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Prediction of slug carry-up by the punch in blanking by air-blow of the slug

R.Q. Hsu*, J.R. Chang, D.L. Liang

Department of Mechanical Engineering, National Chiao Tung University, EE407 1001 Ta Hsueh Road, Hsinchy 300-10, Taiwan

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ABSTRACT

Blanking is one of the press working operations most often encountered in sheet-metal processing. The punched part or slug which should fall down through the die cavity was occasionally brought upward by the punch and dropped on the strip stock which will hinder the following blanking operation. Though there are many ways to reduce this problem, however, this phenomenon still exists when stamping a very thin gauge strip in a high-speed press. Methods which can help us predict the occurrence of the slug suck-up by the punch in blanking are thus important. In this study, a prediction method is proposed for the occurrence of the phenomenon by air-blow of the slug. Parameters like material tensile strength, punch/die clearances, punch chamfer degree, punch corner radius were considered in organizing the experiment plans. The results showed that the slug carry-up forces measured from direct air-blow of the slug can be adopted as a criterion for the occurrence of the phenomenon. The best and worst parameter combinations were also identified by this method.

1. Introduction

In continuous blanking or stamping of sheet-metal stock, slugs are sometimes brought-up by the punch head (Fig. 1). When these punched parts or slug fall down on the strip stock, a defect part will arise from this phenomenon. Especially when the sheet stock becomes thinner, the slug carry-up phenomenon also becomes more often. The result is that the continuous press operation has to be stopped, which in turn greatly reduces the efficiency of the blanking operation.

Several forces are responsible for slugs being carried up by the punch. Namely, the vacuum force created between punch and slug, galling force of the punch on the slug or sticking force of the lubrication (Nobuhiro and Isamu, 2007a). It is obvious that light gauge slugs have less weight to counter the above forces. Thus, they are far easier to suffer the problem. Though many counter measures (Nobuhiro and Isamu, 2007b) could be taken in order to avoid the phenomenon, however, there are side-effects like concave or convex products which are not tolerable in many applications. In this study, we proposed a prediction method for the occurrence of the slug carry-up phenomenon by air-blow of the slug. Four parameters, namely material tensile strength (A), punch/die clearance (B), punch chamfer degree (C), punch corner radius (D) were considered as the major parameters in the experiment.

2. Experimental procedure

Force that might cause a punch head to carry up the slug from the die cavity was measured individually by compressed air-blow of the slug and push–pull scale after the punch was

* *Corresponding author*. Tel.: +886 3 5712121.
E-mail address: starpiece@gmail.com.tw (R.Q. Hsu).
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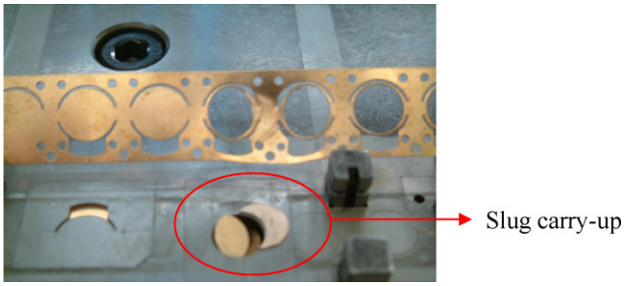

Fig. 1 – Defects caused by the slug carry-up in blanking.

retracted from die cavity. Fig. 2 shows a schematic of the slug carry-up force-measuring device. Tensile strength, punch/die clearance, punch chamfer degree and punch corner radius were selected as the major parameters in the study. Each parameter with three variations was selected for construction of an experiment plan as shown in Table 1. Table 2 shows the parameter combination of the experiments as organized by Taguchi method. Nine experiments in total were required to carry out in order to investigate the interaction of each parameter on the slug carry-up phenomenon. The punch used in the experiments was made of tool steel SKD11 with a hardness of HRC58. The minimum force that can push the slug out from the die cavity was measured by blowing the slug from under-side with compressed air right after punch head was retracted from the die cavity. The pressure of the compressed air was adjusted until the slug was blow out from the die cavity. Accordingly, 10 repeated experiments for each parameter combination were conducted, and the measured forces were recorded in Table 3. Furthermore continuous blanking was carried out for each parameter combination for at least 10 punches. Besides, the occurrence of the slug carry-up was recorded in Table 4. Here "OK" indicates no slug carry-up by the punch is observed, while "NG" means slug carry-up occurred. Slug carry-up forces after 100, 1000, 10,000, 20,000 and 30,000 strokes were measured for experiment no. 5 and no distinctive differences were found from those shown in Table 3. However, after about 300,000 strokes, the punch began to exhibit edge wear and punch corner burrs appeared, which require re-grinding.

