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Hydrostatic Press Forming of Microparts

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Abstract

Microforming technology becomes crucial in variety of industries as up-to-date machinery products and parts are miniaturized Therefore research on microforming processes are actively conducted because of its high productivity, high precision and efficienct material usage. Since friction during microforming has greater influence than macroforming, hydrostatic pressing is much more efficient. In this paper minimization of bur during fine sheet shear forming and hydrostatic process of multi-filament extrusion to obtain fine wire of micro-order have been conducted.

1. Introduction

While products and parts for electronics and communication have a tendency to become miniaturized, slim and light, customers want them to be of large capacity and multi-functional in its capability. Therefore, much interest in fine forming process technology is getting increased in the viewpoint of superior mechanical properties and the economics of mass production. In the near future Fine Mechanism System (FMS) utilized in electronic products such as PDA, DVD, miniaturized computer is expected to be handier and more microsized. However, it is important to maintain or even enhance the various mechanical properties of microparts such as fatigue resistance specific strength, homogeneous deformation during microforming to produce required ability. In this respect it is neccessary to develop new fine forming processes, which can be applicable to any type of microparts. Despite of the advantage of conventional metal forming processes it is not easily applicable to microforming processes because of difficulties in fabricating precise die sets, increase in loading force due to high surface force and finally difficulty in removing burr after forming process. In order to overcome these problems substitutional fine forming process can be suggested using fluidic medium. This process have several advantages such that it can reduce the number of dies and friction forces during forming.

In this study hydro-mechanical burr-free hole punching process and multi-filament extrusion process using hydrostatic pressure are introduced and some results are reported.

1. Hydro-Mechanical Burr-Free Hole Punching Process

The burr is an unavoidable annoying companion to metal cutting. Taking a punching/blanking process as an example in Fig.1.1, the sheared section is consisted of roll-over, burnish, fracture and burr. Burr is not only irritating hinder but also high cost demanding hitch to remove afterward. Our final object is to get fine blank/hole consisted of maximize burnish area and minimized roll-over on both side of the hole.

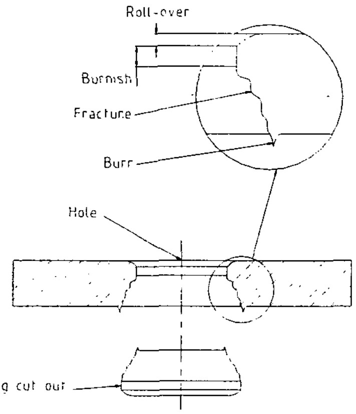


Fig.1.1 Detail of sheared surface.

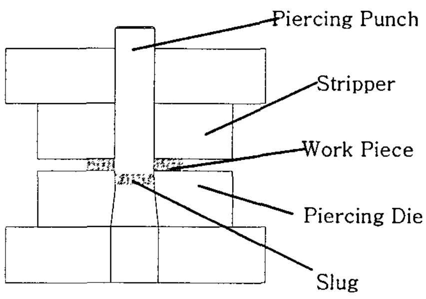
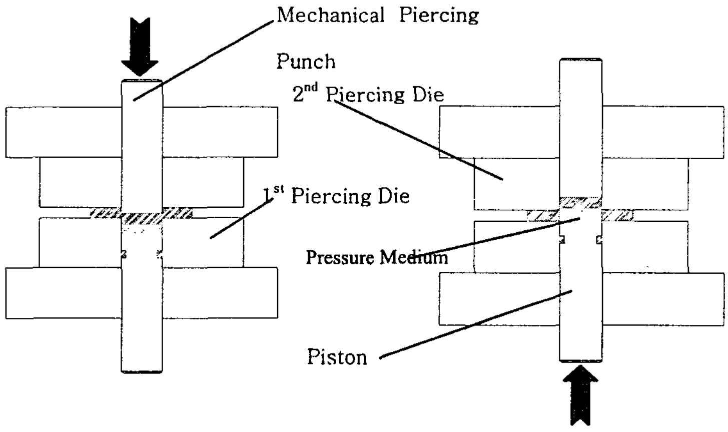


Fig.1.2. Schematics of conventional punching

In conventional punching process slug is pushed away by mechanical punch and die. A typical punching process is shown in Fig.1. 2. Clearance and sharpness of the tools are critical factors of burr formation. With proper clearance and sharp tools we can reduce the burr size but burr-free punching is almost impossible.

