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An evaluation of the seizure process for pure titanium by a draw bending method

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Abstract

In order to evaluate the seizure of pressing process, we adopted a draw bending method to use pure titanium sheets of 1.0mm in thickness (JIS TP340, ASTM Grade2). The draw bending method was simulated under the conditions of die wall for pressing the glasses frame. The titanium sheet was dragged into the clearance between upper punch and die by the descent motion of the upper punch. The seizure occurred at the shoulder part and side wall part of the die. The working conditions changed within the bending radius of die, the lubricating condition and punch speed. The surface roughness of titanium sheets and die surface were measured by the surface measuring instrument using PGI (Phase Grating Interferometry) system (Taylor Hobson Form Talysurf 1200). The surface roughness and the punch load increased intensely within a 10mm of sliding distance under the non-lubricant condition, and increased gradually within a range of 10 to 50mm in every die radius. The load of draw bending process was related to the variation of surface roughness. The seizure of the pressing process, occurring between surfaces of specimen and die, was estimated by measuring the arithmetic mean roughness.

Selection and peer-review under responsibility of Nagoya University and Toyohashi University of Technology

Keywords: seizure; draw bending; titanium; arithmetic mean roughness

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1. Introduction

To produce the titanium glasses frame, the seizure occurred on the surface of frame was prevented by the oxide film treatment on the titanium material. The anodic oxidation coating was a method widely used in pressing process from the titanium wire to the glasses frame. However, for the perfect prevention of seizure, an excess film was coated on the titanium surface. To increase the productivity of glasses frame, the necessary and sufficient thickness of the oxide film was requested. The optimum thickness of the film was obtained by grasping the boundary point which was transited from mild wear to the seizure. The draw bending method was simulated under the conditions of die wall for pressing the glasses frame.

Nomenclature

R_d	radius of die
R_p	radius of punch
C_l	clearance between punch and die
V	down speed of punch
W	punch load
F	sheet holding force
l	sliding distance
S_b	area of contact
S_w	evaluation area
S	ratio of contact area
R_a	arithmetic mean roughness

2. Draw bending method and items of estimation

2.1. Experimental procedure

The images of the draw bending method and cross-sectional view of die are shown in Fig. 1. In the first step, the titanium specimen was holed at a horizontal level of the die surface with the sheet holding force F=600N occurred by the coil spring. As the next step of the holding situation, the specimen was dragged into the clearance between upper punch and die by the descent motion of the punch.

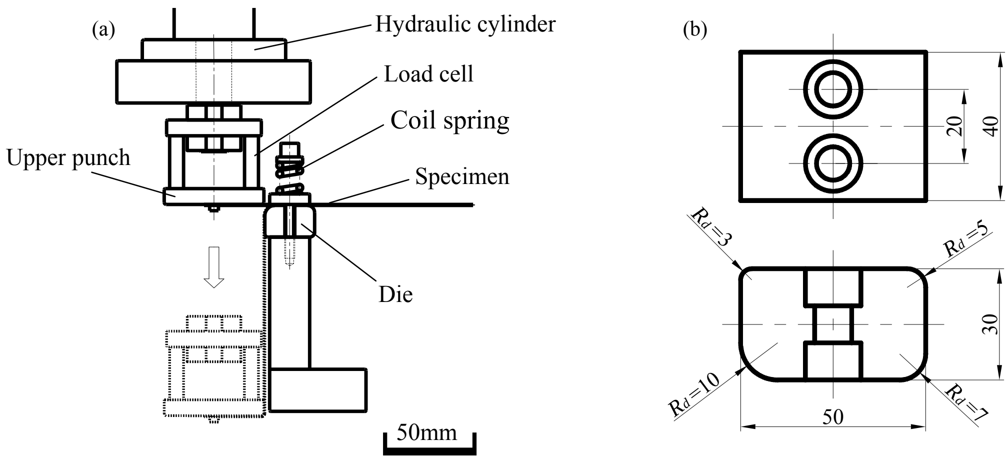


Fig. 1. (a) Experimental apparatus and (b) cross-sectional view of die

The experimental conditions are shown in Table 1. The die, which has the four different radius of the edge, was made by the cold work tool steel (JIS SKD11) and used to change the corner, both top and bottom, left and right. Pure titanium (JIS TP340) sheets of 1.0mm in thickness were used in this test. And cold rolled carbon steel (JIS SPCC) sheets were used to the material of a comparison. The lubricating conditions, which called from Type A to Type D, were changed to three types of the application and two kinds of the lubricant.

