Research of Computer Aided Select Plank of Optimal Layout

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***Abstract*—Enterprise must select plank specification when cutting rectangle fragments in a plank. An analysis system of computer-aided optimal layout has been designed in this paper. Run this system, it could show optimized layout figure, output material utilization and cutting-tool wear's parameter. The elements, the methods and algorithms of optimal selecting plank are introduced in this paper; by running the analysis system, some simulation experiments have been done. According to the result of experiments, the paper concludes that if plank specification could be selected which second round optimization choice in all kinds of planks scientifically, it would ensure maximum utilization rate of materials and minimum wear of cutting-tool when cutting rectangle fragments in one plank. It is very important to achieve the target which reduce costs and improve enterprise's profits.**

Keywords-Optimal layout; Computer-aided design; Analogy experiment; Optimal select plank

I. INTRODUCTION

Plank's specification must be selected when cutting some original rectangle fragments in a plank. First, do optimal layout design in every plank. Second, analysis and contrast various layout schemes. Third, calculate material utilization and cutting-tool wear parameters in different planks. In the end, select the specification of plank that has the highest material utilization ratio and the lowest wear of cutting-tool, show optimal layout schemes of selected-plank. These are works of optimal select planks.

Select one plank scientifically is based on the optimal layout design. In computer-aided optimal layout's research, the literature [1] made research methods' guidance about planks' layout optimization and selecting planks, laid a solid research foundation for computer optimal layout algorithms. Refer to the recent literature [2] - [8] in the field of computer- aided optimal layout, experts and scholars in the research of algorithm theory about cutting rectangle fragments in plank have made great progress and breakthrough. But literatures are focusing on the theoretical research of algorithm. On the basis of optimal layout of plank, the literatures about selecting planks' specifications scientifically are not much.

Paper in view of the above problems and the current research status, referring to a large number of references on optimal layout algorithms which cutting rectangle components in a plank. Analysis, comparing the algorithm of references [2] - [8], according to specific application of computer- aided select planks' specifications, a computer-aided optimal layout analysis system is designed. By running this analysis system, input size of plank and rectangle fragment, it can generate emulation layout figure, and output data of material utilization and cutting-tool wear parameters. On the basis of single plank optimal layout, put forward some methods and algorithms of optimal selecting plank scientifically. It is very meaningful to research how to choose material specification to achieve the target of reduces production costs and improve corporate profits.

II. THE ELEMENTS OF OPTIMAL SELECTING PLANK

A. Maximization of Material Utilization

1) The plank's utilization rate:

Set *bc* is the length of plank, *bk* is the width of plank; *gc* is the length of component, *gk* is the width of component; *m* is number of components in a single plank; *y* is plank utilization rate.

$y = [(gc \times gk \times m) \div (bc \times bk)] \times 100\%$[1]

The more the utilization rate of a plank is, the less the scrap will be.

2) The method of research:

The procedure of optimal solution is described below:

{
Input sizes of plank and fragment;
Do function of calculate *m;*
Calculate *y;*
If there is only one plank whose material utilization ratio is highest
Then
The plank is solution;
Do 2) of C // solution of a single plank optimal layout;
Else
Record these planks whose material utilization ratios are highest;
Do 2) of B // minimum of cutting-tool wear.
Endif
}

B. Minimum of Cutting- Tool Wear

1) Relevant basic concept:

a) Stripe: Several same size components row together as a belt, this belt is referred to as a stripe. As be shown in figure 1[1].

Figure 1. stripe

b) Process of cutting a stripe into small components: Firstly, cut a plank into stripes with cutting tool; secondly, cut stripes into components with different cutting-tool according to this plank's material.

c) Cutting-number of cutting stripes into components: If there are n ($n > 1$) kinds of layout solutions whose components' number in the same plank are the same, then the cutting-number which cutting stripes into components is the same [1].

d) Cutting-number of plank: The cutting-number of plank = the number of cutting a plank into stripes + the number that stripes are cut into small components.

The less the stripes' number is, the less cutting-number that cutting a plank into small components will be, and the wastage of cutting-tool is also less.

2) The research methods: The procedure for optimal solution is described as below.