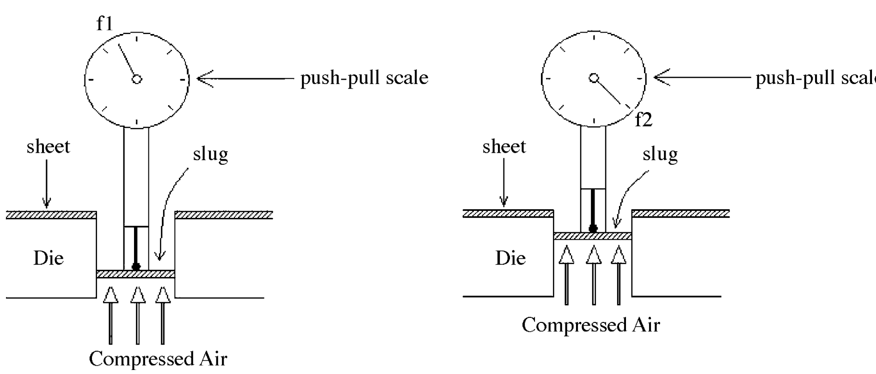

Fig. 2 – Slug carry-up force-measuring device.

Table 1 – Experiment parameters and variation

Control factors	Level 1	Level 2	Level 3
Material types and tensile strength, σ_{ts}	Brass C2680H and 42–55 kgf/mm^2	Phosphor bronze C5210H and 60–72 kgf/mm^2	Phosphor bronze C5210SH and 75–81 kgf/mm^2
Punch/die clearance (% blank thickness)	1	3	5
Punch chamfer (°)	0	5	10
Punch corner radius, R (mm)	<0.1	0.1	0.2

Table 2 – L9 (3^4) orthogonal array

Experiment	Material	Clearance	Punch chamfer (°)	Punch corner radius (mm)
1	C2680H	1%(t)	0	<0.1
2	C2680H	3%(t)	5	0.2
3	C2680H	5%(t)	10	0.1
4	C5210H	1%(t)	5	0.1
5	C5210H	3%(t)	10	<0.1
6	C5210H	5%(t)	0	0.2
7	C5210SH	1%(t)	10	0.2
8	C5210SH	3%(t)	0	0.1
9	C5210SH	5%(t)	5	<0.1

Table 3 – Slug carry-up forces (kg)

Experiments number	Repetitions number												
	1	2	3	4	5	6	7	8	9	10	S/N ratio	Average	S.D.
1	2.6	2.7	2.55	2.95	3.6	4.4	3.3	3.5	4.0	3.2	9.930	3.280	0.612
2	1.1	1.4	1.2	1.4	1.1	1.1	1.9	1.6	1.5	1.7	2.478	1.400	0.279
3	2.3	1.7	1.75	1.9	1.7	1.9	1.9	1.7	2.4	2.0	5.516	1.925	0.249
4	3.0	2.2	2.7	2.3	2.2	2.4	2.5	2.4	2.6	2.4	7.749	2.470	0.245
5	2.9	3.5	3.4	3.3	3.9	2.7	3.5	3.4	3.3	3.5	10.346	3.340	0.334
6	0.01	0.01	0.01	0.01	0.01	0.1	0.1	0.01	0.01	0.01	−39.042	0.028	0.038
7	1.7	2.8	2.4	1.8	2.4	2.3	2.0	2.3	2.2	2.1	6.594	2.200	0.320
8	0.01	0.01	0.01	0.01	0.2	0.3	0.4	0.01	0.01	0.01	−38.454	0.097	0.148
9	1.0	0.7	0.2	1.9	0.1	0.01	0.01	0.01	1.7	0.01	−36.035	0.564	0.735

