Research on material loading problem of coal mine car for reverse logistics

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Abstract. Coal underground reverse logistics is a subject that requires special attention in coal production. Waste materials or equipment, etc. produced by underground production need to be transferred to the surface and sorted according to the requirements and finally passed to different processing departments for treatment. The transfer operation is carried out by mine trucks, and when loading underground, there is a phenomenon of low utilization of the vehicles due to the urgency of time, and the disordered loading leads to difficulties in sorting the materials after ascending to the wells, thus generating unnecessary waste. Aiming at the above problems, a solution is proposed. Firstly, according to the final flow of materials to the department and the volume of materials for clustering, complete the distribution of materials and vehicles; Secondly, according to the idea of block loading, the establishment of the three-dimensional loading planning model with the goal of maximizing the utilization rate of the volume of the vehicle, and the use of the lowest level algorithm algorithm for solving. By obtaining the actual data of a coal enterprise for analysis, the average volume utilization rate of vehicles after clustering loading is 77.59%.

Keywords: Reverse logistics; Material clustering; Three-dimensional loading; Lowest horizontal plane algorithm

1 Introduction

The coal underground production process will produce all kinds of materials to be recycled as well as equipment in need of repair and maintenance, which need to be transferred to the surface, and handed over to the relevant departments, for the next step of recycling, reuse, repair, and waste operations. Generally, there are many types and numbers of materials at a loading point downhole, and often mixed loading operations are conducted. The tight production schedule causes the vehicles to spend a lot of time sorting after ascending the well. At the same time, when loading operations are carried out at the loading point downhole, due to the lack of guidance on loading principles, the problem of overweight, overcapacity, or poor loading utilization often arises, which is not conducive to safe production and also results in a waste

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of capacity. This paper will study this problem from the perspective of material classification and vehicle loading.

Many scholars have studied the problem of material classification and three-dimensional loading. In the classification problem of materiel, Stoll, J [1] and Bamford D et al. [2] classified different types of warehoused spare parts using improved hierarchical analysis respectively. Rauf M et al [3]. optimized the criteria of the ABC classification method of materiel using the TOPSIS method. Xiang et al [4]. classified material based on the information of orders. In a three-dimensional loading problem, Eley et al [5]. used a heuristic algorithm combined with a tree search to solve this problem. Bortfeld et al [6]. used a parallel forbidden search algorithm to solve the weakly heterogeneous loading problem. Martello S et al [7]. proposed an exact-fill-single-box algorithm to solve the orthogonal loading of cubic-shaped items into three-dimensional quantities of rectangular boxes. Davies et al [8]. considered the effect of weight constraints on loading. Bischoff et al [9]. considered whether stacking between items is allowed. Alonso et al [10]. considered constraints in terms of weight, volume, and stability.

To adapt to the characteristics of coal well production oriented to reverse logistics, this paper first utilizes the tree diagram clustering to carry out the vehicle-cargo matching between the idle vehicles and the materials to be loaded in the wells, and then carries out the loading planning and designing after obtaining the corresponding matching scheme between the vehicles and the materials, and selects the loading algorithm based on the lowest level according to the loading characteristics of the materials, to solve the problems in the field of reverse logistics of the coal wells in a fast and effective way.

2 Modeling and Solving

2.1 Problem description

There are N (N=1,2,3...) loading points with M (M=1,2,3... I,...) types of materials, each with n (n=1,2,3,...k,...), idle in the wells There are P (P=1,2,3...) types of vehicles available for loading operations and Q (Q=1,2,3...) of each type; the i-th type of the kth material has length, width, height of lik, wik, hik, and mass of gpq, respectively; and the P-th model of the Q-th vehicle has length, width, height of Lpq, Wpq, Hpq, the load is gpq, and the volume is vpq.

2.2 model assumption

Combined with the actual situation of production, this paper will establish the following assumptions:

(1) Materiel flowing to the same processing department on the same surface will be referred to as the same class of materiel, and materiel flowing in different directions will be regarded as different classes of material;

(2) Utilizing the idea of block loading, the materials to be loaded are regarded as rectangular bodies of different sizes and masses, the loading vehicle is regarded as a

cubic container, and all the materials to be loaded are regarded as being put into this container in the form of rectangular bodies;

(3) There are a sufficient number of turntable vehicles downhole to be able to meet the requirements for the quantity of material to be loaded. At the same time, the transportation path of the vehicle downhole is not considered.

