การศึกษาประสิทธิผลของระบบไกด์ของแม่พิมพ์ภายใต้แรงกระทำแบบเยื้องศูนย์บนเครื่องเพรสโครงสร้างรูปตัวซี

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บทคัดย่อ

บทความนี้นำเสนอการตรวจสอบการเปลี่ยนแปลงในช่วงยืดหยุ่นของเครื่องเพรสโครงสร้างรูปตัวซีภายใต้สภาวะการรับแรงที่ไม่ตรงศูนย์กลางของเครื่อง ตรวจสอบการบิดตัวของโครงสร้างเครื่องขณะที่มีแรงกระทำเมื่อมีการใช้ระบบไกด์ในแม่พิมพ์ประเภทต่างๆ เพื่อช่วยเพิ่มความเที่ยงตรงให้กับชิ้นงานที่ผลิต จัดสร้างอุปกรณ์ในการทดสอบกับแม่พิมพ์อัดขึ้นรูป โดยทำการติดตั้งอุปกรณ์ในการวัดแรงและระยะการเปลี่ยนแปลงในทิศทางต่างๆ เพื่อบันทึกข้อมูล ทำการทดสอบโดยเพิ่มโมเมนต์จากการกดอัดที่ค่าต่างๆ กัน การใช้ระบบไกด์ช่วยในชุดแม่พิมพ์ให้ผลของการเปลี่ยนแปลงในช่วงยืดหยุ่นของเครื่องเพรสน้อยลงเมื่อเทียบกับไม่ใช้ระบบไกด์ จากการทดสอบพบว่าระบบไกด์ที่ให้ผลดีที่สุดคือการใช้ร่วมกันระหว่างไกด์ฮีลบลอคและพิลล่าร์ขนาดเส้นผ่านศูนย์กลาง 32 มิลลิเมตร ซึ่งทำให้เกิดการปรับปรุงระยะการเปลี่ยนแปลงเชิงมุมในช่วงยืดหยุ่นร้อยละ 61.09 และระยะการหมุนของเพรสสไลด์ร้อยละ 49.13 เปรียบเทียบกับไม่ใช้ระบบไกด์ช่วยของเครื่องเพรสแบบเยื้องศูนย์ และเกิดการปรับปรุงระยะการเปลี่ยนแปลงเชิงมุมในช่วงยืดหยุ่นร้อยละ 58.3 และระยะการหมุนของเพรสสไลด์ร้อยละ 54.02 เปรียบเทียบกับไม่ใช้ระบบไกด์ช่วยของเครื่องเพรสแบบไฮดรอลิก

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Experimental Study on the Effectiveness of Guiding System under Eccentrically Loaded Condition of C-Frame Press

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Abstract

This paper presents an investigation on the elastic deflection of C frame press under eccentric load. Various types of guiding system were examined for their effectiveness to increase the process accuracy. Special tool was designed to measure the deflection of C-frame press in various directions. The experiments were carried out with various amount of eccentric loading on various types of guiding system as well as without guiding system. The result shows less deflection of the press when using die-guiding system as expected. The combination of large diameter guide pillar and heel block guide provides the maximum improvement of 61.09% in angular deflection and 49.13% in rotation for eccentric press and 58.3% in angular deflection and 54.02% in rotation for hydraulic press.

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1. Introduction

Nowadays, high quality parts with low cost are increasing in demand in order to compete in the world market. To produce accurate press working parts, especially parts produced by progressive die, tool of high quality and strong press of high resistance to eccentric load are required. This will result in high investment and high price of the product accordingly. This work is aimed to provide information to assist in producing accurate parts of small size using simple machine. C-frame press is notable for its inaccuracy and less stiffness. However, it has been used extensively to produce small parts in the industries due to its ease of use and low price. This research work focused on using die-guiding system to obtain better accuracy of the part being produced by C-frame press. Several types of die-guiding systems which are available in the market namely pillar type, ball bearing pillar type and heel block type, were tested for their resistance to tilting and off center loading. Not only better accuracy of the parts obtained but also easy alignment and quick die change are integrated. Wagener [1] has investigated the deflection of press under loaded state. However, his work has been carried out on large o-frame press with high level of eccentric load for the application of large automobile parts.