{
If there are k kinds of planks whose materials utilization ratios are highest
Then
Calculate their stripes' number/m^2 in a plank;
The plank whose stripes' number/m^2 plank is lest;
This plank is solution;
Do 2) of C // solution of a single plank optimal layout.
Endif
}

C. Optimization of plank layout scheme

Set m is the number of components which are layout in a plank, and d is the number of stripes in one plank. The procedure for optimal solution is described below.

{
If the layout scheme that a plank contains maximum components is only one
Then
This solution is optimal layout scheme;
Show the optimal scheme;
Else
Set $d_{min} = \min\{d_1, d_2 \cdots\cdots d_k\}$; d_i is the stripes' number of this plank on one of layout ways;
The solution of $d = d_{min}$ is optimal layout solution;
Show the optimal scheme.
End if
}

III. THE METHOD AND ALGORITHM OF OPTIMAL SELECTING PLANK

A. The method of selecting plank

1) The method of selecting plank when all planks' material utilization are not the same: On the basis of plank optimal layout, all kinds of planks' material utilization should be record, if all kinds of planks' material utilization rate are not the same, the plank which has the largest material utilization rate will been optimal solution.

2) The method of selecting plank when several kinds of planks' material utilizations are the most: If there are several kinds of planks' material utilizations are the most, stripes' number in per square meters should be calculated, and if there is one plank whose number of stripes in per square meters is the least, this plank will be identified as optimal plank's specification.

B. The Algorithm

Let $y_{max} = Max\ \{y_1, y_2 ... y_n\}$; //$n$ is the sorts of plank specifications.

{
If there are k kinds of planks , their material utilization ratios = y_{max};// k is natural number ,and $k \leqslant n$.
Then
{
If $k \neq 1$
Then
Calls the function of calculating d_k ;// d_k is stripe's number/m^2 in this plank;
Let $d_{min} = Min\ \{ d_1, d_2, ... d_k \}$;
{
If $d\ (a, b) = d_{min}$
Then $a \times b$ plank specification is optimal plank;
Show this plank's layout scheme whose strips' number is the least;
This is optimal layout scheme.
Endif
}
Else
The plank whose material utilization ratio= y_{max} is optimal layout plank;
Show this plank's layout scheme whose strips' number is the least.
Endif
}
Endif
}

IV. SIMULATION EXPERIMENT

A. *The experiment of determining optimal layout scheme*

1) The goal of experiment: Determine the optimal layout diagram.

2) The experiment process: 200 set inputting data which computer randomly made have been finished in this paper. Input-data include size of plank, size of component, blade length.

a) The simplest layout way : The layout way which number of stripes is minimum= the simplest layout way.

Run system→Choice "Parameter input interface" → Input the blade length in "Enter the blade length"→ Select "The simplest way of layout" to generate the simplest layout diagram which has the largest material utilization rate and the lest stripes number , as shown in figure 2 .

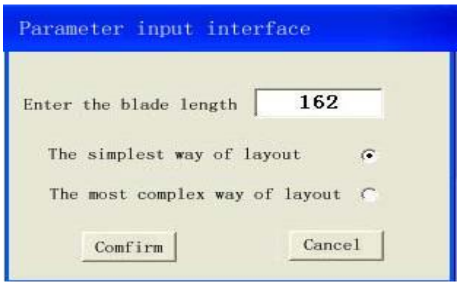

Figure 2 Parameter input interface- the simplest way of layout

b) Maximum number of stripes layout way: Return to "Parameter input interface" →Input the blade length in "Enter the blade length" → Select "The most complex way of layout" to generate the most complex layout diagram which has the largest utilization rate of material and the most stripes number , as shown in figure 3.

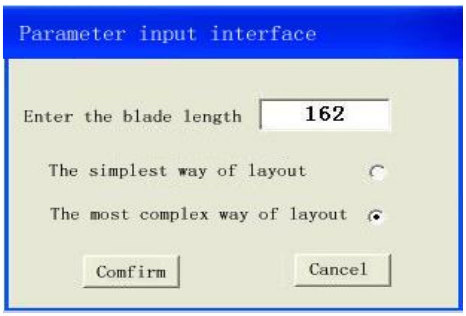

Figure 3 Parameter input interface- the most complex way of layout

c) Account for: if the minimum number of stripes layout diagram and the maximum number of stripes layout diagram are the same, then layout diagram of plank which there is the highest material utilization rate is only one; If the simplest layout diagram and the most complicated layout diagram are not the same, then the layout scheme whose material utilization are the most would have two or more, there is only one is the optimal layout diagram.

d) The blade length's influence to layout way: Test statistical data results as shown as in figure 4.

