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New abrasive deburring method using suction for micro burrs at intersecting holes

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ABSTRACT

As industrial technology advances functionally, there is an increasing necessity to treat edges of products well to satisfy the required function. Specifically, burrs inside products at intersecting holes are very difficult to remove because the accessibility of the burr location inside the product to tools is very limited. We propose a new deburring method called abrasive deburring. This method uses a pipe with a hole as a deburring tool to move water with an abrasive and a pump for suction. To determine the suitability of the proposed deburring method, abrasives with different sizes and specific gravities are used. The geometry of the tool and the operating conditions were specified using the following parameters: the diameter of the crossing hole, the diameter of the suction tool, the gap between the sample hole and the tool, the pressure of the pump, and the location of the hole of the tool. The suction-deburring method was very useful for removing micro burrs formed at intersecting holes with an appropriate pump pressure, which is not as high as that in the water-jet or extrude-hone method. However, given the limited deburring force, the method is only applicable for removing micro burrs; other burrs are reduced to stable burrs, which do not require removal from the product.

1. Introduction

As technologyadvances, the demand for machines with a high efficiency and high performance increases. To satisfy these demands, more complex and precise fabrication is required; therefore, the cleanability of products is important. Cleanability refers to the treatment of burrs or chips remaining within a product after fabrication [1]. Burrs occur at the edges of a fabricated part because of the plastic deformation that occurs during machining, and chips remain after the detachment of burrs [2]. After a drilling process, although large burrs can be initially removed via reaming, it is impossible to deburr perfectly, as relatively small burrs remain near the hole even after removal [3]. Such remaining burrs can be detached because of the fluid movement during operation; by scratching the fabricated surface; or by blocking a micro hole or clearance with major functionality for hydraulic pressure control, as in solenoid valves. Micro burrs inside a product containing intersecting holes are especially difficult to remove. This is because visual inspection is difficult, as the burrs are within the product and access for the tool is highly limited. To resolve this issue, many deburring techniques have been developed, including mechanical tools, waterjets, the extrude-horn method, and brushing processes. However, these methods have limitations owing to their high cost and specific applications. As there is an increasing need for a new deburring method, we developed suction deburring.

Among the various deburring methods, mechanical deburring with a special tool, the brush deburring method, and the water-jet deburring method are recommended as the most appropriate methods for removing burrs at intersecting holes. Special tools for the mechanical deburring of burrs at intersecting holes have been developed recently [4–6]. Although each mechanical tool has its own specialty, the application of mechanical tools is highly limited by the stiffness of the tool and the location of burrs. The stiffness of the arms of the tool must be properly designed for the specific location and size of the burr. The brush deburring method is effective for removing relatively large burrs. However, secondary burrs remain in most cases of brush deburring for burrs along edges perpendicular to the feed direction of the brush at the windows formed in the main holes in the transmission valve body, as shown in Fig. 1 [7]. A transmission valve body is shown in Fig. 2 with a view of the internal structure, which shows the windows formed, crossing the main hole of the valve body. Similarly, the removal of burrs at crossing holes was performed using abrasive magnetic deburring, but this was insufficient to completely remove the burrs because of the limited access [8].

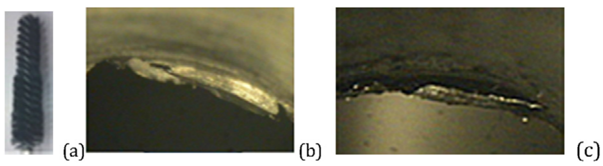

Fig. 1. Results of brush deburring. (a) Brush (b) Before deburring (c) After deburring [7].

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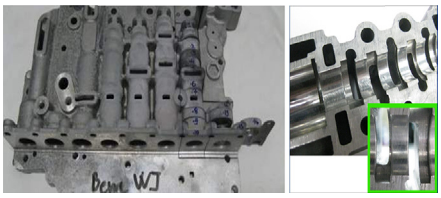

Fig. 2. Transmission valve body and its internal structure.

Waterjet deburring with or without an abrasive has the advantages of the capability to fabricate a fine geometry and avoid deformations or changes in the material properties after operation owing to the absence of thermal damage or mechanical thermal stress [9]. However, weak edges that contain burrs are broken because of the high pressure, as shown in Fig. 3, which becomes the source of secondary particles during operation in hot oil [10]. The fractured surface in Fig. 3 shows the possibility of the generation of particles during operation in a transmission valve body or a similar condition.

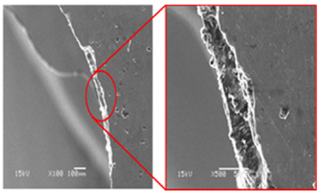

Fig. 3. Examination of the fracture surface of the edge after high pressure waterjet deburring.

However, suction deburring has the advantage that the deburring is performed locally on an edge containing burrs by generating a local shear stress using only suction to change unstable micro burrs to stable burrs economically, as it utilizes low-power pumps. It is also suitable for space utilization, as it has a relatively simple structure.