2. Methodology

The coordinate system used to explain the elastic behavior of press as determined in DIN 55189 [2] is shown in Fig. 1. For non-symmetrical presses, elastic deflection causes error on the accuracy of part produced. Error in height caused by elastic deflection of press slide in Z direction. The property of press to resist this elastic deflection is press stiffness, Q which can be determined as follow [3];

$$C_{press} = QX\sqrt{F_N} \tag{1}$$

Where C_{press} is spring constant (kN/m) in Z direction and F_N is nominal force (kN) of press. For non-symmetrical loading, tilting of slide around X and Y-axes is introduced as shown in Fig. 2. Slide tilting causes angular deflection that leads to error in parallelism. The property of press corresponding to accuracy under unsymmetrical loaded state is designed as factor P, angular stiffness of press which can be determined as follow;

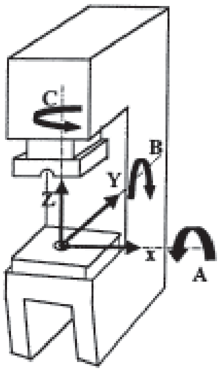


Fig. 1 Press coordinate system [2]

$$C_K = PX\sqrt{F_N^{\,3}} \tag{2}$$

Where C_K is spring constant of tilting or angular spring constant.

$$C_K = \frac{\Delta M}{\Delta K} \tag{3}$$

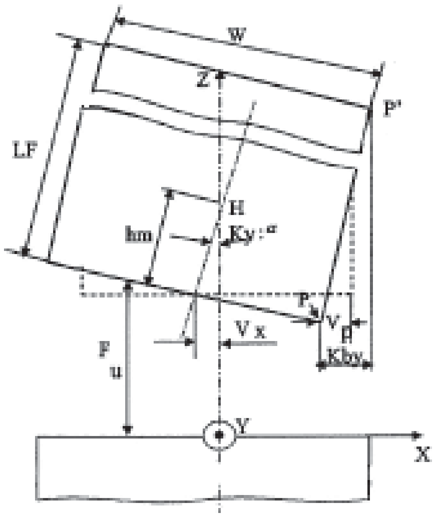
Where ΔM (kNm) is moment of tiling and ΔK (mm/m) is angular deflection.

Under eccentric loading, press slide can be tilted in 3 directions (C, B and A as shown in Fig. 1). The properties of press to resist tilting around Z, Y and X axes are represented by C_{KZ}, C_{KY} and C_{KX} respectively.

Die-guiding system that is added on the tool set will provide extra spring constant to resist tilting action. Thus angular deflection can be decreased.

$$C_{total} = C_K + C_G \tag{4}$$

Where C_G is spring constant originated from die-guiding system



W	:	Width of slide
LF	:	Guide length
hm	:	Height of pole
H	:	Pole
V_x	:	Offset in X-direction
Ky	:	Augular deflection about Y axis
Kby	:	Distance P-P' slide tilt

Fig. 2 Press slide tilting around Y-axis

For the experiment, eccentric loads were generated on X and Y axes for both positive and negative directions. The amount of slide tilting can be detected by measuring of angular deflection. Measurements of angular deflection around X, Y-axes and slide rotation around Z-axis were recorded under loaded state. The degree of angular deflection is not only depended on off-center loading but also on the clearance setting. The effect of clearance between press frame and slide on elastic deflection was also investigated. The percentage of improvement in elastic deflection referenced to that without die-guiding system is calculated.

