Archives of Materials Science and Engineering

Volume 30
Issue 1
March 2008
Pages 57-60

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Employment of alumina suspension pad for v-bending of SUS304 strip

T. Ohashi *, H. Chiba, H. Takano
School of Science and Engineering, Kokushikan University,
3-4-1 Setagaya, Setagaya-ku, Tokyo 154-8515, Japan
* Corresponding author: E-mail address: tohashi@kokushikan.ac.jp

Received 15.01.2008; published in revised form 01.03.2008

ABSTRACT

Purpose: Authors have suggested employment of dilatant fluid for metal forming tools, and report an application on v-bending of thin stainless steel strips in this paper.

Design/methodology/approach: An alumina concentrated hard-sphere suspension is employed as dilatant fluid for forming. The authors evaluated the suspension with backward extrusion test. Followed by SUS304 stainless strip with 0.25mm thickness and 30mm width on the pad of the suspension with a v-bend punch.

Findings: Behaviour of the suspension is revealed in the backward extrusion test. Migration of water takes important role in it. In v-bending test, including acute angle bending, the authors bend the strip with only the v-bend punch and the alumina concentrated hard-sphere suspension pad successfully. It is thought that forming load is less than with general polyurethane tools.

Research limitations/implications: Spring-back in partial bending, which is similar to the suggested process, is larger than in bottoming and coining with dies and bending with polyurethane tools. Therefore, the authors will evaluate the spring-back in the suggested process in further study.

Practical implications: Polyurethane pad is used in bending process generally because of advantageous points in easy-design, and safe from scratch. However it has disadvantageous points in its limited life and necessity of large forming load. The alumina concentrated hard-sphere suspension can be employed for such a pad with unlimited life. In addition, such dilatant fluid can be applied on other metal forming process as easy tool.

Originality/value: Employing dilatant fluid for forming tools is new idea. V-bending with an alumina concentrated hard-sphere suspension was attempted.

Keywords: Plastic forming; Sheet metal forming; Bending; Easy tool ; Dilatant fluid

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

A metal tool and die cost predominantly in most metal forming process. Therefore, die-less forming process [1-2] and substitutes of a metallic tool have been studied. Elastomer tools [3-9], such as polyurethane, are generally used in bending, punching, deep drawing, bulging, embossing and other forming processes. Especially, we can see its most effective application in bending. Polyurethane-die-pad is easy to design, easy to set-up in manufacturing, and safe from scratch between die and product. In addition, the process using the polyurethane pad can keep spring-back smaller than the process using the steel die. However, it requires several times larger forming load than the latter, and the polyurethane pad has lifetime problem.

Life of elastomer tools is a common problem for the other processes. For punching process using polyurethane pad, it is well known as ‘Guerin Process,’ its life-time is several thousand cycles generally. K.Sato investigated life time of a polyurethane pad for punching of aluminium sheet. In the condition of 10% cyclic reduction of the pad, its lifetime is less than 4000 cycles [5].

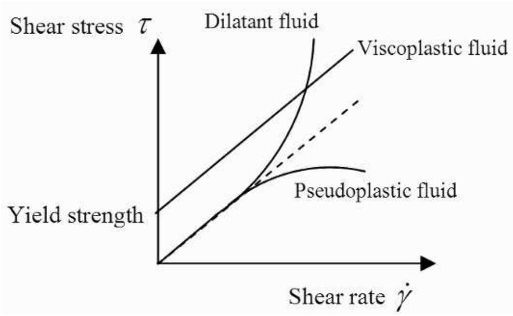

Fig. 1. Typical non-Newtonian fluid

On the other hand, fluid, ice and low temperature melting alloy are used for pressure medium in sheet or tube forming[10-12]. Furthermore, Y.Kurosaki et.al. suggest the idea employing viscoplastic pressure medium with impact compression instead of elastomer pad [13]. They apply it onto piercing of 0.05-mm-dia fine holes on a SK3 foil 0.01 mm thick. Such a fluid seems hopeful as an alternative tool for metal forming. It is free from lifetime problem. As shear rate increases, shear strain dos as well, and increased deformation resistance of the fluid drives metal forming. Therefore they choose impact condition.

