Optimized Design of Laundry Cleaning Based on Linear Programming

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***Abstract*:** This paper presents an optimized design for laundry cleaning, utilizing linear programming and Python and SPSS software programming. It aims to achieve cost-effective and good cleaning effects under different conditions. The core challenge addressed in this paper is balancing cost-effectiveness and cleaning effectiveness. First, a mathematical model is developed to describe dirt solubilization in water and the relationship between wash frequency and water consumption. Second, a cost-effective cleaning scheme is identified, considering water rates and other factors. Additionally, factors such as clothing types and quantities, dirt types, detergent types, and the constraint of mixing certain clothing items during washing are taken into account. By solving the laundry cleaning mathematical problems using an optimization model in mathematical modeling, factor analysis is conducted considering various factors including a given amount of dirt, water, dirt solubility in water (function), wash frequency, water consumption per wash, dirt type, detergent type, detergent solubility in dirt, detergent unit price, water rates, and the constraint of certain clothing items not being able to be washed together. The goal is to achieve a lower-cost laundry cleaning solution that is both effective and tidy.

Keywords: Laundry Cleaning Optimization Design; Linear Programming

1. Issue Restatement

Problem 1 Given a garment with dirt and give the amount and water available and the solubility of dirt in water at k wash is a_k, where $a_1 = 0.8$, $a_k = 0.5a_{k-1}, k = 2,3,L$ 。 Give the best solution for the number of washes and water consumption per time, and discuss the effect of a_k, the initial amount of dirt, and the amount of water available on the target.

Problem 2 Assuming that each wash takes the same time, there is no limit on the water available, and the final dirt residue does not exceed one-thousandth of the initial amount of dirt, other conditions are similar to Problem 1. Provide the most effective cleaning plan and analyze the effect of a_k and initial dirt amount on the optimal solution.

2. Literature Review

Multiple constraints can be addressed effectively, thus enhancing the efficiency and accuracy of sample arrangement[1]. Ding Ke et al. utilized a greedy-genetic optimization algorithm to enhance the rationality and productivity of ship entry and exit scheduling for medium- and long-term operations[2]. Yu Ying et al. applied a greedy algorithm in optimizing the lighting system design of a comprehensive sports stadium, making it more energy-saving and intelligent[3].

Other studies have examined the relationship between detergent and laundry effects. Li Xiaorui and Yao Chenzhi studied the improvement of the standard system for washing products, leading to better standards for laundry beads and enhancing industry quality[4]. Gao Wanxiang established a mathematical model for laundry liquid washing clothes to explore how the hydrodynamic characteristics of the liquid affect laundry effectiveness[5].

In summary, this paper introduces an innovative laundry cleaning optimization design that improves efficiency and quality in laundry cleaning. Using mathematical modeling, we aim to provide an economical and efficient solution to real-life laundry cleaning challenges.

3. Assumptions and Symbols Description

3.1 Assumption

1. Consider the traditional water washing method;

2.The washing effect without considering the material, the type and concentration of detergent, water temperature and other factors.

3.2 Symbol description

sequence number	sign	symbol description
1	k	Washing times
2	a_k	Solubility, representing the proportion of the dirt dissolved by an equal amount of detergent relative to the initial dirt amount during the k th wash.
3	D_0	Initial dirt amount, indicating the amount of dirt on the clothing before washing, was measured in grams.
4	D	The amount of dirt
5	D_k	Amount of dirt from the k th wash
6	W	Available water consumption
7	W_k	Water availability for the k th wash
8	S	Solubility of the dirt in the water
9	N	Washing times
10	M	Water consumption per time
11	P	Number of dirt removed per wash
12	PN	The total amount of dirt removed after N washes
13	m	Proportion of the reduced washing effect

4. Modeling and solution of Problem 1

Let the number of washes be k and the amount of dirt remaining after the first k wash be D_k . The following formula can be obtained:

$$D_k = D_{k-1} - a_k D_{k-1} \qquad (4\text{-}2\text{-}1)$$

$$a_k = \frac{a_{k-1}}{2} \qquad (4\text{-}2\text{-}2)$$

From (4-2-1) and (4-2-2) it follows that

$$D_k = D_0 \prod_{i=1}^{k} \left(1 - \frac{a_1}{2^{i-1}}\right) \qquad (4\text{-}2\text{-}3)$$

where assuming $D_0 = 1, a_1 = 0.8$, the above equation can be written as

$$D_k = \prod_{i=1}^{k} \left(1 - \frac{0.8}{2^i}\right) \qquad (4\text{-}2\text{-}4)$$

