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Mathematical Modeling and Analysis of Steel Cutting Blanking Problem

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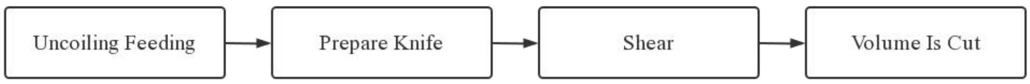
Abstract. The utilization rate of materials largely determines the efficiency of the factory. In this paper, the material is assumed. Based on the inherent material, three different types of order requirements are modeled to explore the optimal material cutting method. In the process of model construction, we should not only consider the order situation, but also deal with the relationship between orders, that is, the utilization of ' surplus material '.

Keywords: steel cutting, residual material utilization, rectangular layout optimization, tool arrangement optimization.

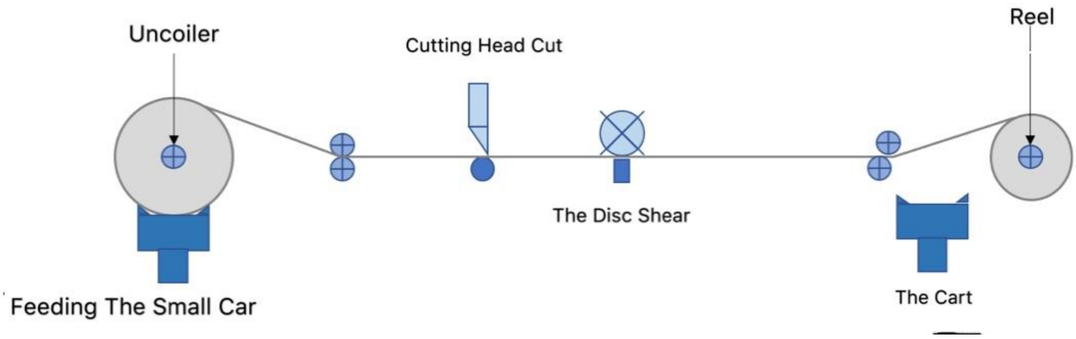
1. Background restatement

With the rapid development of the economy, many light and heavy industries have mushroomed and flourished, which also increases the consumption of raw materials for production. Steel, as one of the most important raw materials, has attracted much attention. Whether it can improve the utilization rate of steel also reflects the production efficiency of a factory. Based on the above social background, we analyze the cutting and cutting of steel.

The cutting of steel is mainly divided into four parts: uncoiling and feeding, knife preparation, cutting, coiling, and unloading. The flow chart is as follows:



The uncoiling feeding link is to place the raw material steel coil on the uncoiling machine, unfold and flatten it and send it to the operation area. The shear process is completed on the shear table, which is successively equipped with head shear and disc shear, as shown in the figure below:



The head cutter is the so-called one cut, that is, the whole steel plate is completely cut horizontally.

The core of the device is a disc shear, the main role of which is to use a rotating blade on the longitudinal movement of the raw material for continuous cutting. Before cutting the disc, it needs to be arranged according to the demand. It can be arranged arbitrarily but the line cannot exceed five knives. The order cut with the same row knife scheme is called a group of orders, cutting different groups of workers need to rearrange the knife, also known as a knife change, cutting each volume of raw materials need to change the knife. The details are shown in the figure below:

