Knowledge-Based Sequence Planning of Shearing Operations in Progressive Dies

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Introduction

This paper aims to study the methodology of building the knowledge of planning adequate punches in order to complete the task of strip layout for shearing processes, using progressive dies. The proposed methodology uses die design rules and characteristics of different types of punches to classify them into five groups: prior use (the punches must be used first), posterior use (must be used last), compatible use (may be used together), sequential use (certain punches must precede some others) and simultaneous use (must be used together). With these five groups of punches, the searching space of feasible designs will be greatly reduced, and superimposition becomes a more effective method of punch layout. The superimposition scheme will generate many feasible solutions, an evaluation function based on number of stages, moment balancing and strip stability is developed for helping designers to find better solutions.

Introduction

Progressive dies design is a highly experience-intensive task. Designers have to do a lot of time-consuming trial and error, involving tradeoffs and compromises [1]. Although the design rules and empirical equations are all listed in the die design handbooks and publications [2-3], they are too scattered and incomplete. They can do little to help designers, who need a more efficient and effective way to manage the design process.

With drawing of a sheet metal part, a progressive die designer begins to decide the appropriate punches according to internal holes and external profiles; this process is called dedicated punch design. The designer will plan how to superimpose the designed punches on the strip in question. Using the sheet metal part in Fig. 1 as an example, the 8 punches used to produce the part are shown in Fig. 2. Punch layout using superimposition is quite straight-forward. The designer simply tries to place each punch on an appropriate stage of the strip(see Fig. 3) [4].

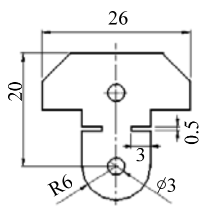

Fig. 1 Sheet metal part

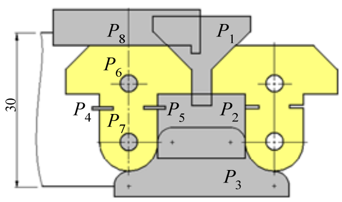

Fig. 2 Dedicated punch design

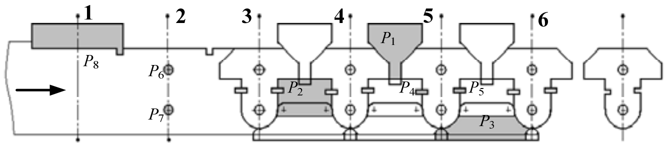

Fig. 3 Punch layout by superimposed punches

Punch Layout Process

In this study, there are three steps needed to solve the punch layout.

Step 1: Punch design

The punch design is to envision and then design all the punches needed to form every feature on the product.

Step 2: Feasible punch layout

When all the punches needed are well designed from the last step, we will then find the entire feasible punch layout; this means to find the entire layout that does not violate the punch and die design rules.

Step 3: Layout evaluation

There are many feasible punch layouts. We use an evaluation function to find out better layouts for the designer. In this study, the punch design is assumed to be a known condition, which lists and reserves all the punches needed for the product. So, we will stress feasible punch layout and layout evaluation.

Feasible Punch Layout

We needs three steps to deal with feasible layout: punch grouping, expansion of number of punches and punch layout.

(1) Punch grouping

Punch grouping involves dividing punches into five groups: prior use, posterior use, compatible use, sequential use and simultaneous use.

(a). Prior rules: In figure 4, the running stop and side cut punch P_8 must be placed in the first stage, and the pilot punches of P_6 and P_7 will be next to them.

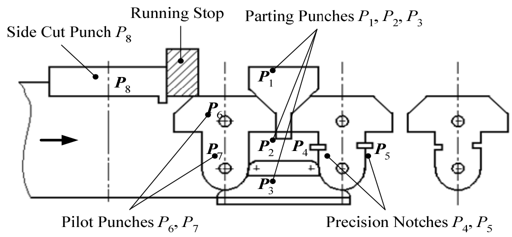

Figure 4 Punch grouping

(b). Posterior rules: The parting punch for bridge or carrier should be placed at the last stage. So at least one of punches P_1, P_2, or P_3 is used as a parting punch for disconnecting a part from the strip at the last stage.

(c). Simultaneous rules: If the dimensional accuracy among some of the features is of great concern, the features should be created in the same stage; this means the punches for the features should be in one group. The pilot punches [P_6, P_7] and the notch punches [P_4, P_5] are all required to be in one stage due to accuracy concerns.