3. Experimental Procedure

Compression tests of eccentric loading were carried out. Cylindrical workpiece material is AISI 1045 of 17 mm in diameter and 25 mm in height. Flat top and bottom dies made from JIS SKD11 hardened to 60 HRC were used. Each experiment, the workpiece was placed at 30 mm from center of press table in both x and y, positive and negative direction to generate eccentric load. LVDT sensors were set up in the way that angular deflection and slide rotation could be measured as shown in Fig 3. Forming force was directly recorded by load cell attaching to the die set. Each test was repeated three times and average value was recorded. There are two C-frame presses employed; a 630 kN eccentric press and a 500 kN hydraulic press. The pictures and specifications of both presses are illustrated in Fig. 4. Clearances of 0.1 mm and 0.2 mm between press slide and frame without using any guiding system were tested for the first set of experiments. Subsequently, several types and sizes of guiding system attaching to the die set were employed at constant clearance setting of 0.1 mm. which are;

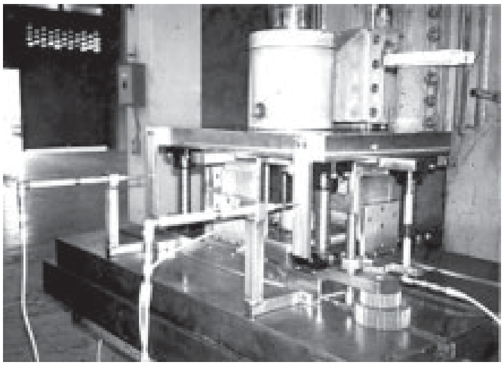
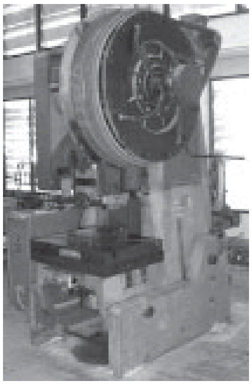


Fig. 3 Set up of experimental tool

- pillar type of ϕ 25 mm
- pillar type of ϕ 32 mm
- ball bearing pillar type of ϕ 25 mm
- brass heel block type of size 100x100 mm in contact area
- heel block & pillar ϕ 25 mm
- heel block & Ball Bearing Pillar ϕ 25 mm
- heel block & pillar ϕ 32 mm



Eccentric Press

Hydraulic Press

	Unit	Press	
Machine		Eccentric	Hydraulic
Manufacturer		SMERAL	INOUE
Type		LEN 63 C	BC 50
Nominal force	kN	630	500
Stroke length	mm	10-105	420
Speed	min^{-1}	45	-
Slide height	mm	625	200
Slide width	mm	335	125
Max pressure	Kg/cm^2	-	250
Motor	kW	4	11

Fig. 4 Press used and their specification

4. Results and discussions

4.1 Influences of slide clearance

Angular deflections and rotation of the presses and the tools as a function of moment in various directions are shown in Fig. 5 and Fig. 6 respectively. The results obtained from eccentric press are illustrated in Fig. 5(a) and Fig. 6(a). Those from hydraulic press are shown in Fig. 5(b) and Fig. 6(b). At small moment, angular deflection increases substantially. This is due to all clearances in the press parts. The deflection is increased gradually with increasing eccentric force. Increase slide clearance results in a little larger angular deflection and rotation of the press. Rotation of the press slide around Z-axis is found similar between placing the specimen in x-x direction and y-y direction. Whereas angular deflection around Y-axis, place the specimen in x-x direction, is larger than that around X-axis, place the specimen in y-y direction, at constant value of moment. This is due to additional resistance to angular deflection from the frame of the press, which is position in Y direction.

The amount of angular deflection and press slide rotation are found larger on eccentric press than those on hydraulic press under the same condition. The reason is that the frame of eccentric press made from cast iron while the frame of hydraulic press made from steel. The property of elastic modulus which is 69 GPa of cast iron is poorer than that of steel which is 200 GPa. Therefore, the stiffness of the hydraulic press design is superior than that of the eccentric press used in this experiment.