Table 4 – Occurrence of the slug carry-up phenomenon

	1	2	3	4	5	6	7	8	9	10	Normal	Slug carry-up occurrence
1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	10	0
2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	10	0
3	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	10	0
4	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	10	0
5	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	10	0
6	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	0	10
7	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	10	0
8	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	0	10
9	OK	NG	NG	OK	NG	NG	NG	NG	OK	NG	3	7

3. Results and discussion

It is interesting to note that the force recorded in Table 3 can be divided into two categories. One category of these forces have fairly large blow out force value (>1.0 kgf) and the other category are the forces with very small value, usually in the order of 0.01 kgf. For parameter combinations which produce very small slug carry-up forces, for example, experiment no. 6, continuous blanking of the sheet strip was also tried. However, we found, for each stroke, the punch brought-up the slug from the die cavity, making continuous press operation impossible. We concluded that the differences in slug carry-up force could be adopted as a criterion for judgment of the occurrence of slug carry-up phenomenon. Thus, we postulate that forces smaller than 1.0 kgf may selected as a criterion for possible slug carry-up occurrence in this particular experiment.

The validity of this criterion is then subjected to an independent experimental verification as shown below. Slug carry-up forces measured per experiment conditions of Table 3 were checked for S/N ratio. The result is recorded in Table 5. In this case the larger S/N ratio is, the larger the force required for slug to be carried upward by the punch. Combination of A1, B1, C3 and D1 was found to have the largest S/N values of the slug carry-up forces among all the parameter combinations. That is to say the least possible occurrence of the slug carry-up phenomenon. The data acquired from the experiments were then subjected to analysis of variance (ANOVA) to check for errors and the significance of each parameter. Table 6 presents the calculated results. Also, from ANOVA results, punch/die clearance, punch chamfer degree, and material strength are much more significant in terms of effects on the slug carry-up forces. On the contrary, punch radius has almost no effect at all. The best parameter combination obtained from analysis was A1, B1, C3 and D1, which corresponds to materials C2680H, 1% die/punch clearance, punch chamfer 10°, punch radius <0.1 mm. This parameter combination was undergone a continuous stamping test. No slug carry-up occurred even after 300,000 strokes. On the other hand, the worst parameter combination of C5210SH 5% punch/die clearance, 0 punch chamfer, and 0.2 mm punch radius could not be stamped continuously since for each stroke, the punch brought-up the slug. The experiments stopped at 10 repetitions. The same phenomenon occurred for experiment conditions 6, 8, and 9. Thus it seems reasonable to say that differences in the slug carry-up forces could be used as a criterion for the possible occurrence of the phenomenon.

Table 5 – S/N ratio of the parameters

Level	A	B	C	D
1	5.97	8.09	−22.52	−5.25
2	−6.98	−8.54	−8.60	−8.40
3	−22.63	−23.19	7.49	−9.99
Effect	28.61	31.28	30.01	4.74
Best combination	A1	B1	C3	D1

Table 6 – Analysis of variance

Factor	Sum of squares	Degrees of freedom	Mean square	Variance ratio	Confidence
A	26.08	2	13.04	86.84	1.00
B	49.55	2	24.77	165.00	1.00
C	29.70	2	14.85	98.91	1.00
D	22.93	2	11.47	76.37	1.00
Others	0.00	0	0.00	0.00	0.00
Error	12.16	81	0.15		
Total	140.41	89			

4. Conclusion

Occurrence of the slug carry-up phenomenon in blanking was predicted by forces measured from air-blow of the slug. Punch/die clearance, punch chamfer degree, punch radius and materials tensile strength were selected as the experimental parameters. Analysis of the slug carry-up forces leads to the following conclusion:

(1) Slug carry-up forces can be measured from direct air-blow of the slug and load indicator.
(2) Differences in slug carry-up forces could be adopted as a criterion for the occurrence of the slug carry-up phenomenon.
(3) Punch corner radius has no apparent effects on the phenomenon.

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