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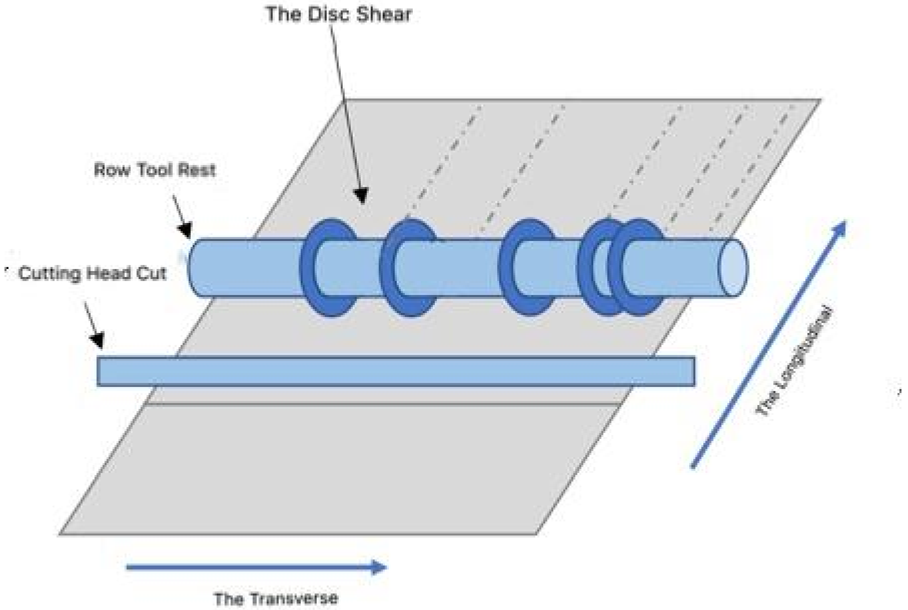

After the lateral cutting, if and only if an additional lateral cutting is needed to separate it from the waste, it can be moved to a small machine and cut again. The same order in the same group can be transformed into finished products at the same time with a single cutting. There are two kinds of steel cutting orders, namely sheet orders, and coil orders. The finished sheet orders are directly packaged by the feeding trolley and put into storage, while the winding materials need to be rolled by the pressure arm of the coiler and then put into storage.

If there is a surplus of raw material while cutting the finished product, and they meet the requirements of the surplus material standards. They can be recycled according to the surplus material standard for next use. If they do not meet the criteria, treat them as scrap and must be discarded. The defined yield is the ratio of the area of the finished product to the total area of the raw material used, plus the area of the surplus material that can be recycled into the storehouse.

Based on the above actual background, we simulate the following two problems: the factory has given the demand for a future batch of orders, and the quantity of order demand must be exactly met (oversupply is not allowed). According to the factory's existing raw material cutting orders, each raw material should not be used more than its inventory, asking the following questions

1. Use the minimum number of sheets for all the raw materials shown in the diagram below. It meets the requirements for 5 types of roll in the order. At the same time try to improve the overall yield. The cutting plan is given.

Residual material standard.

1. The length is not less than 50000 and the width is not less than 100
2. Length and width, one of which is not less than 2000 and the other is not less than 1000

Table 1 List of raw materials

The raw material number	The length of the	The width of the	Inventory (Zhang)
1	148623.91	1519.91	5
2	32960.49	999.35	10
3	75508.72	1232.32	8
4	14091.52	920.62	2
5	75040.31	1573.71	3
6	138570.39	844.99	10
7	98641.28	1184.54	12
8	114074.27	879.02	9
9	104637.72	969.02	3
10	58023.82	1785.45	10

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Table 2 Order demand table

The order no.	The length of the	The width of the	Quantity demanded (sheet)	species
1	44351.13	422.88	36	coil
2	39229.01	282.88	29	coil
3	54787.74	268.36	42	coil
4	45284.39	277.70	32	coil
5	53479.79	332.29	18	coil
6	897.32	603.06	38	Sheet metal
7	896.09	714.72	23	Sheet metal
8	1096.33	435.84	31	Sheet metal
9	890.53	343.08	40	Sheet metal
10	752.61	641.45	42	Sheet metal
11	970.16	667.21	34	Sheet metal
12	998.29	472.30	25	Sheet metal
13	1024.87	340.51	24	Sheet metal
14	621.91	476.60	22	Sheet metal
15	1243.03	471.25	28	Sheet metal

2. For all raw materials given, please use the minimum number of raw materials to meet the requirements of all orders. At the same time, try to improve the total yield of the cutting scheme.

2. Problem analysis

Through the analysis of the constraints in the title, we can find the following basic requirements:

1.Raw materials need to have a priority order, to decide which raw materials to choose first Cutting.