Table 1. Experimental conditions

Name	Material	Experimental condition
Punch	SKD11 Surface Hardness HRC=60~62	R_p =3mm (Constant)
Die	SKD11 Surface Hardness HRC=60~62	R_d =3,5,7,10mm
Clearance	C_l =1.0~2.0mm	
Down Speed	V =0.01~0.1mm	
Sheet Folding Force	F =600N	
Sliding Distance	L =200mm	
Workpiece Material	Pure titanium (t =1mm) width(mm)×length(mm) =30×300 Cold rolled carbon steel (t =1mm) 30×300	
Lubricating Condition	Type A: Non-lubricant	
	Type B: stearic acid ($C_{17}H_{35}COOH$) coated on the specimen	
	Type C: Molybdenum disulphide (MoS_2) coated on the specimen	
	Type D: MoS_2 brushed on the die surface	

2.2. Items of estimation

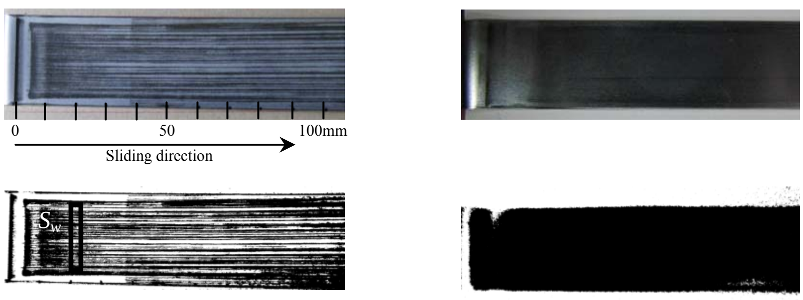
The surface roughness of sheets and die surface were measured by the surface measuring instrument using PGI (Phase Grating Interferometry) system (Taylor Hobson Form Talysurf 1200). The arithmetic mean roughness was measured from sliding distance l=0mm to 60mm for every 3mm, and the sliding points at l=70mm, 100mm, and 130mm. Fig. 2 shows the photos of the surface of specimen and the binarization images of surface photos. The ratio of contact area S is given by

$$S = S_b / S_w \times 100 \quad [\%] \tag{1}$$

where S_w is the square estimate area of 24mm in width and 3mm in sliding length in the binarization image of Fig. 2, and S_b is the black area in the estimate area.

Photo image

Binarization image



(a) Titanium (b) SPCC

Fig. 2. Examples of formed surface for each materials, (a) titanium, (b) SPCC.

3. Results and discussion

3.1. Variation of surface of specimen

The variation of surface of specimen under the non-lubricant condition is shown in Fig. 3. The surface roughness of titanium for every die radius R_d, increases intensely within a 10mm of sliding distance, and increases gradually within a range of 10 to 50mm in every die radius. On the other hand, the roughness of SPCC does not increase through the all sliding distance. No seizure appears on the SPCC surface. The ratio of contact area *S*, obtained by the binarization image, decreases at the inverse to the roughness of surface because the scratch wound caused by seizure is grown up.