Main idea of hydro-mechanical punching can be summarized as followings. Instead of one cutting through stroke, if the blank or slug is pushed back and forth reciprocally, surface burr can be avoided. The counter blanking process is based on the same idea, which is schematically shown in Fig. 1.3



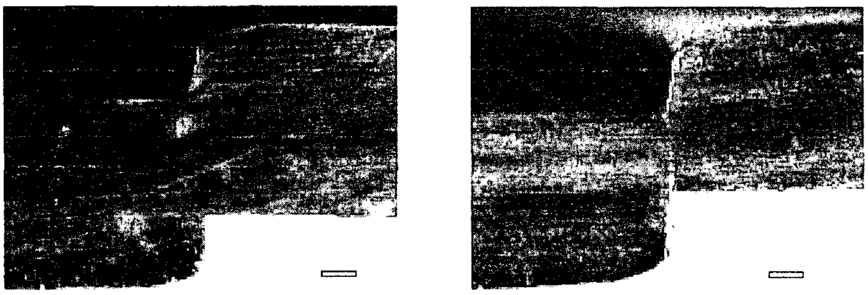
(a) Mechanical half piercing *(b) Hydro punching*

Fig. 1.3. Hydro-Mechanical punching

Developing the scheme, we are able to apply pressure medium in the place of counter punch in the counter blanking. The exerted high pressure would increase hydrostatic pressure in shearing zone, which help delay fracture initiation. By postponing the fracture, clean shear surface can be archived.

1.1. Mechanical Half Piercing

As a fist step, mechanical punch is indented on work-piece to specific depth shown in Fig. 4. The punch progress down ward just before crack takes place. So proper depth of half piercing is different for each material, and determined by geometrical factors such as thickness and clearance also.According to experimental result, decent clearance is smaller than conventional punching and negative clearance would give better result in following hydro punching.



(a) (b)

Fig. 4. Section of half piercing (a) Indented Cu sheet. Thickness 1mm, punch diameter 12.06 mm, die diameter 12. 01 mm, penetration 0.45 mm, (b) Indented stainless steel 304 sheet. Thickness 1mm, punch diameter 12.06 mm, die diameter 12.01 mm, penetration 0.65 mm

After the half piercing stage, the bottom of the sheet is extruded through lower die. Sharp edge of the die is engraved on corner of the sheet and the extruded part has upright sidewall. Contrast to the bottom part, shoulder of upper surface edge is rounded and the sidewall is inclined to out side. Those are exact same features that are observed in the mechanical punching mechanism.

1.2 Hydro Punching

Following the half piercing, high pressure is exerted on counter surface of the sheet. As the pressure of pressure medium goes up, the slug is pushed back and neck between the slug and the sheet is narrowed down. Finally crack initiate on both side and meet each other. Some results of the experiment are shown in Fig. 1.5.

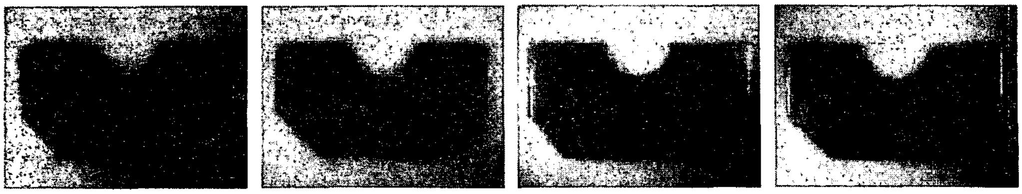

(a) (b) (c) (d)

Fig.1.5 Results of the hydro punching. Thickness of the sheets are 1mm, diameter of cutting die is 12.10mm (half of the work piece is cut off for investigation of the hole) (a) Punched Al sheet, (b) Punched Cu sheet, (c) Punched SPCC sheet and (d) Punched STS 304 sheet.

Without any burr on both side of sheet, smooth holes are archived as intended. But there is discrepancy in hole diameter when it measured in rolling direction and transverse direction.

Table 1 shows the variation of diameter with respect to various materials. The diameter variation is originated from anisotropy of the sheet. When we use pressure medium instead of solid tool, normal component is the only acting traction. So it gives anisotropy more chance to appear.

Table 1. Results of hydro-mechanical punching

Work piece	Penetration depth (mm)	Diameter (mm)	
		RD	TD
Al 6061	0.65	11.70	11.75
Cu B152	0.45	11.72	11.83
SPCC	0.65	11.73	11.73
STS304	0.75	11.74	11.67

Thickness of the sheet: 1.0mm, punch diameter: 12.06mm, diameter of the die: 12.10mm, pressure medium used: hydraulic oil

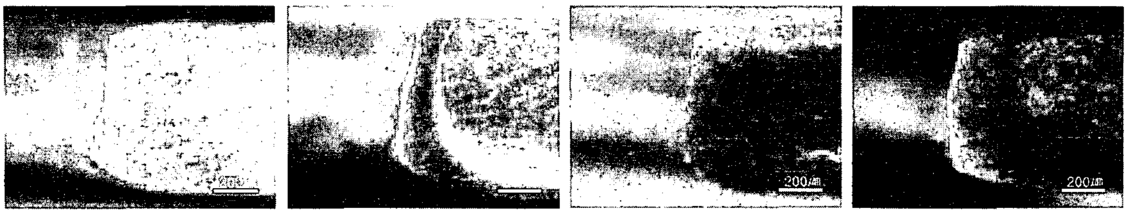
Table 2 shows the effect of backpressure during punching. As shown in the table 2 exerting force on the withdrawing punch to constrain the sheet reduces the difference of diameter.