2.The raw material cutting method needs to select a parameter as a measurement.

2.1 Analysis of Problem 1

Since this article does not need to consider the number of small machines cutting times and the number of rows of knives, we can consider that the most important goal is to use as little as possible of raw materials. That is, like the rectangular layout optimization problem. At the same time, need to pay attention to a row of knives on the line is not more than 5 dollars. So, we can do this first on a wide array and then on a length array on each of the width arrays. Until the length no longer meets the required order requirements. The remaining material can be recycled as surplus material. After the machine runs, the first use of disk shear directly cut raw materials to the farthest end of the arrangement, each time only needs to use the cutting disk shear transverse cutting a knife, so that you can get the length and width of the following figure shown in the neat residual material, greatly increased the residual material area, to yield as a reference standard, cutting.

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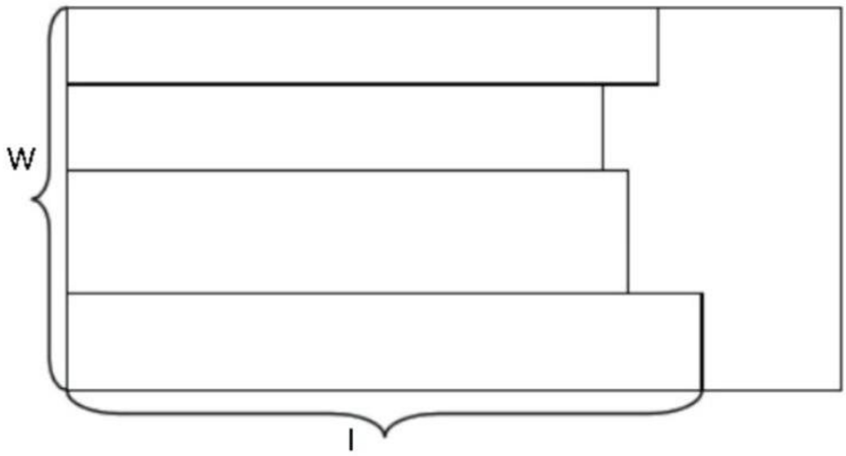
2.2 Analysis of Problem two

Considering that the cutting method of sheet material and coil material is the same in the model, therefore, based on the model established in question 1, our overall cutting method is still divided into two parts, the first part is the width of the knife, the second part is the length of each width of the layout. In addition, there is an obvious difference between the length of the sheet and coiled material in order, the difference is about an order of magnitude, so the coiled material can be used as the raw material of sheet material, thus reducing the consumption of raw material. Compared with the first problem, the second problem still uses the use of raw materials to find the least number of cutting schemes, and then on its basis for optimization and adjustment, using surplus materials to improve the yield, find the best solution.



2.3 Analysis of problem three

Based on problem 1 and problem 2, problem 3 adds two optimization indexes, namely, the number of cutting times and knife changing times of small machine, that is, the raw material is required to use the least while reducing the number of knives changing times of disc scissors and the number of cutting times of small machine as far as possible. Considering the two new constraints, we can make a list of categories, the same production order to get a wide-brimmed flush column, cutting head cut its advantage can be directly used for cutting, meet the requirements of "one size fits all", the cutting plan, must make small machine for cutting the number of times is greatly reduced, In this way, the optimization of the index of small machine cutting number can be realized, and then the problem is simplified to consider only one optimization index that is the number of tool changes.

From the above analysis, to reduce the number of disc shears and cut the number of a small machine, first, the same type of order processing, and ensure that they are on the wide side of them even. This can ensure that the number of small machines cutting to the minimum, and effectively reduce the number of tool changes. In the cutting, each time they use disc scissors cut a group of similar order products, you can use the cutting head scissors to cut the group of order products. If this group of products has met the requirements of the order, then it is necessary to change the knife for the next group of different categories of product cutting. If the remaining length of raw materials is not enough to cut the group of products, then the knife also needs to change to produce orders with the length less than the remaining length of raw materials, to make full use of raw materials.