Run system→ Input 200 set data which are randomly generated by computer→Record and compare the minimum number of stripes layout diagram and the maximum number of stripes layout diagram .

From the results of the experiments see that there are 47 set data which have the largest material utilization, their layout diagram is only one, accounted for 23.5%. The rest there are 153 groups' data which have the largest material utilization, their layout diagrams are two or more, accounted for 76.5%, as shown in figure 4.

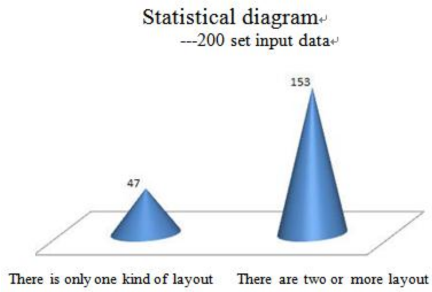

Figure 4 Statistical diagram

From the examination of 200 set data that we can find below law:

Set *kc* is the blade length, *bc* is the plank length:

{
If $bc \leqslant kc$
Then
Most of the data which have the largest material utilization is only one;
Else
Most of the data which have the largest material utilization are not only one
Endif
}

Conclusion: We should select short plank whose length is shorter than the blade length as far as possible, or cut a long plank into segments, because the blade length will affect layout way.

About how to cut a long plank into segments, it will be researched in another paper.

3) The case list: The plank specification is 480 × 192, please layout 18 ×11 components in this plank.

Input data: Run computer aided analysis system→Input plank and component sizes.

Output data: There are two kinds of layout diagrams whose material utilization is the biggest. The number of components is 464, and material utilization is 99.6875% in two layout diagrams.

Two layout figures, as shown in figure 5 and figure 6. The two layout diagrams have the same material utilization, their number of components are 464.

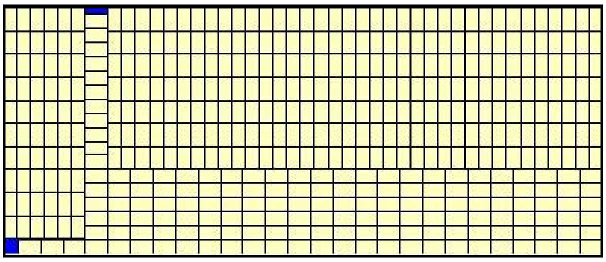

Figure 5. The plank layout diagram 1 of the case

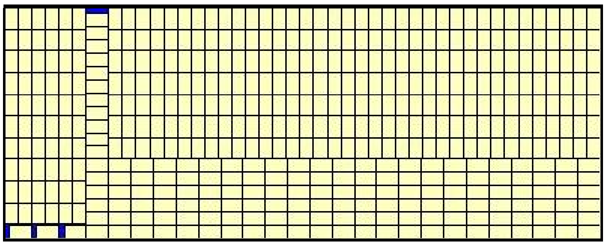

Figure 6. The plank layout diagram 2 of the case

In figure 5, three small blocks at the lower-left corner are together, it is one stripe; and in figure 5, there are three independent components at the lower-left corner, they are three stripes.

Obviously, the layout scheme of figure 5 is more optimal than the layout scheme of figure 6. So the optimal layout diagram is figure 5.

4) Conclusion: Most of input data can produce a variety of layout solutions whose material utilization is the largest.

Stripes' number/m^2 in plank is a very important index.

The layout way of minimum of stripes' number/m^2 in plank is the most simplify layout way. The fewer stripes' number/m^2 in plank is, the less cutting-tool's wear will be.

Therefore, in research of select plank specifications, on the basic of the most of material utilization, select the way of minimum of stripe number/m^2 in plank, achieve target which reduce the production cost and improve enterprise's profit.

B. The optimization of material selection experiment

1) The research goal: The optimization of select plank's specifications.

2) The case: One company needs many *25 cm × 15 cm* original rectangle components, there are five kinds of plank specifications, *300 cm ×200 cm, 380 cm × 250 cm, 420 cm × 328 cm, 286 cm ×143 cm, 334 cm x 243 cm.* The price of per square meter plank is the same.

Please select the most appropriate plank whose material utilization rate is the maximum and the cutting-tool wear is the minimum after optimal layout.