The fluid tool must recover the shape in flat after the process. Such the recovery is deformation by internal shear stress caused by gravity in other word. Figure 1 shows the relationship between shear stress and shear rate of typical non-Newtonian fluid. Viscoplastic fluid has yield strength and we can say that the.viscoplastic fluid tool cannot recover its shape by itself in the case that its yield strength is larger than the internal shear stress caused by gravity. Moreover, viscoplastic fluid having large shear stress has large yield strength generally, and this is restriction to increase substantial forming load.

Thus is suggested the employment of dilatant fluid for forming tools. Shear stress of dilatant fluid approaches zero when shear rate close to zero. Therefore, any dilatant fluid recovers its shape at last.

In this paper application on v-bending of thin stainless steel strips with a dilatant fluid pad is reported. The test includes acute angle bending, which is considered as complicated condition in general bending process with a metal die [14].

2. Evaluation of alumina concentrated hard-sphere suspension

2.1. Employed alumina concentrated hard-sphere suspension

We often find an instance of dilatant fluid in the concentrated hard sphere suspensions, of which grain has weak cohesion force. We can change the behaviour of the suspension by choosing grain-liquid ratio and grain material with regarding hardness and shape of the grain. The authors employ 16μm-dia alumina powder for it (Fig.2). Water to Alumina ratio is 1:4 by weight.

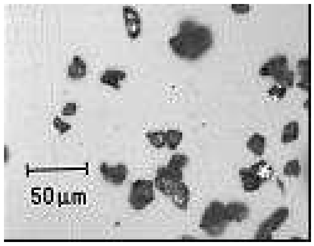

Fig. 2. Employed alumina powder

2.2. Backward extrusion test

Figure 3 shows a schematic drawing of backward extrusion test. The suspension in the container is extruded by hollow punch in speed of press machine employed for v-bending. Detail of the experimental condition are shown in Table 1.

Table 1.
Condition of backward extrusion test.

Specimen	Concentrated hard-sphere suspension of 16μm-dia alumina grain and water. Water to Alumina ratio is 1:4 by weight.
Forming machine	10KN air check press, 200KN hydraulic press, 1000KN universal testing machine
Punch speed	92mm/s- 1mm/s
Outer diameter of punch	ϕ16
Inner diameter of punch ϕ2R	ϕ12, ϕ 10, ϕ 9, ϕ 8
Punch length L	100mm

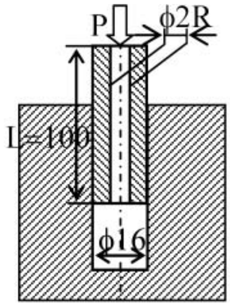

Fig. 3. Backward extrusion test

Shear stress τ_{wa} and shear rate $\dot{\gamma}_a$ can be expressed by the following equations [15],

$$\tau_{wa} = \frac{Rp}{2L} \quad (1)$$

$$\dot{\gamma}_a = \frac{4Q}{\pi R^3} \quad (2)$$

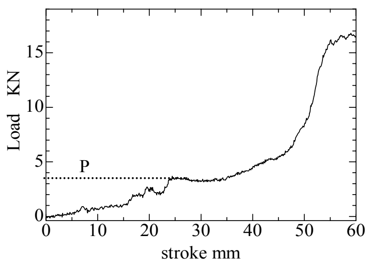

Fig. 4. Load change in backward extrusion test (ϕ2R=8, punch speed:1mm/s)

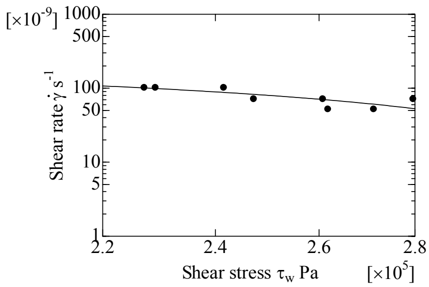

Fig. 5. Shear stress τ_w and shear rate $\dot{\gamma}$

where,
R: inner radius of the punch, p : pressure in the container, L: length of the punch, Q:flow rate.

Here, the pressure in the container p is given by following equation.

$$p = \frac{P - 2\pi R L \tau_{wa}}{A} \tag{3}$$

where,
P: punch load, A: area of the section of the punch.