In the solution to problem three. First, find out some cutting schemes when the number of raw materials is as minimum as possible, then calculate the total yield and the number of knife changes, and then optimize the comparison, and get the best scheme.

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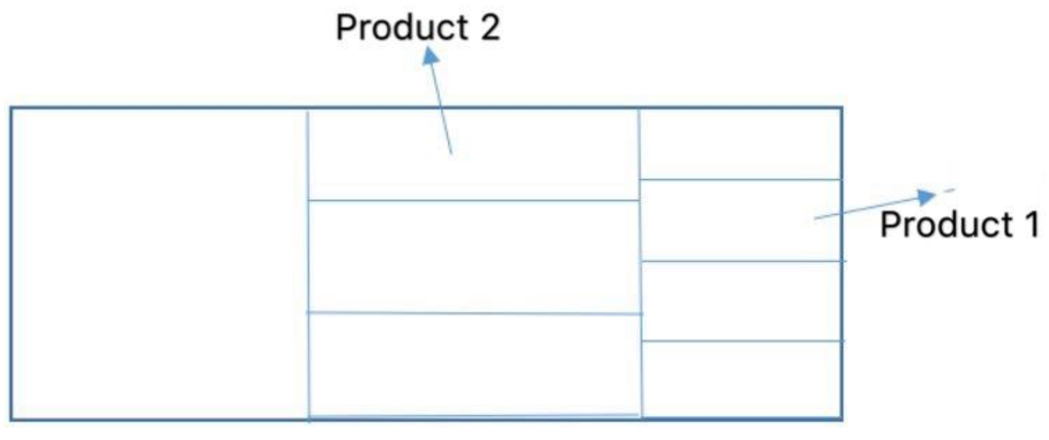

3. Model hypothesis

1. assume that there is no operational error in the machine cutting process resulting in raw material waste.
2. It is assumed that there is no extra cost consumption for the processing times of disk shear and head shear.

4. Symbol description

The raw material length	Li
The raw material width	Wi
Class M order length	lm
Class M order width	wm
Number of sheets used for type I raw material	a_i
The order number corresponding to paragraph K of sheet J of material I	r_{ijk}
The number of orders corresponding to paragraph K of sheet J of material I	p_{ijk}
Number of orders required for category M	b_m
Item I raw material inventory sheet	A_i

5. Model building

5.1 Problem a

5.1.1 Problem 1 model establishment

Because this q does not need to consider the small machine for cutting the number with the number of cutters, it can be similar to the rectangular layout optimization problem, notice a row of the Dao cap was less than 5, so it can be first on the width to the configuration, and then again on the width of each configuration for the length of the arrangement until can't again for the arrangement of the order, began after cutting, Use disk shear cutting raw materials to the farthest end of the product layout, and then use the cutting disk shear transverse cutting a knife, so that you

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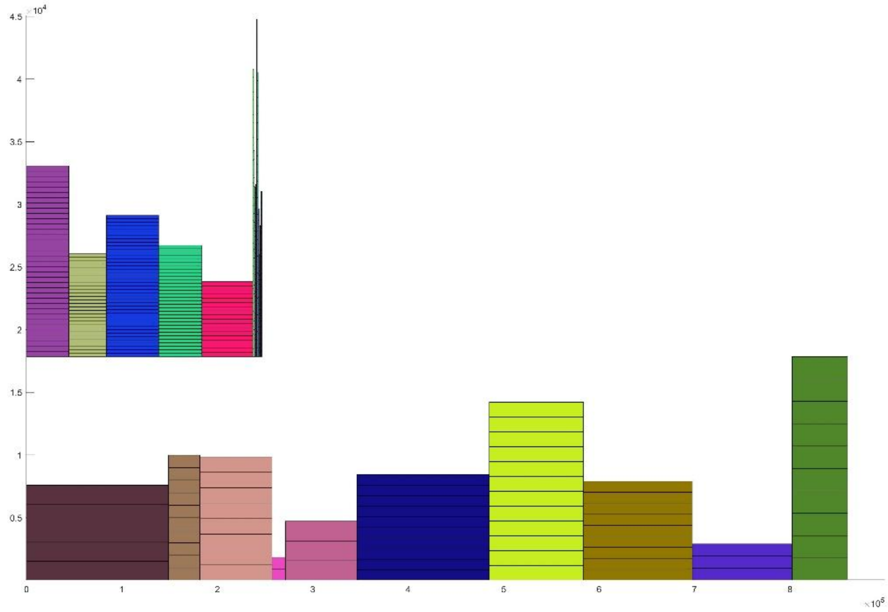
can get two long and wide neat residual material, greatly improve the utilization rate of raw materials.