The experiment process is below:

Input data: plank size, fragment size.

Output data: material utilization, fragments' number, stripes' number, and stripes' number/m^2 in plank.

a) Run the computer aided analysis system: Input plank size, fragment size→Record output data: Material utilization, fragment number, stripe number, stripe number/m^2. As shown in table 1.

TABLE I. TABLE OF INPUT AND OUTPUT DATA

Input			Output			
NO.	Plank size	Fragment size	material utilization	Fragment number	Stripe number	Stripe number/m^2
1	300cm×200cm	25cm×15cm	99.798%	165	9	1.500
2	380cm×250cm	25cm×15cm	99.868%	253	12	1.263
3	420cm×328cm	25cm×15cm	99.085%	364	13	0.944
4	286cm×143cm	25cm×15cm	97.193%	106	16	3.912
5	334cm×243cm	25cm×15cm	98.127%	215	21	2.587

b) Analysis output data: According to optimal selection method, determine the plank's specifications.

We can see from table 1, material utilization rate is 99.868% in the second group of data, it is highest in all planks, the fragment number is 253, the stripe number/m^2 is 1.263, wear of cutting-tool is the minimum in all plank.

Meanwhile, we can also see that material utilization is only 97.193% in the fourth group of data, it is the lowest in all data, and the fragment number is 16, the stripe number/m^2 is 3.912, wear of cutting-tool is the maximum.

c) Select plank's specifications: Select the second plank's specifications.

According to the layout diagram of figure 7, in *380 cm ×250 cm* specifications plank, can be cut out 253 rectangle fragments in this plank, material utilization rate reached 99.868%, cutting- tool wear is the lowest in all plank.

d) Show planks' optimal layout diagram: Figure 7 is layout diagram of the second set data; it is the most optimal layout diagram in five sorts of planks. Figure 8 is layout diagram of the fourth set data whose wear of cutting-tool is the maximum, and material utilization is only 97.193%, is the lowest.

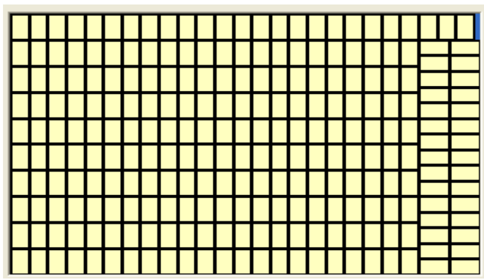

Figure 7. The optimal layout diagram of the second group of data

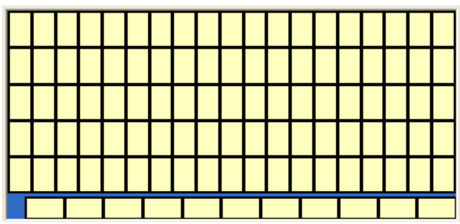

Figure 8. The layout diagram of the fourth group of data

4) Conclusion of optimal select material specifications: In the process of selecting material, if there are two or more planks' specifications whose material utilization are the same, as well as the highest, "stripe number/m^2 plank " will be an important measured parameters.

If stripe number/m^2 in one plank is the minimum after optimal layout experiment in every kinds of plank, this plank will be optimal selected.

V. CONCLUSION

It is a very difficult to select suitable plank for cutting components. First of all, to ensure layout the most fragments in the plank. Second, to ensure cutting- tool wear is the least.

Under the premise of the two conditions for each plank is guaranteed, do the second round optimization choice in all kinds of planks. Choose the plank which can be cut out the most components, and the least cutting-tool wear. This process is very complicated for workers.

To make these complex works become more efficient, paper designed a computer aided optimal layout analysis system, these complex works can be finished efficiently by using this system as the tool of optimal choice materials.

Each plank can achieve maximum materials utilization rate by computer aided layout design.

But, if there are many planks of specifications with the highest materials utilization rate, the stripe number/m^2 in plank will be calculated, select the specifications whose stripe number/m^2 in plank is the least, make the cutting-tool wear is the minimum.

The research methods for selecting plank such as paper not only may be applied on new purchases' plank, but also may be applied on rest of the rectangular plank in the early cutting plank process.

There is very important significance that making full use of plank and reduce wear of the cutting-tool. First it can reduce production costs and improve corporate profits. Second it can also achieve corporate goal of low carbon economic development.

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