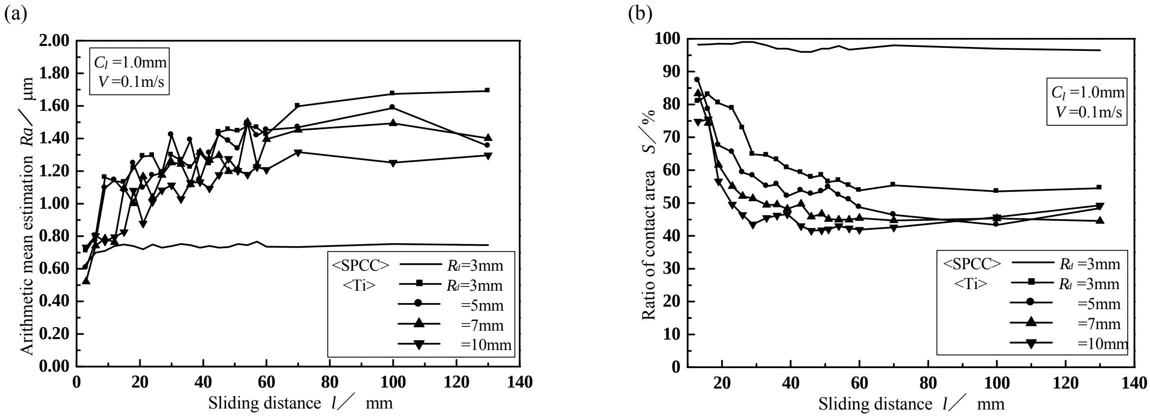


Fig. 3. Variations of surface versus sliding distance to (a) surface roughness, (b) ratio of contact area.

3.2. Variation of roughness with lubricating conditions

Fig. 4 shows the variation of roughness with various conditions of lubricant. The result of coating the titanium surface by the stearin acid (Type B) has the same tendency as the non-lubricate (Type A) result. The case of coating by the MoS_2 (Type C), the variation of surface roughness is pile up to the non-seizure SPCC result. The spreading MoS_2 on the die surface (Type D) makes a slow ascent to a uniform value of the non-lubricate. Therefore, the best experimental condition to evaluation the seizure of draw bending process is the pattern of spreading the die surface with MoS_2 (Type D).

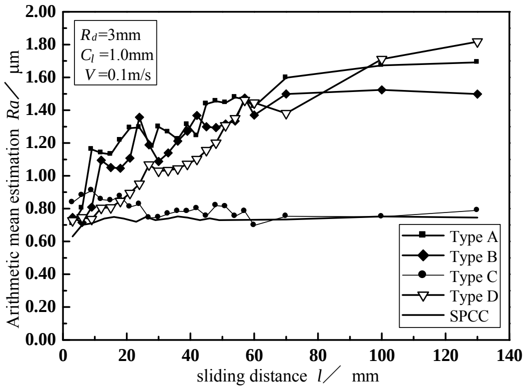


Fig. 4. Relationships between surface roughness and sliding distance with various lubricating conditions.

3.3. Surface properties

The change of surface properties is shown in Fig. 5. Under the condition of Type D which is spreading the die with MoS_2, the surface photos of 135 magnifications and the curve of roughness especially show the points of the arithmetic mean roughness. The minute scratch clucks appear under the arithmetic mean roughness *Ra*=1.0μm. The scratch cluck is bigger up to over the *Ra*=1.0μm. It can be seen that the transition from the mild wear to the seizure occurs up to over *Ra*=1.0μm. It is found that the inception and the development of the seizure on the titanium surface can be estimated by measuring the arithmetic mean roughness.