The goal of problem 1 is to minimize the number of sheets of raw materials. Make it meet the requirements of 5 kinds of coil orders, and on this basis, try to improve the total yield. Problem a substance in order to determine the cutting scheme, considering the different kinds of materials with different length and width of the parameters, and five kinds of coil are width larger orders, so consider them when model synthetic arrangement in order to improve the material yield, and the need to pay attention to the problem is not the desires of a minimum number of sheets of a material, but the least number of sheets of all material, belongs to the whole optimization problem, All models need to be comprehensively optimized.

Based on the above situation, we consider building the R_{ijk} model and divide each raw material into sections and process different orders in each section. I am the i-th raw material, J is the J-th section of raw material, and K is the number of k-th orders that can be made in a section of a raw material. Therefore, R_{ijk} represents the quantity of order k in the j section of material I, and R_{ijk} is known as the determining factor.

Considering the goal is to use the least number of raw materials, at the same time try to improve the overall yield, because don't know the weight, this model USES the first to find the number of raw materials as far as possible at least some of the cutting solution, because each of these materials cutting method is not the same, after the solution by the least number of raw materials, cannot change the number of raw materials, The cutting method within the same material is adjusted so that orders of similar length or the same length are cut on the same section within the material. After this adjustment, the long order in the same piece of raw material can make the full use of raw materials, and improve the rate of production, and the short length of the order is also in the same piece of raw material so that you can use the standard and meet the requirements of the order of surplus materials, also improve the rate of production, to get the best plan. In addition, notice that the lengths of raw materials 2 and 4 are both less than the lengths of the coil order in 5, so in question 1, the usage of raw materials 2 and 4 should be 0.

5.1.2 Problem 1 model solution

First, the objective function is established: the minimum number of raw materials used. Secondly, determine the constraint conditions:

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1. Constraint of appropriateness
2. The number of raw materials used should not exceed the number of inventories
3. Length constraint
4. Width constraint
5. The number of sheets used for raw material 2 and 4 is 0

In the optimization of the algorithm, the model uses genetic algorithm to optimize, the algorithm through the mathematical way, the use of computer simulation operation, and the problem-solving process is like the process of chromosome gene crossover mutation in biological evolution. When solving complex combinatorial optimization problems, compared with some traditional optimization algorithms, it can usually get better optimization results quickly. For this model, rapid global optimization is very important, so a genetic algorithm can help to get the minimum number of raw materials well.

First, quantify the constraint conditions:

$p_{ijk} = [\frac{Li}{l_{r_{ijk}}}]$ （[]It means round down）

Secondly, quantitative constraints:

$$\sum_{i=1}^{10}\sum_{j=1}^{a_i}\sum_{k=1}^{5} p_{ijk} = 36(r_{ijk} = 1)$$

$$\sum_{i=1}^{10}\sum_{j=1}^{a_i}\sum_{k=1}^{5} p_{ijk} = 29(r_{ijk} = 2)$$

$$\sum_{i=1}^{10}\sum_{j=1}^{a_i}\sum_{k=1}^{5} p_{ijk} = 42(r_{ijk} = 3)$$

$$\sum_{i=1}^{10}\sum_{j=1}^{a_i}\sum_{k=1}^{5} p_{ijk} = 32(r_{ijk} = 4)$$

$$\sum_{i=1}^{10}\sum_{j=1}^{a_i}\sum_{k=1}^{5} p_{ijk} = 18(r_{ijk} = 5)$$

The integration results are as follows:

$$\sum_{r_{ijk}}^{5}\sum_{i=1}^{10}\sum_{j=1}^{a_i}\sum_{k=1}^{5} p_{ijk} = b_{r_{ijk}}$$