(4) The vehicles have different transportation capacities, but the transportation capacity is known and the density of the loaded material is uniform and there is sufficient load-bearing capacity.

2.3 model solution

Material Classification Model.

To minimize the difficulty of sorting operation after ascending the well, and also to avoid the situation of overcapacity and overloading when loading, this paper establishes the classification model of the materials at the loading point and uses the tree diagram clustering method to classify the materials to be loaded and allocate them to the vehicles.

Firstly, several common materials to be loaded are classified according to the final flow to the department after ascending the well, and a detailed list of material flow is established with a coefficient of λ_1. For example, the support materials are handled by the production department, the equipment are handled by the electromechanical department, and the ventilation pipes are handled by the ventilation department, etc. The flow of the materials will be used as the main principle of the allocation. Secondly, for the problem of mixed loading operation, from the analysis of quality and volume, the matching relationship between materials and the matching relationship between materials and vehicles are established; the matching of loading materials and vehicles belongs to multi-materials and multi-vehicle matching, and for the matching of sizes, the matching table of sizes between two and two materials and the matching table of sizes between materials and vehicles are established, with the coefficient of λ_2. Because it is necessary to achieve the balance of loading, the matching table of Specific gravity relationship between materials to be loaded and vehicles, the coefficient is λ_3.

Determine the relationship evaluation coefficient $\lambda = \alpha\lambda_1 + \beta\lambda_2 + \gamma\lambda_3$ between materials and between materials and vehicles through the three relationships, where $\alpha + \beta + \gamma = 1$, drawing, for example, the clustering diagram shown in Figure 1 below.

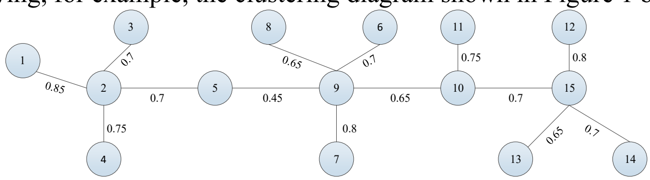

Fig. 1. Example of a cluster graph

The distribution of materials to vehicles is gradually divided according to the direction from the ends to the center. The collection of material is determined by selecting appropriate λ, α, β, and γ; secondly, the weight of the collection of material generated in the previous step is clarified by data comparison and arranged in descending order according to the weight size; next, the materiel in each collection is determined to be matched with the vehicle model and loading order according to the size, and those with large sizes are prioritized to be loaded, until all the materiel in the collection is loaded Or more than the maximum volume of the vehicle; Finally, each collection of materials have the appropriate vehicle for loading, but there are some collections of materials are not loaded into the vehicle, these materials are categorized as a class of collection, and select the appropriate vehicle for loading operations. The allocation is completed and transferred to the loading planning model.

Material loading model.

In this paper, the loading model with maximum volume utilization as the optimization objective:

$$MaxZ = \sum \left(\frac{\alpha_{ik} \beta_{ik} \left(l_{ik} w_{ik} h_{ik} \right)}{V_{pq}} \right) \tag{1}$$

$$\sum l_{ik} w_{ik} h_{ik} \beta_{ik} \le V_{pq} \tag{2}$$

$$\sum g_{ik} \beta_{ik} \le G_{pq} \tag{3}$$

$$l_{ik}^{'} \le \frac{\sum g_{ik} x_{ik} \beta_{ik}}{\sum g_{ik} \beta_{ik}} \le l_{ik}^{"} \tag{4}$$

$$w_{ik}^{'} \le \frac{\sum g_{ik} y_{ik} \beta_{ik}}{\sum g_{ik} \beta_{ik}} \le w_{ik}^{"} \tag{5}$$

$$\frac{\sum g_{ik} z_{ik} \beta_{ik}}{\sum g_{ik} \beta_{ik}} \le h_{ik} \tag{6}$$

$$\varphi = \frac{\sum l_{ik} w_{ik} h_{ik} \beta_{ik}}{V_{pq}} \times 100\% \tag{7}$$

$$\beta = 0,1 \tag{8}$$

$$l, w, h, x, y, z \in N \tag{9}$$

The first equation is the objective function expressed as the maximum volume utilization or the maximum load capacity; the second and third represent the volume and load constraints, respectively; the fourth, fifth, and sixth represent the center of gravity constraints; the seventh is the formula for calculating the volume utilization of the vehicle; and the eighth and ninth qualify β to be a 0-1 variable, and *l*, *w*, *h*, *x*, *y*, and *z* to be positive integers.