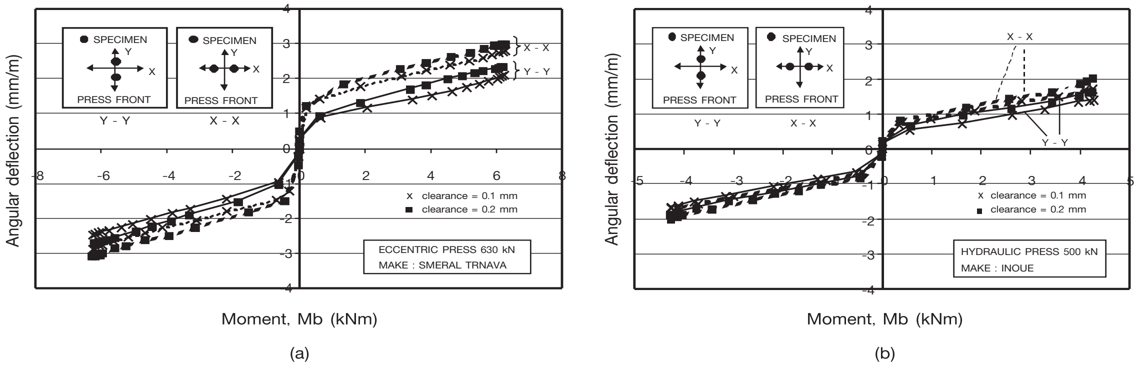


Fig. 5 Influences of slide clearance on angular deflection of eccentric (a) and hydraulic presses (b) from off-center loading without guiding system.