We analyzed the performance of suction deburring experimentally with different sizes of abrasives, different tool geometries, and different locations of the tool on an intersecting hole, in order to enhance the efficiency of suction deburring. Moreover, it was verified through ANSYS simulation that the examination of the shear stress on the wall where burrs are located during suction deburring can be effectively used to determine the optimal conditions.

2. Mechanism of suction deburring

As shown in Figs. 4 and 5, a test sample with intersecting holes is located inside a tank filled with water mixed with abrasives. A pump is located outside the tank, which is connected to the suction and exhaust ducts through their respective hoses, for circulating the water in the tank. A suction tool is equipped at the end of the hose connected to the suction duct, and the suction holes of the suction tool are aligned with the crossing hole containing burrs, as shown in Fig. 5. The specimen has an inner diameter D_1 and a crossing-hole diameter D_2. The suction tool is designed with an outer diameter d_1, a suction-hole diameter d_2, and N holes. The suction holes are located on a circle with diameter D, as shown in Fig. 4. For example, when D = 5 mm and D_2 = 5 mm, the centers of the suction holes are located along the edges of the crossing hole. When D increases, the flow of the water with the abrasive is induced in a direction perpendicular to the direction of burr formation, which assists efficient deburring.

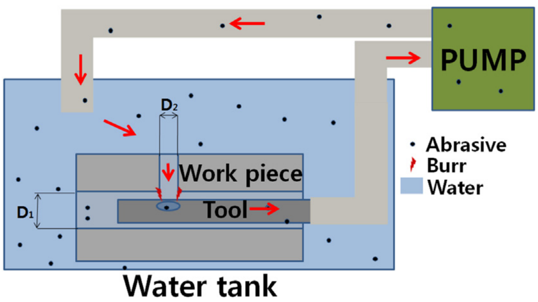

Fig. 4. An experimental apparatus for suction deburring.

The two-dimensional shear stress in fluids can be expressed as

$$\tau_{xy} = \tau_{yx} = \mu\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)$$

The cutting force for burr removal can be assumed to be mainly related to the shear force due to the shear stress on the wall where the burr is located. In the above equation, the shear stress is proportional to the viscosity and the gradients of the velocity, $\partial u/\partial y$ and $\partial v/\partial x$. The operating principle of suction deburring is to generate velocity gradients in order to generate a shear force by adjusting the geometry and location of the suction tool.

The distribution of velocity can be obtained by the operation conditions shown in Fig. 5: the gap size, $(D_1 - d_1)/2$, which is determined by the inner diameter of the hole D_1 and external diameter of the tool d_1; the size and number of the suction holes, d_2 and N, respectively; and the location of the suction hole D. Fig. 6 shows that the stream changes when D changes from 5 to 8. Using the generated shear force, micro abrasive cutting is performed from the contact with the floating abrasives contained in the water. Therefore, the density of the micro particles must be controlled such that they follow the fluid flow, and the surface geometry must be maintained to enable cutting upon contact with a burr. When the pump is operated, water flows through the tool, and the abrasives mixed with the water move along with the flow of the water. During this process, the abrasives come into contact with and cut the burr. The deburring performance was evaluated for different abrasives and process times. Therefore, the aim of the experiment was to determine the optimal conditions by varying the geometry and location of the tool.

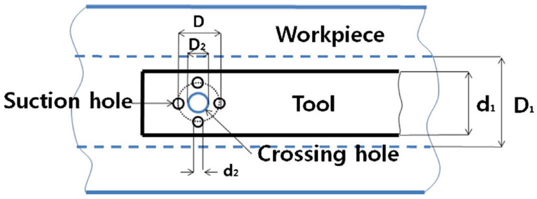

Fig. 5. Top view of the setting of workpiece and deburring tool.

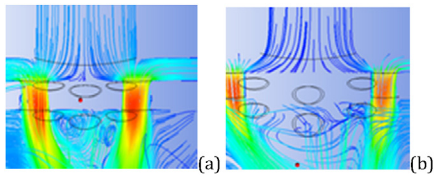

Fig. 6. Change in the water flow with different locations of the suction holes: (a) D = 5 mm, (b) D = 8 mm.

3. Experiment and discussion

The material AL6061 was selected, and the abrasive used was aluminum oxide (Al_2O_3), which has a specific gravity of 3.9 and a hardness grade of MOHS-9. Three different abrasive sizes were used: #100 (125–150 μm), #180 (63–90 μm), and #240 (44.5 ± 2 μm). The selection criterion for the abrasives was to choose sizes that were 1.5, 0.5, and 1 times larger than the average size of the burrs, which was ~100 μm. A diaphragm pump with a flow rate of 20 L/min was used.

Fig. 7(a) shows a photograph of the abrasive with a particle size of 150 μm. The suction tools were classified into two categories – targeted tools and general-purpose tools – as shown in Fig. 7(b).

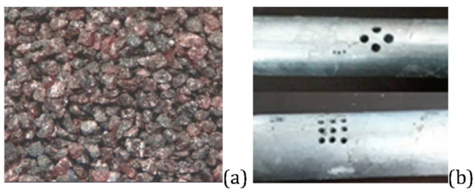

Fig. 7. (a) Selected abrasive (X150); (b) Targeted tool and general-purpose tool.