In this paper, the solution is carried out by the lowest horizontal plane algorithm, which starts with the generation of blocks, mainly including the generation of simple blocks and composite blocks. When loading items to the carriage, the materials are often placed on the bottom of the carriage first, and the bottom is covered with priority and then gradually placed upward until the carriage is full. It is common to think of the object to be placed as a cuboid. When loading, preferentially place cuboids with smaller areas, because smaller cuboids may be more difficult to use behind them.Simple blocks are blocks stacked by the same kind of material, there is no gap between the materials, and composite blocks are stacked by simple blocks along the x, y, and z axes given by the vehicle. The stacking type of cuboids shown in Figure 2.

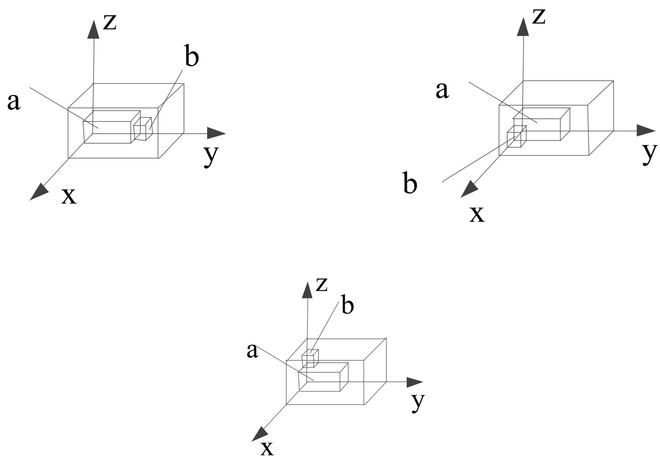

Fig. 2. Stacking type of cuboids

Next is the generation of the plane and the filling of the material, after the continuous stacking of the composite block, the plane is formed, and the filling of the material is carried out by updating the position of the plane. Finally, in the composite process, fully consider the composite situation in the three coordinate points, so that the material to be loaded into the plane after filling the plane can make the plane the smallest remaining area.

3 Case Study

In this paper, a coal mine is selected as the research object, the main parameters of materials are shown in Table 1 below, and the vehicle information is shown in Table 2 below.

Table 1. Material parameters and vehicle information

Type	Number	Quantities	Lengths/cm	Height/cm	High level/cm	Mass/kg
A	1	30	20	20	40	33
A	2	36	24	24	50	7
A	3	115	90	30	30	5
A	4	38	15	15	41	6
A	5	235	180	120	130	1
B	6	50	30	5	37	11
B	7	160	130	120	46	1
C	8	60	40	15	70	7
C	9	100	60	50	84	2
C	10	80	50	30	29	2
C	11	45	30	20	30	9
D	12	100	90	70	23	2
D	13	42	40	20	67	7
E	14	51	40	30	33	5
E	15	165	103	18	34	6

Table 2. Vehicle parameters

Vehicle number	Weight/Volume	length/cm	Height/cm	High level/cm	weight capacity of a vehicle /kg
1	1/3	300	200	150	3000
2	1/2	210	140	130	2000
3	1/2	210	140	130	2000
4	1/2	210	140	130	2000
5	1	180	105	80	1500
6	1	180	105	80	1500

According to the distribution and loading planning design in the previous section, the final matching relationship between the vehicle and the material to be loaded, as well as the data on the volume utilization of the vehicle after loading are shown in Table 3 below.

Table 3. Vehicle loading and load utilization rate

Vehicle number	Type	Quantities	Volume utilization rate
1	A	48	76.78%
2	B	12	73.09%
3	C, D	16	85.58%
4	E	4	69.69%
5	A, C, E	14	89.92%
6	C	10	70.50%

4 Conclusion

Aiming at the problems existing in the process of reverse logistics in coal mine, this paper proposes to use the clustering method of tree graph to distribute materials, and then use the lowest level algorithm to solve the loading model. By collecting the actual data of a coal enterprise to simulate the operation, the proposed method is verified by a practical case, which can effectively sort the materials transferred to the surface and improve the utilization rate of vehicle loading. This paper can provide some references for the topic of reverse logistics of coal enterprises, but there are also some research deficiencies in this paper, such as the classification of materials that need to be transferred to the surface of coal mines is not detailed enough, and relevant research can be carried out in the future.

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