In terms of width, there are the following constraints:

$$\sum_{i=1}^{10}\sum_{j=1}^{a_i}\sum_{k=1}^{5} w_{r_{ijk}} \le W_i$$

$$\sum_{i=1}^{10} a_i \le A_i \ （a_i = 0 \ （i = 2，4））$$

By substituting the above equation into the calculation, the optimal distribution of raw materials can be obtained as shown in the figure below:

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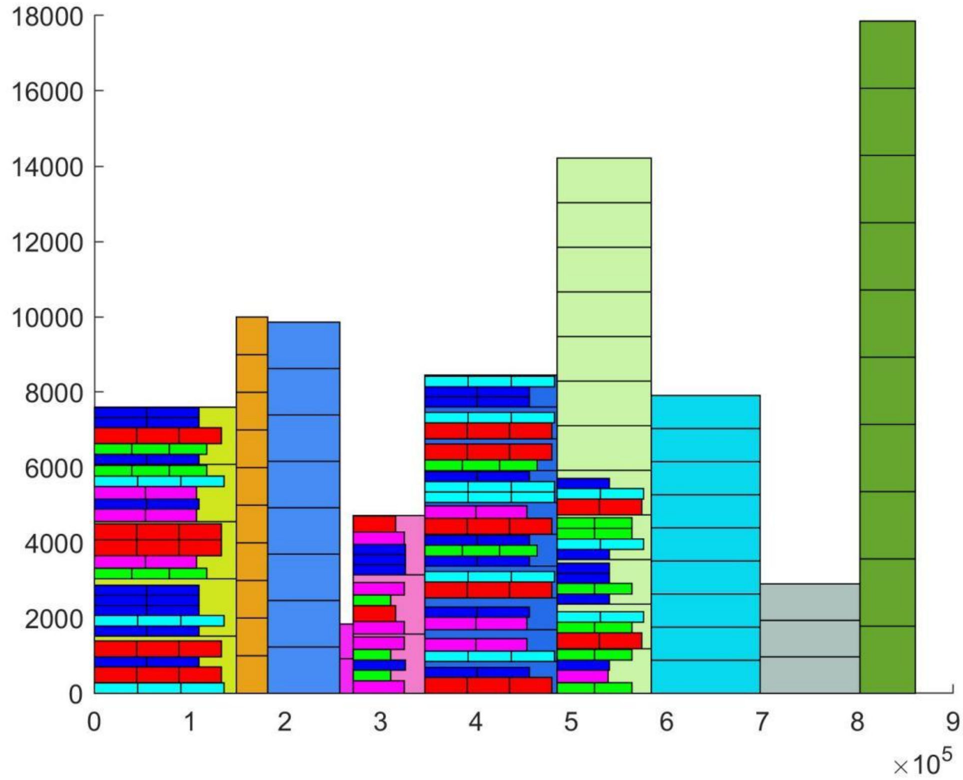

The abscissa is the location of raw materials, each column is a raw material, the ordinate is the cutting position, the five colors on each raw material respectively represent the cutting mode and position of five orders, and each color represents an order. (Both horizontal and vertical units are mm)

The number of sheets required for each raw material is as follows:

1	5
2	0
3	0
4	0
5	3
6	10
7	5
8	0
9	0
10	0

The result is that one raw material needs 5 pieces, five raw materials need 3 pieces, six raw materials need 10 pieces, seven raw materials need 5 pieces, a total of 23 raw materials are needed.