(d). Sequential rules: If a small internal feature is very near to a large processing area, then the small feature must be processed after the previous processing is finished to avoid unwanted deformation. The accuracy of the distance between the two narrow notch features is crucial; the punches [P_4, P_5] should never be applied earlier than the P_2 punch.

(e). Exclusive rules: If footprints of punches overlap in their superimposed layout, or the punches are so close that the dies may become too weak to sustain the punching force, these punches should not placed at the same stage.

With rules as above, we will find all the compatible groups for the punches in one stage.

1-punch compatibility= (P_1), (P_2), (P_3)
2-punch compatibility= (P_1, P_3), ([P_4, P_5])
3-punch compatibility= (P_1, [P_4, P_5]), (P_3, [P_4, P_5])
4-punch compatibility= (P_1, P_3, [P_4, P_5])

(2) Expansion of number of punches

Progressive dies have at least two sets of die combined; hence with n punches, the minimum number of stages is two, and the maximum is n. The next problem is how many punches at one stage; this can be solved by expansion of number of punches. Using 8 punches as an example, 2-stage design can be expanded totally in 7 ways; there are 1+7, 2+6, 3+5, 4+4, 5+3, 6+2 and 7+1. A 3-stage design can be found by expanding a 2-stage. Taking 2+6 as an example, there are 2 punches at the first stage and 6 punches at the second, and it can be expanded into 2+1+5, 2+2+4, 2+3+3, 2+4+2 and 2+5+1. With the process, we will find all the possible combinations of stage design.

(3) Punch layout

The punch layout is a process to arrange the five groups of punches into stages, there are two steps in this process:

(a). Eliminate infeasible expansions of number of punches.

(b). Arrange appropriate punches into stages.

Layout evaluation

Through the process of punch layout, many inappropriate layouts have been deleted, and the rest are feasible solutions. This study uses three evaluation criteria to find better solutions from among them. The evaluation criteria are: number of stages (F_n), moment balancing (F_b) and strip stability (F_s). The evaluation score E_v is calculated using the following equation.

$$E_v = w_1 \times F_n + w_2 \times F_b + w_3 \times F_s \quad (1)$$

Where $0 \le w_1, w_2, w_3 \le 1$, and $w_1 + w_2 + w_3 = 1$. The weighting factors w_1, w_2, w_3 in (1) are chosen by the designers. All these three evaluation factors are formulated to range from 10 to 100. The sum makes up the evaluation score.

(1) Number of stage factor F_n

The number of stage factor is a measurement of cost and production flexibility.

$$F_n = 100 - 90 \times (N-2)/(n-2) \quad (2)$$

(2) Moment balancing factor F_b

The moment balancing factor is a measurement of how close the center of the resultant reaction force is to the position of the ram of the press.

$$F_b = 100 \times (1 - 0.9 \times d / D_{max}) \quad (3)$$

(3) Strip stability factor F_s

The Strip stability factor is a measurement of how stable the strip is when moving through stages..

$$F_s = 70 \times \{\sum_{k=1}^{N-1} k \times (L_k / L_{Lk})\} / \sum_{k=1}^{N-1} k \quad (4)$$

Example: A 4-stage design (see Fig. 5)

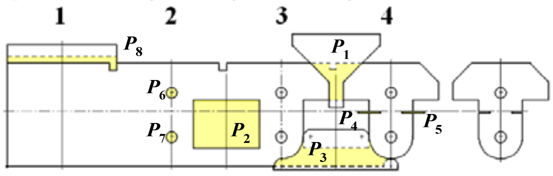

Fig. 5 (P_8)+([P_6,P_7])+(P_2)+(P_1,P_3, [P_4, P_5])
F_s= 70; F_b = 95.24, F_s = 96.40,
E_v=82.97

Conclusions

The punch layout for progressive dies is a design work trying to place punches into a die block, and it needs experienced designers to handle it. The real challenge is that n punches will have many possible solutions. Even after screening with design rules, the number of feasible solutions is still many for designers to choose from, and it becomes difficult to quickly produce a good layout. In our study, we propose a new approach to solve superimposed punch layout problems. The method can effectively reduce the searching space first, and then the use of three evaluating factors with user-defined weightings helps to find appropriate layouts. The procedure of punch layout takes designer's expertise and die design rules into consideration, so the result can yield better performance.

References

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