Development of Practical Blank Layout Optimization System for Stamping Die

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Abstract

The optimization of blank layout is of great importance in the design of stamping die. When developing the computer-aided optimization system for blank layout, not only the reasonable algorithm for blank layout, but also the practical manufacturing and the operation for user should be fully considered. In this paper, a practical AutoCAD-based optimization system for blank layout is introduced. The system has innovations on core algorithms for shape offsetting and calculation of layout parameters. So, the problems such as the pre-process of the blank graph and the accurate calculation of the layout parameters have been solved. Meanwhile, the general frame and the key technologies of the system are put forward.

Key words: stamping; blank layout; optimization

1. Introduction

Blank layout means the layout for stamping blank on coiled strip or board material. It is used to get higher material utilization while meeting the requirements of stamping technology. In addition, the result of blank layout is the premise of the design of strip layout and some die-parts such as die plate and stripper, so blank layout is of importance in stamping die design. Since 1970s, many researches have been done in the blank layout algorithm, but few concern how to build a practical optimization system for blank layout in which not only reasonable algorithm, but also the practical manufacturing and the operation for user can be fully considered. Based on the reasons mentioned above, a practical AutoCAD-based optimization system for blank layout has been developed by using ObjectARX toolkit. In this paper, the general structure and the key technologies of the system are introduced.

2. Blank layout analysis and layout algorithm selection

To simplify the problem, only the layout for one type of blank in 'infinite-length strip' will be considered, then the material utilization ratio

$$\eta = n \times A / (P \times W) \times 100\%$$

Here, P is feed pitch, W is strip width, n is blank number in one feed pitch, A is area of 1 blank.

The selection of layout algorithm is the core of system. Some algorithms have been known such as '*functional optimization method*', '*enumeration method*' and '*pixel intersection method*'. In the selection of algorithm, the practical manufacturing should be fully considered and the following constraints should be satisfied:

① Get higher material utilization ratio;

② To the part with bending, the bending line should be constrained in a certain angle range with the grain flow direction of the strip;

③ To the narrow part, the part should be constrained in a certain angle range to ensure the flatness of the strip;

④ Consider the constraint of strip width (max/min value is given) or feed pitch (max/min value is given) to satisfy certain strip width or feed pitch demands of user;

⑤ Consider the reasonableness of die structure design;

⑥ Accurately calculate the feed pitch and strip width (within the tolerance).

The material utilization is the aim function for optimization in blank layout, but not the only factor. Therefore, the enumeration method is much closer to the real practice. In this method, different layout angles and deviation-distances will be enumerated, and all possible plans with an array-type according to the utilization ratio will be generated; meanwhile with the constraints, the best plan will be decided.

3. Realization of blank layout optimization

The general structure of blank layout system is shown as Fig.1.

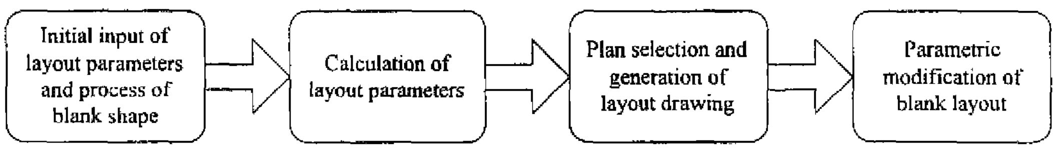


Fig.1 General structure of blank layout system

3.1 Initial input of layout parameters and process of blank shape

(1) Initial input of layout parameters

To provide all initial parameters for the whole system, it mainly includes:

① *Pre-selected layout mode*: 9 types of layout modes have been defined, and almost cover the 1, 2, 3-row regular layout for single blank and the layout for mirrored parts.

② *Angle range of optimization*: the default value is 0°~180°, and the default increment is 5°; moreover, it can be elaborated near the optimal plan.

③ *Constraints of bending and flatness of strip.*

④ *Webs*: include web among parts (pitch web) and web between part and edge (edge web).

⑤ *Value of strip width and feed pitch constraints.*

(2) Process of blank shape

It mainly includes blank shape acquisition, blank contour checking and shape offsetting, etc. The core is the offsetting technology of blank shape, it is described as follows.

In order to take the pitch web into account, the outer contour of the part will be enlarged (offsetted) by half of the pitch web along the normal line. During the blank layout, the original blank will be replaced by the enlarged contour, and the enlarged contours should be tangent each other to ensure the minimum space between the original blanks (shown in Fig. 2). The conventional offset algorithm is mature, but to the shape with concavity, if the offset distance is bigger than certain value, the self-intersection will occur, as shown in Fig. 3. Since some software has problem in dealing with such interference, a simple and convenient algorithm is put forward in this paper. The main idea is as follows:

① By using conventional offset algorithm, get an offset curve which has end to end nodes and also obtain all self-intersection points. Break all the graph elements which go through these self-intersection points and create graph set *SET1* without self-intersection. Calculate the highest and lowest points of *SET1*, and if such points are inside an arc, also break the arc at these points.