The above result must be corrected with regarding inlet and outlet effect. Corrected shear stress τ_w is given as following equation by Bagley correction [15],

$$\tau_w = \frac{Rp}{2(L + nR)} \tag{4}$$

where n is given by Bagley plot. Corrected shear rate $\dot{\gamma}$ is given as following equation by Rabinowitsch correction[15].

$$\dot{\gamma} = \frac{4Q}{\pi R^3}\left(\frac{3}{4} + \frac{d \log \dot{\gamma}_a}{4d \log \tau_w}\right) \tag{5}$$

2.3. Evaluation of the alumina suspension

Figure 4 shows one of typical load change during backward extrusion test. The load increases until the head of the flow goes out of the outlet of the extrusion punch. It is thought that supernatant water and the layer having more moisture content is purged in this term. After then, the load change becomes flat for a while. This load is employed for calculation of τ_w and $\dot{\gamma}$ to evaluate typical behaviour of the suspension during forming process. Next the load increases again because of squeeze of the water from the suspension. After finishing squeezing, Then load becomes constant again. Thus, migration of water takes important role in the change of the load. Figure 5 shows relationship shear stress τ_w and shear rate $\dot{\gamma}$.

3. V-bending with alumina concentrated hard-sphere suspension pad

3.1. Experimental conditions

Figure 6 shows a schematic drawing of V-bending with alumina concentrated hard-sphere suspension pad. Detail of experimental condition is shown in Table 2. Bending angle and forming load with changing stroke end point was investigated.

Table 2.
Condition of V-bending test.

Specimen	SUS304 stainless strip with 0.25mm thickness and 30mm width
Forming machine	10KN air check press
Punch speed	92mm/s(max)
Punch	V-bending punch (Top angle: 55 degree)
Punch stroke h	0–30 mm

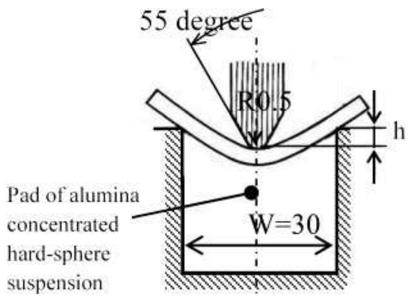

Fig. 6. V-bending with alumina concentrated hard-sphere suspension pad

3.2. Results and discussions

Figure 7 shows sample strips bent by the same tools shown in Fig.6. The left one is a sample product of partial bending without the alumina suspension pad, and the right one is with it. Span between the die shoulders (W=30mm) is too wide for partial bending, however we can see that the strip is bent successfully in the case using alumina suspension pad. This indicates the suspension can transmit enough load for bending.

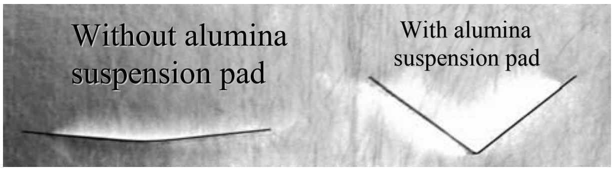

Fig. 7. V-bending samples. The left one is a sample of partial bending without the alumina suspension pad (air bending), and the right one is with it

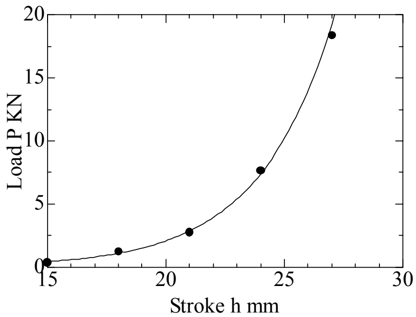

Fig. 8. Punch stroke and forming load

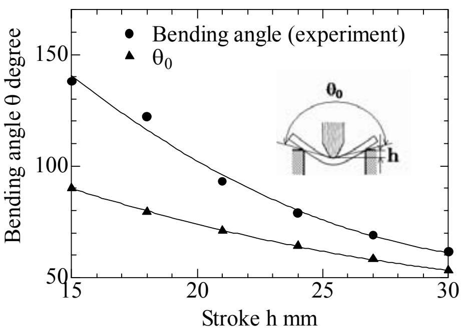

Fig. 9. Bending angle

Figure 8 and 9 shows relationship amongst punch stroke h, forming load and bending angle. Forming load with the suspension pad seems to be less than the process with the general polyurethane pad. The bending angle becomes more accurate with larger load. Narrower span between the die shoulders might be necessary for extra accuracy, and the authors going to investigate spring-back in the process with regarding it in further study.