The yield of each piece of raw material is shown in the following table:

1	0.98756
2	0.897161
3	0.960186
4	0.95524
5	0.859858
6	0.892317
7	0.960186
8	0.991091

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9	0.950182
10	0.899635
11	0.780313
12	1
13	0.9565
14	0.780313
15	0.827037
16	0.921439
17	0.786593
18	0.881586
19	0.980391
20	0.966596
21	0.807478
22	0.968195
23	0.753408

The total yield of raw materials is about 90.3%

5.2 Question 2

5.2.1 Model establishment of problem 2

Based on the first question, because there is no difference between the sheet material and coil material in cutting, the establishment of the model is the same as the first question. In addition, it is observed that there is a significant gap between the length of the sheet demand order and the length of the roll demand order. They differ by about an order of magnitude. Therefore, the remaining material can be used as the raw material for sheet metal cutting, thus reducing the consumption of raw material sheets. But at the same time, considering that the width of the sheet material demand order is almost the same as the width of the coil material demand order, surplus 1 meets the requirements and surplus 2 does not meet the requirements.

Same with model 1, this model adopts the cutting scheme with the minimum number of raw materials first, and then carries on the optimization adjustment, to improve the total yield and get the best scheme.

5.2.2 Model solution to Problem 2

Based on the first question, because there is no difference between the sheet material and coil material in cutting, the establishment of the model is the same as the first question. In addition, it is observed that the length of the sheet demand order and the length of the coil demand order has a significant gap, the difference is about an order of magnitude, so the rest of the coil cutting can be used as the raw material of the sheet cutting, to reduce the consumption of raw materials. But at the same time, considering that the width of the sheet material demand order is almost the same as the width of the coil material demand order, surplus 1 meets the requirements and surplus 2 does not meet the requirements.

According to the demerit calculation, only the spare material of cutting coil in question 1 can meet the order demand of sheet metal, so the total consumption of raw materials is still 23 pieces: 5 pieces of raw material for one, 3 pieces of raw material for five, 10 pieces of raw material for six and 5 pieces of raw material for seven. Its cutting shape is shown in the figure below:

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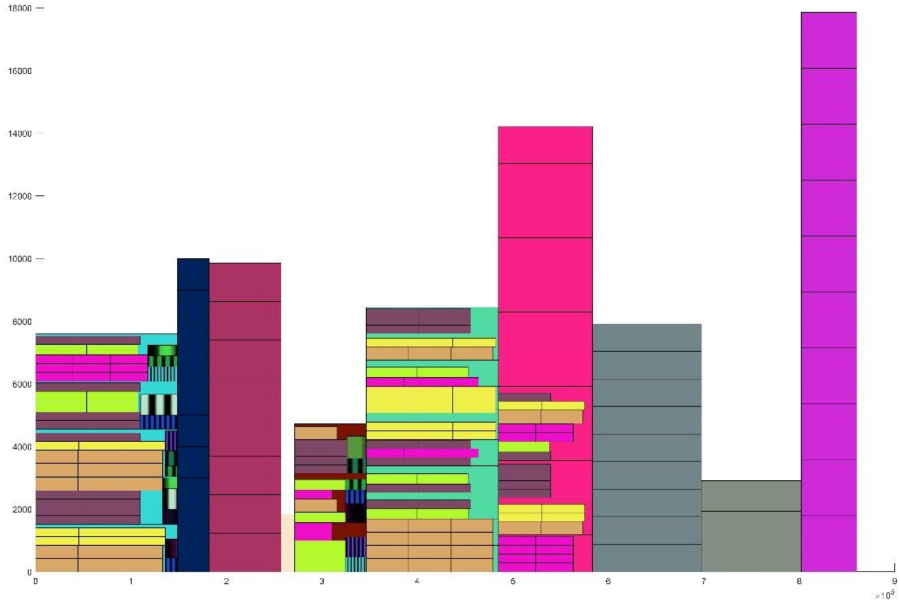