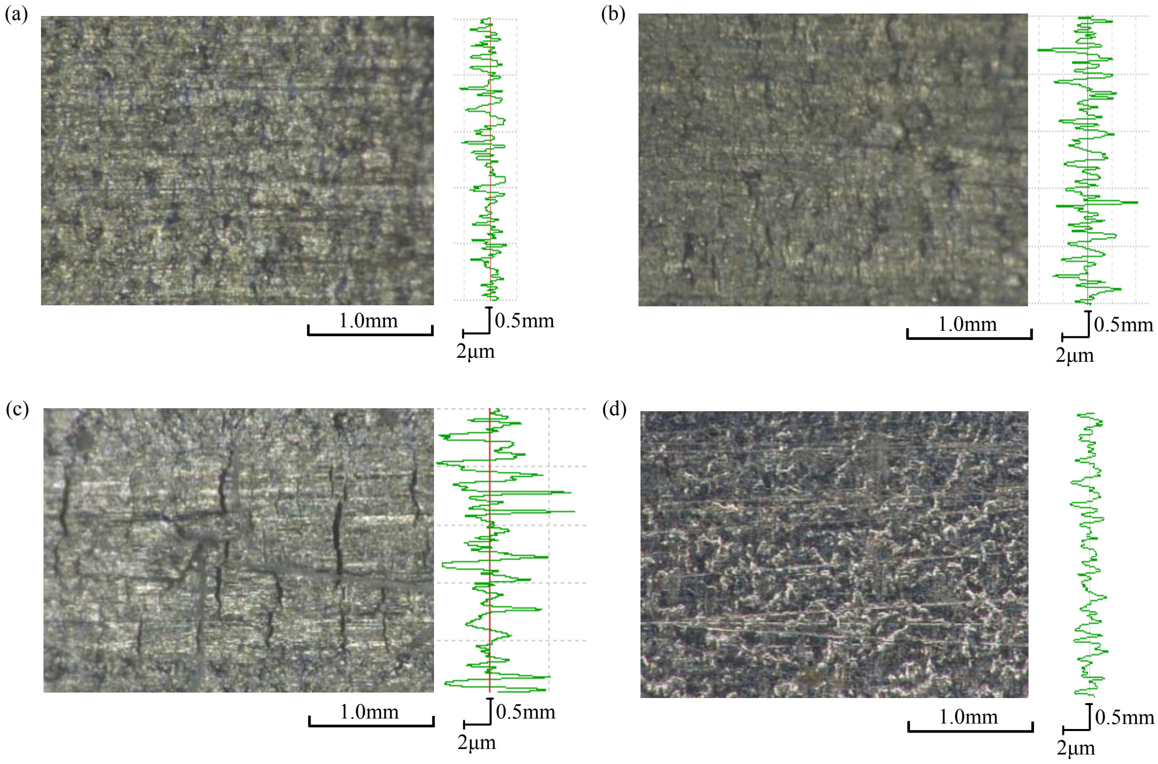


Fig. 5. Examples of the surface photos and the curve of roughness at the estimate square area S_w on the points of (a) sliding distance *l*=10mm, (b) *l*=25mm, (c) *l*=60mm, and (d) *l*=25mm on the SPCC.

3.4. Step to prevent the seizure

We can control the pressing machine set in motion based on the punch load. The relationships between punch load and surface roughness are shown in Fig. 6. On the conditions of occurring the seizure, Type A, Type B, and Type D, the punch load increases exponentially and crosses over the horizontal line of *Ra*=1.0μm. On the other hand, non-seizure conditions, Type C and SPCC, no points exits to over the *Ra*=1.0μm. The control of punch load is effective method to prevent the seizure as the arithmetic mean roughness *Ra* remains under the *Ra*=1.0μm.

4. Conclusions

We propose a new draw bending method by using pure titanium sheets to evaluate the seizure of pressing process. The produce tests were carried out by changing the experimental conditions such as die radius, punch speed, lubricant condition etc. The following results are obtained.

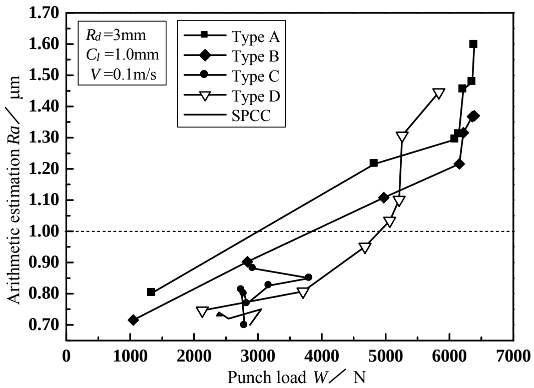


Fig. 6. Relationships between surface roughness and sliding distance with various lubricating conditions.

(1) The surface roughness of titanium for every die radius R_d, increases intensely within a 10mm of sliding distance under the non-lubricant condition, and the ratio of contact area *S* decreases at the inverse to the roughness of surface.

(2) The best experimental condition to evaluate the seizure of draw bending process is the pattern of spreading the die surface with MoS_2 (Type D).

(3) The inception and the development of the seizure on the titanium surface can be estimated by measuring the arithmetic mean roughness.

(4) The control of punch load is effective method to prevent the seizure as the arithmetic mean roughness *Ra* remains under the *Ra*=1.0μm.

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