torch and horn on Vickers hardness of alumina coating.

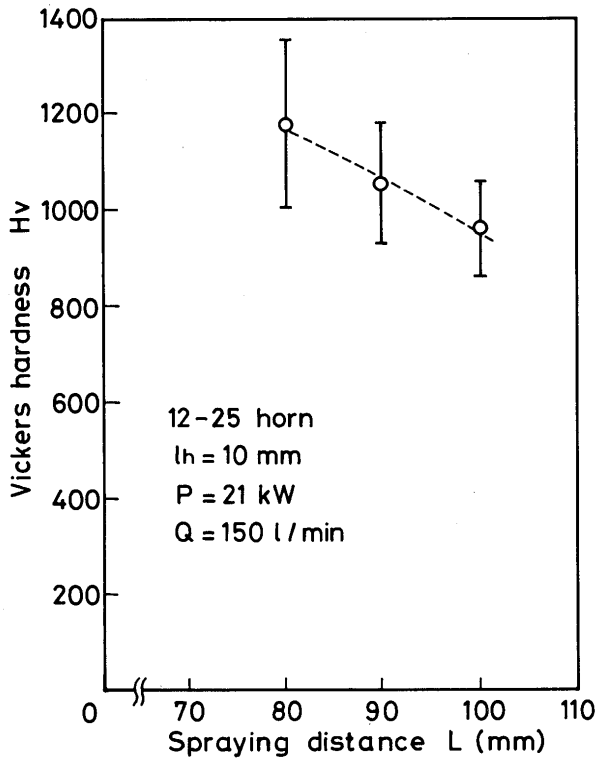

Fig. 4 Effects of spraying distance on Vickers hardness of alumina coating.

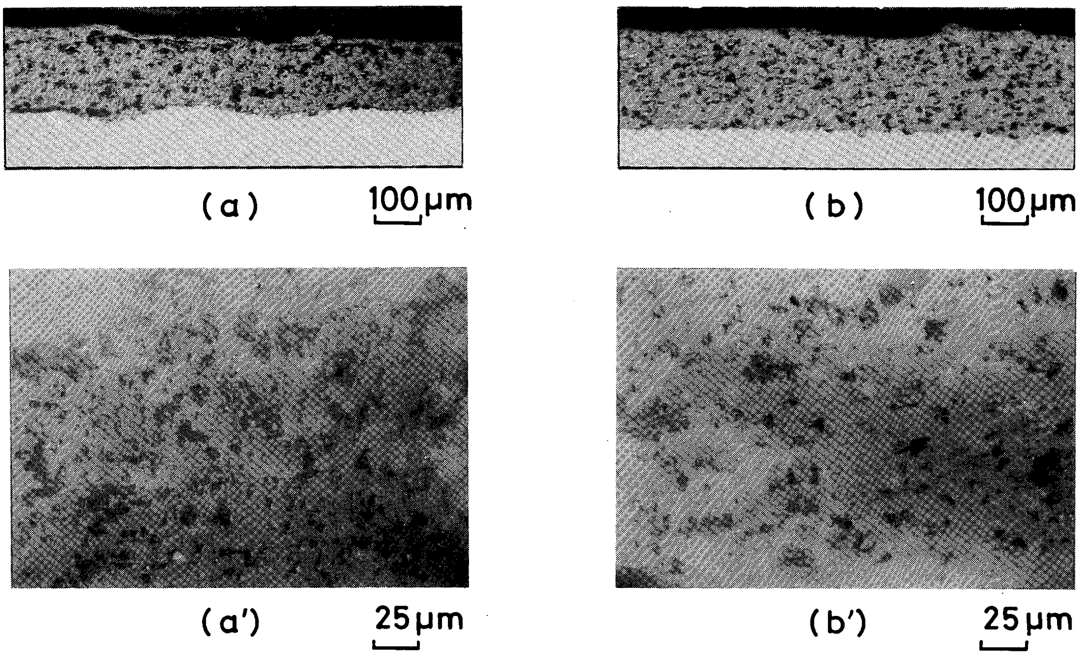

Fig. 5 Photographs of cross section of alumina coating.
(a) (a') : without horn; L = 100 mm, H_v = 850
(b) (b') : with 12-25 horn; l_h = 10 mm, L = 100 mm, H_v = 980

coating obtained is as hard as 1200 in the Vickers hardness, when the electrical power is 20 kW and the spraying distance is 80 mm.

Reference

1) Y. Arata, A. Kobayashi, Y. Habara and S. Jing: Trans. JWRI, **15** (1986) 227.