② Go through *SET1* clockwise from the very bottom-left node P_1 (start node), and find all elements with the same node P_1. By using certain judging method, such as the angle between 2 vectors, find the very external element to generate the offset curve. Iterate the above-mentioned step till the node goes back to the start.

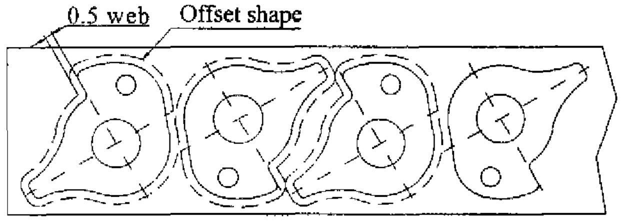


Fig. 2 Web process in layout

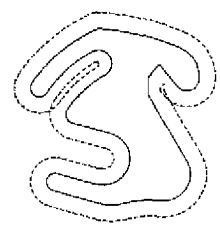


Fig. 3 Self-intersection of offset shape

3.2 Calculation of layout parameters

Optimize the layout by using certain algorithm, and save the result parameters of each plan, such as utilization ratio, strip width and feed pitch, into the corresponding data structure. Here the '*1-step translation method*', a traditional enumeration method, is improved to solve the contradict between precision and efficiency during layout calculation. Take the *opposite 2-row layout* as an example: since here, $\eta=\eta(\alpha, u)$ (u is for offset shape), fix the angle α firstly, and then do as follows:

① At this angle α, copy, rotate and translate the offset shape I and the corresponding original shape I_0, get II and II_0 (Fig. 4(a)).

② Translate II and II_0 along with Y direction upwards, and keep the increment as Δu. When the deviation is u ($u=Y^{II}_{\min}-Y^{I}_{\min}$, $u\in[-\Delta y(\alpha), \Delta y(\alpha)]$, $\Delta y(\alpha)=\left(y'_{\max}-y'_{\min}\right)\big|_{\alpha}$), in the interlocking area of I and II in Y direction, calculate the extremum of transversal distance of all elements of I and II in this area, which is named as P_A (Fig. 4(b)). In addition, calculate the strip width W (in current u) according to the geometry relationship between I_0 and II_0, and the edge web as well.

③ Translate II and II_0 towards right direction (P_A is algebraic value), get III and III_0, that is the position of the second shape in layout drawing (Fig. 4(b)).

④ In the interlocking area of I and III in Y direction, also calculate the extremum of transversal distance of all elements of I and III in this area, which is named as P_1; furthermore, calculate the transversal distance of I itself, which is named as P_2. Set feed pitch $P = max(P_1,P_2)$.

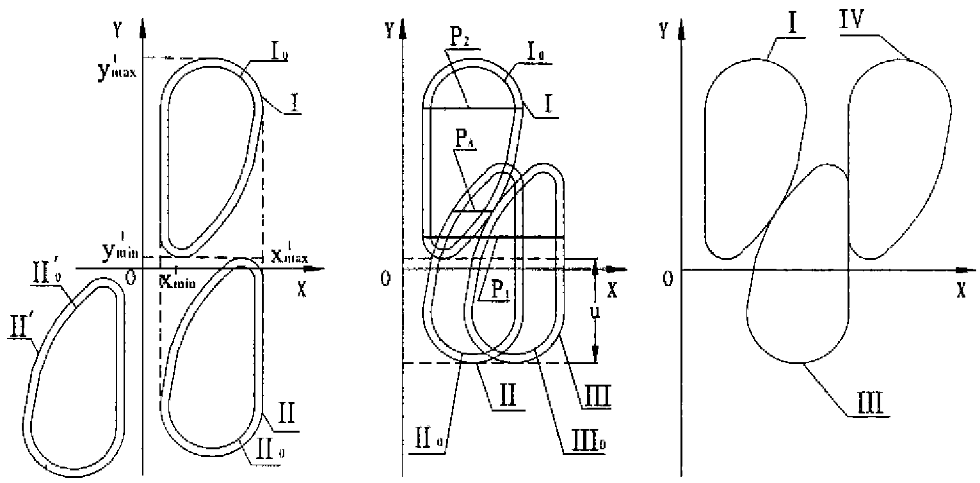
⑤ Copy I and translate it right direction with P and get IV, that is the position of third shape in layout drawing (Fig. 4(c)). Calculate the utilization ratio η in current u.