4. Conclusions

It is suggested to have the employment of dilatant fluid for metal forming tools, and report an application on v-bending of thin stainless steel strips with alumina concentrated hard-sphere suspension pad. Shear stress of dilatant fluid approaches zero when shear rate close to zero. Therefore, there is no barrier for dilatant fluid to recover its shape by the gravity. Backward extrusion test is employed for evaluation of the suspension. Migration of water takes important role in the change of the load. Shear stress does not change match within the capable shear rate from the ability of the employed press machine. In v-bending test including acute angle bending, bending the strip with only the alumina concentrated hard-sphere suspension pad and v-bend punch was done successfully.

Dilatant fluid tool, or concentrated hard-sphere suspension can be employed for other forming processes, such as bending, punching, deep drawing, bulging, embossing and tube forming.

References

[1] J. Kopac, Z. Kampus, Incremental sheet metal forming on cnc milling machine-tool, Proceedings of the 13th International Science Conference "Achievements in Mechanical and Materials Engineering" AMME'2005, Gliwice – Wisła, 2005, 335-338.

[2] A. Petek, K. Kuzman, J. Kopac, Forces and deformations analysis of incremental sheet metal forming, Proceedings of the 13th International Science Conference "Achievements in Mechanical and Materials Engineering" AMME'2005, Gliwice – Wisła, 2005, 793-802.

[3] S. Thiruvarudchelvan, M.J. Tan, Investigations into collar drawing using urethane pads, Journal of Materials Processing Technology 191/1-3 (2007) 87-91.

[4] A.C. Girard, Y.J. Grenier, B.J. Mac Donald, Numerical simulation of axisymmetric tube bulging using a urethane rod, Journal of Materials Processing Technology 172/3 (2006) 346-355.

[5] K. Sato, Blanking die using urethane-gum, Metal Working Technology ('Press Gijutsu') 22/9 (1984) 34-38 (in Japanese).

[6] K. Sato, T. Asaoka, R. Miya, Study on hole punching with elastic tools, Advanced Technology of Plasticity 3 (1996) 1624-1629.

[7] F. Takahashi, T. Nishimura, I. Suzuki, A method of blanking from amorphous alloy foils using rubber tool, C.I.R.P. Annals 40/1 (1991) 315-318.

[8] G. Laszlo, Sheets forming by elastic die I, Rubber, Plastics 60/8 (2007) 484-488 (in Germany).

[9] G. Laszlo, Sheets forming by elastic die I, Rubber, Plastics 60/9 (2007) 560-564 (in Germany).

[10] A. Comşa, G. Cosovici, P. Jurco, D. Banabic, D. Banabic, Simulation of the hydroforming process using a new orthotropic yield criterion, Proceedings of the 10th Jubilee International Science Conference "Achievements in Mechanical and Materials Engineering" AMME'2001, Gliwice – Zakopane, 2001, 79-84.

[11] T. Ohashi, H. Ito, K. Shinozaki, S. Ito, H. Watari, Analytical and experimental study on lateral extrusion of cross fittings with a lost core, Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 399-402.

[12] T. Ohashi, Experimental and Analytical Study on the lateral extrusion with a lost core, Proceedings of the 13th International Science Conference "Achievements in Mechanical and Materials Engineering" AMME'2002, Gliwice – Zakopane, 2002, 391-394.

[13] Y. Kurosaki, I. Fujishiro, A manufacturing process using the impact compression of a viscoplastic pressure medium. Application to the piercing of fine holes, International Journal of Japan Society for Mechanical Engineers 30/262 (1987) 653-660.

[14] I. Pahole, S. Bonifarti, M. Ficko, B. Vaupotic, S. Kovacic, J. Balic, Bending of sheet metal of complicated shapes (for 90° angle and more) in combined tools, Proceedings of the 11th International Scientific Conference "Contemporary Achievements in Mechanics, Manufacturing and Material Science" CAM3S'2005, Gliwice – Zakopane, 2005, (CD-ROM).

[15] Y. Ohno et.al, Measurement and analysis of rheology data, and new technologies for viscosity control, gijutsu-jyoho-kyokai, Tokyo, 2005 (in Japanese).