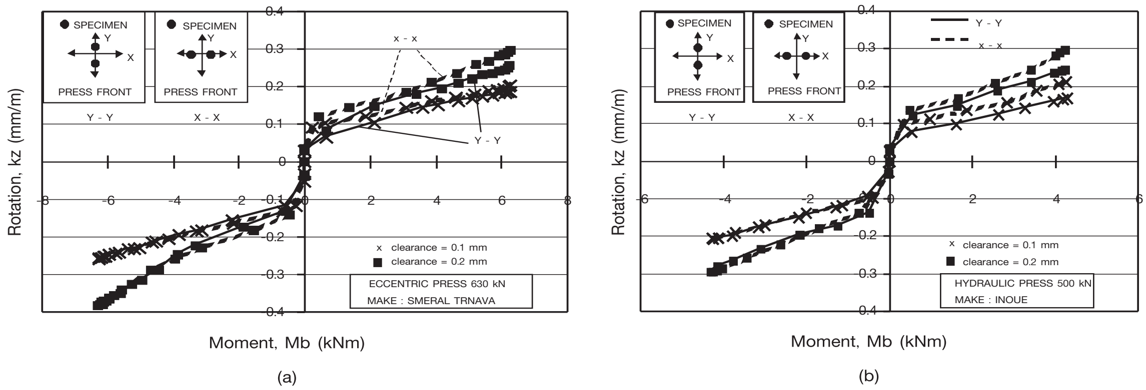


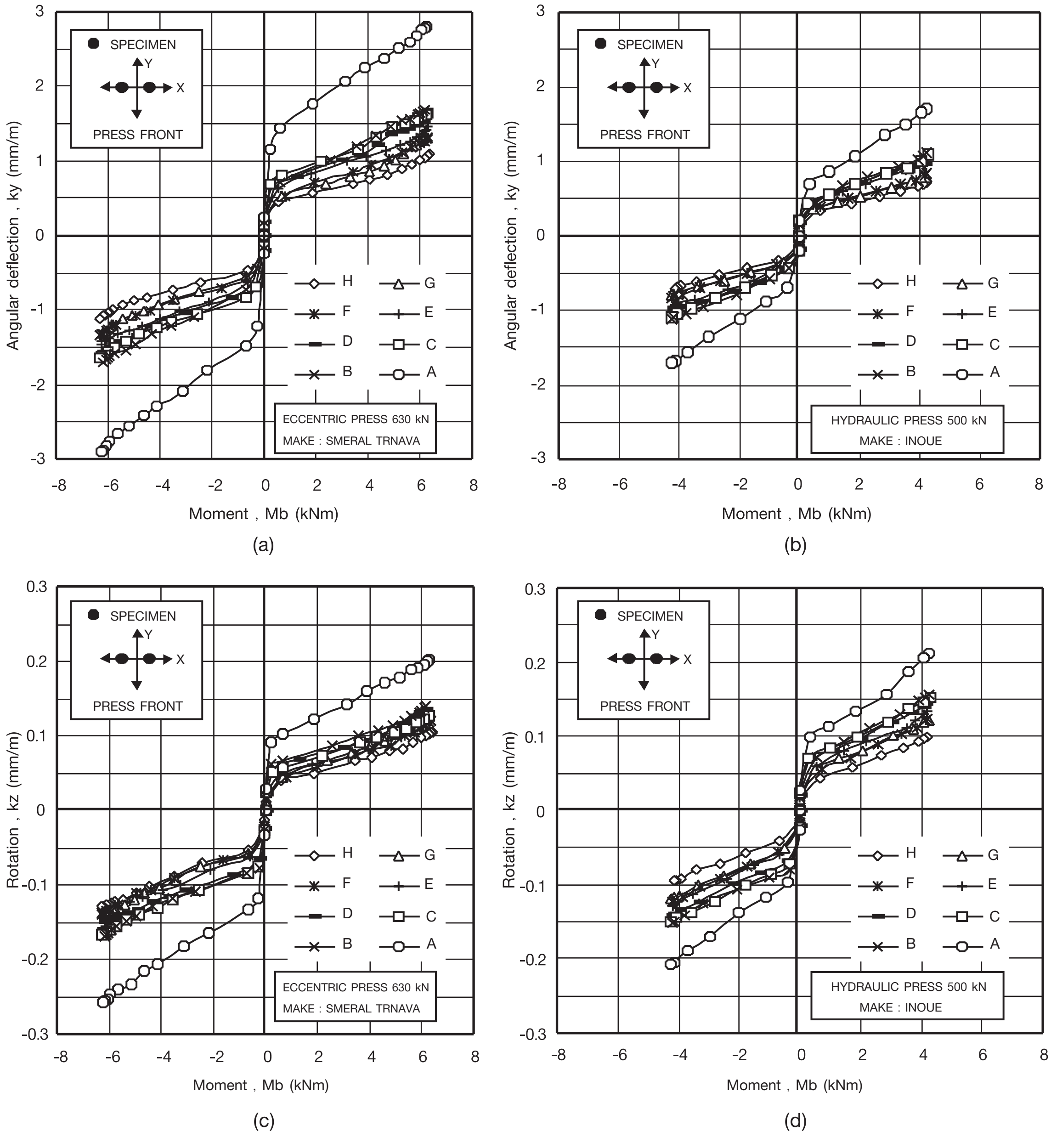
Fig. 6 Influences of slide clearance on rotation of eccentric (a) and hydraulic presses (b) from off-center loading.

4.2 Influences of guiding systems

The results of angular deflection around Y axis, specimens were placed off center in x direction, and rotation of press slide around Z axis when using various type of die guiding system are shown in Fig. 7. The results of those when the specimen was placed eccentrically in y-y direction are not shown here due to small values and having the same trend. The slide clearance was set to be constant at 0.1 mm. It can be noticed that by using any types of die-guiding system, the amount of angular deflection and rotation is significantly reduced for both presses. Pillar type with larger diameter provided better result than smaller diameter for both plain and ball bearing types. It is obvious that large diameter of guide pin and bush has high resistance to angular deflection. The experiments using ball bearing pillar type had shown negligible improvement when compare to that using plain pillar type of comparable diameter. Heel block type provided better improvement than pillar type. This is due to the surface area resisting bending force of heel block guide is larger than that of pillar type. Moreover, the surface perpendicular to the bending force for heel block guide is flat while that of pillar guide is cylindrical. The combination of heel block type and large diameter of 32 mm pillar type had undoubtedly shown maximum improvement of slightest deflection.

The angular spring constant around Y-axis (C_{KY}) and the improvement in angular deflection for each type of guiding system under eccentric loading were calculated and illustrated in Table 1. The result of angular deflection detected from hydraulic press is lower than that from eccentric press when using no guidance. This indicated that angular stiffness from original design of the hydraulic press is higher than that of eccentric press. The combination of 32 mm diameter guide pillar and heel block guide provides the maximum improvement of 61.09% in angular deflection for eccentric press and 58.3% for hydraulic press.