Table 2 Effect of backpressure

Workpiece	Backpressure (MPa)	Diameter (mm)	
		RD	TD
Al	0	11.70	11.75
	5	11.99	11.99

The other conditions are same except for backpressure

From the hole profile inspection, it can be speculated that the roll-over on upper surface is pushed up to upper die and reduced. Newly formed roll-over on lower surface has relatively large radius of curvature.



(a) (b) (c) (d)

Figl. 6. Profile of the punched holes formed by hydro-mechanical punching process. Thickness of the sheet is 1mm, Diameter of half piercing punch is 12.06mm. Diameter of cutting die is 12.10mm

In the middle of the hole surface, narrow facture zone is shown. And the hole diameter has smaller dimension at bottom where hydrostatic pressure was applied, which is shown in Fig. 7. There is room for enhancement of hole quality by altering depth of half piercing, clearance and counter pressure yet.

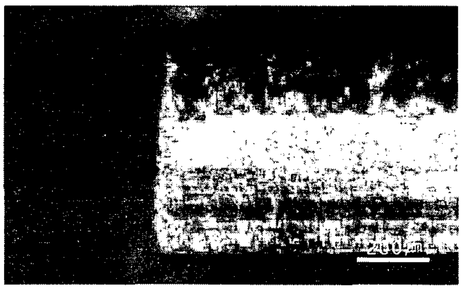


Fig. 7. Inner surface of the hole punched in SPCC sheet. Thickness of he sheet is 1 mm. Hole diameter is 11. 73mm

1. 3 Comparison with conventional forming

To verify the significance of hydro-mechanical punching, conventional punching is performed under similar conditions. The result shows typical shear profile composed of roll-over, burnish, fracture, and burr shown in Fig. 8. The conventional punching hole has opposite inclination angle to hydro-mechanical punching hole. There is diameter expansion along the punch movement line and burr is protruded out in the same direction. And the relatively larger portion of fracture surface draws our attention.

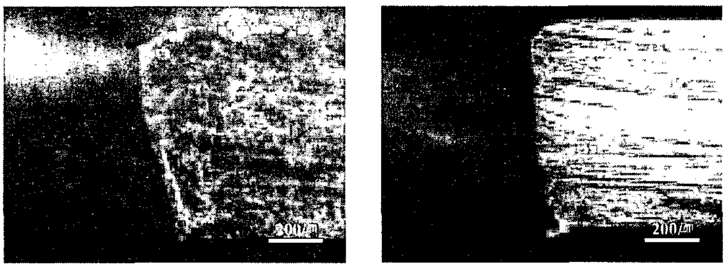


Fig. 1.8. Profile of the punched holes formed by conventional punching. Thickness of sheet is 1mm. Diameter of the die is 12.10mm. Clearance is 0.08mm

2. multi-filament extrusion process using hydrostatic pressure

2.1. Hydrostatic extrusion at high temperature

Multi-filament fabrication process using Hydrostatic clad extrusion of two different materials at high temperature is schematically shown in Fig. 2.1. An aluminum rod claded with a copper tube is extruded to obtain a single cable. A number of the single extruded cables are bundled together and subjected to extrusion to obtain multi-filament wire bundle. In this experiment 19 and 37 single clad cables were bundled together. Fig. 2.2 shows the high temperature hydrostatic extruder with a forming load of 150tonf utilized in this experiment. It consists of bed, moving crosshead and punch and these elements are connected with tie-rods. The shapes of an extrusion die and pressure sealing are shown in Fig. 2.3. A cone angle of the die is 30° and linear low density polyethylene (LLDPE) was utilized as a pressurizing medium. Heating temperature of specimens and container was set to 320°C.