Iterate u according to above steps and get η of different u at that angle, and take η_{max}; then iterate α and record optimal layout plans.

The main characters of the algorithm are as follows:

① Get accurate feed pitch by calculating the extremum of transversal distance of two elements. The method can be resolved as line-line, line-arc and arc-arc situations. The main idea is to get the pitch by creating transversal line through nodes of element and stationary point of arc.

② Since some variations will take place from original shape to offset shape, especially at the non-arc transitional places, so it is difficult to arrange the original shape in generating layout drawing and calculating the strip width accurately by using traditional algorithm. In this improved algorithm, the original shape join the layout process and the relationship between original shapes will be recorded, so it is convenient to create the drawing and the strip width will be accurate.



(a) Layout step ①   (b) Layout step ②③④   (c) Layout step ⑤

Fig.4 Illustration of blank layout procedure

3.3 Plan selection and generation of layout drawing

To the regular layout, a chart of *Utilization ratio vs. Part rotation angle* like Fig. 5 will be created to help user select best plan. In this chart, different colors can be used to describe the attribute of the plan. For example, the red indicates current plan, the blue indicates the non-current plan, the gray indicates the plan not satisfying certain constraints (such as the strip width requirement). After user select a certain plan, the real layout drawing can be displayed by the *Preview* function to compare possible plans easily. In brief, the convenient operation and friendly interface for user is the purpose of this module.

3.4 Parametric modification of blank layout

The parametric modification of blank layout responds to user's modification requirements after finishing the blank layout design. It will calculate the corresponding parameters automatically and refresh the layout drawing. During development, it is of great importance to define the modification methods which are both easy to realize by the developer and acceptable by user. Following functions are defined:

(1) *Plan re-select*: Select another plan from the plan list.

(2) *Change feed pitch*: Change the distance between adjacent blanks of the same row. The change in opposite 1-row is complex in realization, as shown in Fig. 6. The key is to find the proper position of blank II to keep almost same minimal distance with blank I and III in normal direction after the change from *Pitch1* to *Pitch2*. Here the 'binary divide searching method' is used to translate II left or right till *dist1*'-*dist2*'<ε (ε is defined according to the tolerance of feed pitch).

(3) *Change strip width*: The function only changes the top and bottom webs, and will not change the position between blanks in different rows.

(4) *Change webs*: The top, bottom web and middle web (only for mirrored part layout) can be

modified separately, and the corresponding strip width will be calculated.

(5) *Change deviation-distance*: The 'deviation-distance' is used to express the relative distance of two adjacent blanks. The definition is: if *origin1* and *origin2* are the geometrical centers of the first and second blank in layout drawing, then the deviation-distance:

$$X12 = origin2[X] - origin1[X]$$

$$Y12 = origin2[Y] - origin1[Y]$$

The relative distance of two adjacent blanks can be modified by changing $X12$ and $Y12$. The nest problem, which is difficult to solve in automatic layout, can also be realized by changing the deviation-distance interactively.

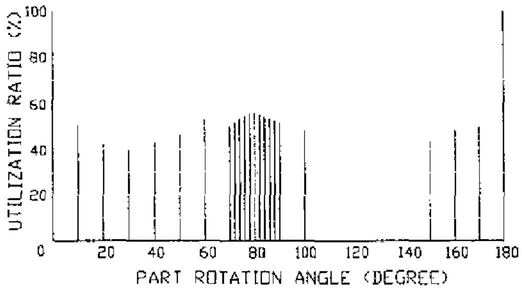
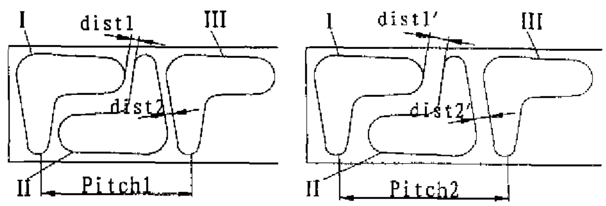


Fig.5 Chart of *Utilization ratio vs. layout angle*



(a) Before modification (b) After modification

Fig. 6 Feed pitch modification in *opposite I-row layout*

4 Conclusion

(1) To a practical optimization system for blank layout, not only the reasonable algorithm for layout, but also the practical manufacturing and the operation for user should be fully considered.

(2) A new algorithm for offsetting blank shape is put forward and it can basically solve the interference problem of offset shape, and satisfy the pre-process requirements of blank layout. An improved layout algorithm can get the feed pitch by calculating the extremum of transversal distance of two elements, and solve the problem of accurate calculation of layout parameters.

(3) A complete set of modification mechanism of blank layout is an important way to make the system more practical.

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