The rotation of slide around Z-axis and the improvement in rotation for each type of guiding system under both eccentric press and hydraulic press are shown in Table 2. The amount of rotation around Z-axis is a lot less than angular deflection around Y-axis. This is due to the direction of moment applied. Therefore, the angular spring constant around Z-axis is always higher than that around Y-axis. However, similar trend of the maximum improvement is yielded when combination of 32 mm diameter pillar type and heel block type guide is used.



A = No Guidance B = Pillar Dia. 25 mm C = Ball Bearing Pillar Dia. 25 mm

D = Pillar Dia. 32 mm E = Heel Block F = Heel Block & Pillar Dia. 25 mm

G = Heel Block & Ball Bearing Pillar Dia. 25 H = Heel Block & Pillar Dia. 32 mm

Fig. 7 Experimental results when using various die-guiding systems

(a) angular deflection as a function of off center loading for eccentric press

(b) angular deflection as a function of off center loading for hydraulic press

(c) rotation as a function of off center loading for eccentric press

(d) rotation as a function of off center loading for hydraulic press

Table 1 Improvement in angular deflection around Y axis for each type of guiding system under both eccentric press and hydraulic press

Die Guiding System	Eccentric Press			Hydraulic Press		
	Angular Spring Constant (C_{ky}) (KNm/mm/m)	Angular deflection (mm/m)	Improvement (%)	Angular Spring Constant (C_{ky}) (KNm/mm/m)	Angular deflection (mm/m)	Improvement (%)
No guidance	3.79	2.84	-	4.20	1.71	-
Pillar dia. 25 mm	6.39	1.69	40.60	6.29	1.11	35.01
Ball Bearing Pillar 25 mm	6.61	1.64	42.23	6.50	1.08	36.58
Pillar dia. 32 mm	6.94	1.55	45.30	7.43	0.99	42.35
Heel block	7.58	1.45	48.95	7.87	0.95	44.46
Heel block & Pillar 25 mm	8.08	1.32	53.38	9.76	0.83	51.75
Heel block & Ball Pillar 25 mm	8.16	1.29	54.63	9.91	0.80	53.27
Heel block & Pillar 32 mm	9.79	1.10	61.09	11.26	0.71	58.30

Table 2 Improvement in rotation around X axis for each type of guiding system under both eccentric press and hydraulic press.

Die Guiding System	Eccentric Press			Hydraulic Press		
	Angular Spring Constant (C_{ky}) (KNm/mm/m)	Rotation (mm/m)	Improvement (%)	Angular Spring Constant (C_{ky}) (KNm/mm/m)	Rotation (mm/m)	Improvement (%)
No guidance	50.55	0.23	-	37.96	0.21	-
Pillar dia. 25 mm	72.68	0.15	32.83	52.29	0.15	26.60
Ball Bearing Pillar 25 mm	74.39	0.15	34.15	53.34	0.15	27.88
Pillar dia. 32 mm	77.81	0.14	40.15	56.22	0.14	32.02
Heel block	80.32	0.13	42.20	59.28	0.13	37.43
Heel block & Pillar 25 mm	82.18	0.13	43.87	62.14	0.12	41.40
Heel block & Ball Pillar 25 mm	83.14	0.13	45.35	63.51	0.12	42.83
Heel block & Pillar 32 mm	90.61	0.12	49.13	77.62	0.10	54.02

5. Conclusions

1. Clearance setting on the press slide is found small effect to angular deflection and rotation of press slide under eccentric load.
2. Angular deflection and rotation of press slide under eccentric load can be reduced by using die-guiding system.
3. Heel block type guiding system yields better performance to the part accuracy comparing to ball bearing pillar or pillar type. Improvement in angular deflection for eccentric and hydraulic press are 48.95% and 44.46% when using heel block guide, are 42.23% and 36.58% when using ball bearing pillar type and are 40.60% and 35.01% when using pillar type.
4. The combination of large diameter guide pillar and heel block guide provides the maximum improvement of 61.09% in angular deflection and 49.13% in rotation for eccentric press and 58.3% in angular deflection and 54.02% in rotation for hydraulic press.

6. References

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