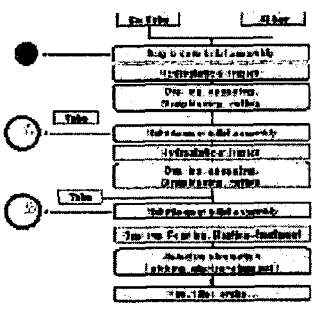


Fig 2.1 Flowchart for repetitive bundle forming

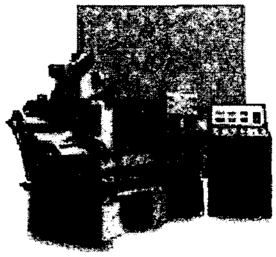


Fig2.2 Hot hydrostatic extruder

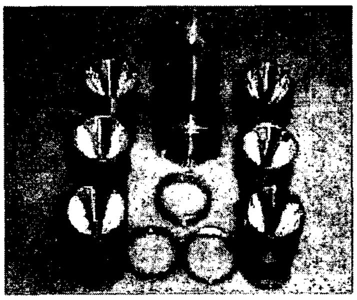


Fig. 2.3 Extrusion dies and seal rings

An aluminum rod (3003 alloy) was inserted in A pure copper tube with outer diameter of 35mm and inner diameter of 25mm for single clad extrusion. For multi-filament extrusion a copper tube with a outer diameter of 35mm and a thickness of 1.4 mm was employed. Extrusion shape was designed to hexagonal shape for easy stacking of multi cables. The length of the hexagonal face was selected to 4.7 and 6.4 mm taking into an account the maximum diameter and the number of staking for the extruding sample. To prevent leaking of pressing medium into the space between cladding of the specimen the end of the specimen was sealed by plug and the front part was bent around by spinning process.

2.2 Multi-filament extrusion experiment

Fig.2. 4 shows a cable of single clad extrusion. The 19 cables by single clad extrusion were combined together to make a bundle core and subjected to first bundle extrusion as shown in Fig. 2. 5. The second bundle extrusion was conducted to obtain a bundle of 361 filament,

which is shown in Fig. 2. 6. Although hexagonal shape of cross section was selected to attain high close packing ratio, close inspection showed that space had existed between outer clad and each filament core. It is, however, recognized that these spaces were minimized in the extruding container before extrusion under Hydrostatic pressure. Fig. 2. 7 shows a bundle sample subjected to the third bundle extrusion having 6859 (19×19×19) filaments. The average diameter of a single filament wire was 33μm despite the local distortion of the cross-section that has occurred on some areas. Two reasons of local distortion can be suggested. It is, first, attributed to friction between the extruding die and material during hydrostatic extrusion although it is small in its magnitude. In practice, while the center part of the cross-section of the material experiences an elongation in the direction of the extruding axis, the outer part is subjected to shear deformation by severe friction between the die and material. Second, the local distortion occurs when the hexagonal shape of material is not fit in the same shape of the die. For example, when the angle defined by hexagonal shape between the die and material is mismatched, material flows along the hexagonal face of the die, not along edges of the die, which results in local distortion of the filament. Since the second effect is more influencing on the distortion. It is thought to be very important to match the hexagonal angle of material in the die.

Fig.2.4 Cu/Al Clad extrusion

Fig. 2.5 First bundle extrusion (19 filaments)

Fig. 2.6 Second bundle extrusion (361 filaments)

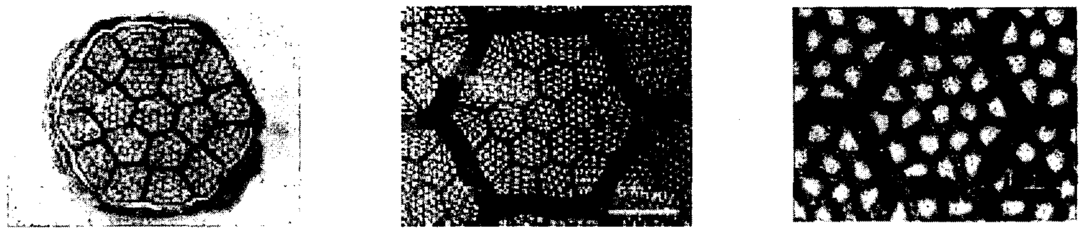


Fig. 2.7 Section of 19 × 19 × 19 filament wire (width of filament: 33μm)

3. Conclusion

Sheet shear forming process, one of the representative fine forming and clad material extrusion facility have been developed and the experimental studies were performed. In this study the following results were obtained.

1. In order to minimize the generation of burr during sheet shear forming partial shear by the punch and continuous shear process in reverse direction by hydrostatic pressing has been

suggested. Using the facility by the suggested method and a die with the diameter of 12.10 mm smooth shear forming without burr was accomplished

2. when the sheet shear forming is conducted by the suggested method, the shear planes of the sheet is not in good condition. Therefore it is necessary to do theoretical approach to solve this problem

3. Cu/Al clad materials were hydrostatically extruded. Repitition of extrusion and stacking process allowed to acquire 33μm diameter of Al wire.

4. During the hydrostatic extrusion distortion on the cross-section of the extruded cable and to minimize this phenomena more study on multi-filament forming is thought to be necessary for improvement

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