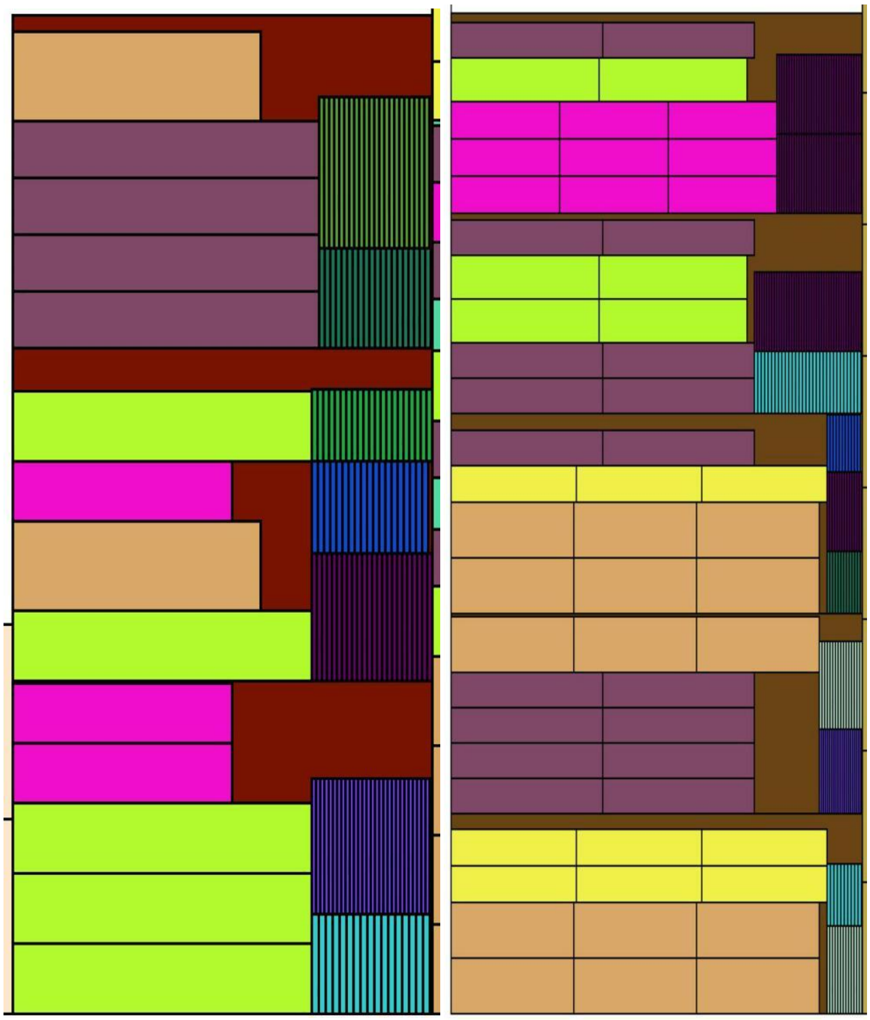

Material one partial enlargement of material five partial enlargement of material

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6. Model evaluation

6.1 Evaluation of Model I

In this model, there is no specific plan to limit its cutting, so the number of raw materials used is highly optimized, which can reduce the number of raw materials to the maximum extent. However, there are also defects in the model. For example, the model is first processed on a wide layout. When the length of the ordered product is large, but the length of raw materials is low, it is easy to produce wastes with a large area that does not meet the standard of residual materials, thus reducing the total yield. However, the overall process of the model is to get the lowest raw material sheet program, and then cut program adjustment, thus achieving the goal of optimizing the yield. At the same time, the obtained scheme has a high yield, so it can be a good solution to the above problems.

6.2 Evaluation of Model 2

For Model 2, because the length of sheet metal is smaller than that of coil material and raw material, it is more compact in the direction of raw material length. Thus, the waste material which can meet the condition of the waste material can be effectively avoided to get two regular waste materials (as shown in Figure 2). At the same time, the remaining material in question one is utilized as the raw material for the cutting sheet. It can effectively reduce the number of sheets of cut raw materials. But it may also reduce the overall yield. By analyzing the above two points, this paper holds that the former, that is, using surplus material as the raw material in question two, is more suitable for obtaining the minimum number of sheets used for raw materials. From the production practice, the way of using surplus materials for reproduction is also more in line with the actual demand for steel processing.

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