Draw a graph of the trend of D_k as shown in Figure 1

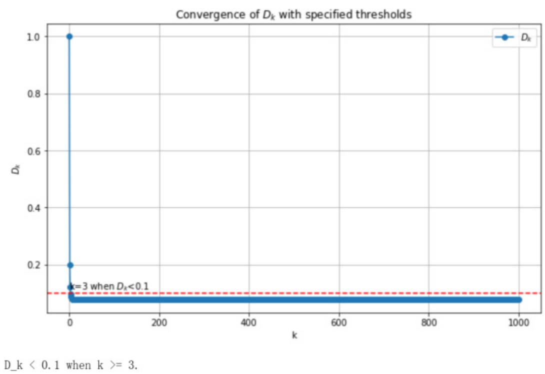

Figure 1 Trend curve for D_k

According to the picture, it can be concluded that at the beginning, as the number of washes increases, the change of the amount of dirt residue is very obvious, but as the number of washes continues to increase, the amount of dirt residue tends to a certain value, according to the assumption of the problem scenario of this question, when the number of washes continues to increase, the D_k tends to $0.08g$, that is to say, at this time, the amount of dirt is the amount of the initial dirt 8% .

5. Modeling and Solving of Problem 2

If the conditions are the same as in problem 1 $a_0 = 0.8$, $a_k = 0.5a_{k-1}$. According to the analysis of Problem 1, it can be obtained that even after several washes, the residual dirt can only be cleaned up to about 8% of the initial amount of dirt.

Let the solubility of the first wash be a_0 , $a_k = ma_{k-1}$, and find an optimal combination that minimizes the number of washes by programming different values of a_0 and m to be taken over.

If you restrict the range of values of both a_0 and m to (,1 , the graph that takes all the values in the interval is as follows:

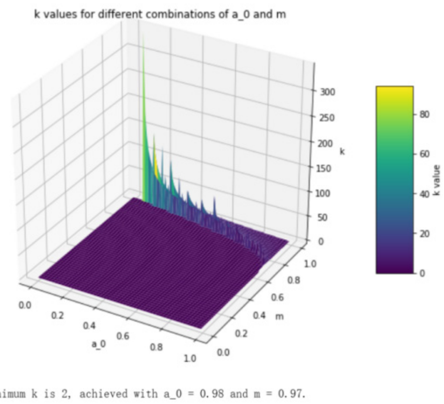

Figure 2 The range of values of a_0 and m are both k values corresponding to (,1 (3D)

Observing the result, it can be seen that as long as m is large enough and a_0 is larger than 0.06 , the amount of dirt remaining in the end can only be reduced to less than one thousandth after many washes, and the maximum number of washes is about 80, but from the above figure, it can be seen that m should be taken as the minimum 0.62 or above, or else it is impossible to reduce the amount of dirt to one thousandth. In this case, when a_0 is taken from 0.98 and m is taken from 0.97 , the value of k , which is the minimum number of washes, is 2 , i.e., the amount of dirt can be reduced to one thousandth of the original amount of dirt after two washes.

If you restrict the range of values for both a_0 and m to (5, 0. 9 , the graph that takes all values in the interval is as follows:

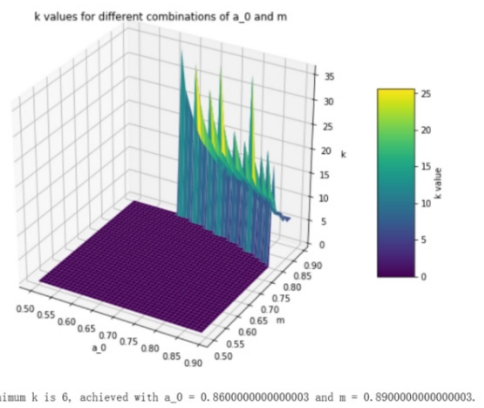

Figure 4 The range of values of a_0 and m are both k values corresponding to (5, 0. 9 (3D)

Observation of the results can be seen, as long as m is greater than 0.8 and a_0 is greater than 0.6 , in order to make the final remaining amount of dirt less than one-thousandth of the maximum number of washings is about 34 times, in this case, when a_0 take 0.86 , m take 0.89 , k that is, the smallest number of washings, the value of 6 , that is, six washings can be the amount of dirt to the original amount of dirt of one-thousandth of the original amount of dirt.

6. Modeling conclusions

6.1 Problem 1 modeling conclusions

The traditional water washing method was considered without considering the influence of the material of the clothes, the type and concentration of the detergent, the water temperature and other factors on the washing effect. A linear programming model was established, and the optimal solutions regarding the number of washing times and the amount of water used per time were obtained by solving the model. The results show that the effect of washing dirt increases significantly with the increase of solubility a_k value. The effect of the initial amount of dirt and the amount of available water on the solution of Problem 1: when the amount of water is insufficient, or the initial amount of dirt is large, each washing is still a unit of water until it is used up; when the amount of water is sufficient, or the initial amount of dirt is relatively small, then the number of washings can be selected according to the curve of D_k .

6.2 Problem 2 modeling conclusions

A linear programming model was developed, and the optimal solution regarding the number of washing times and the amount of water used per time was obtained by solving the model. The results show that with the increase of solubility a_k value, the effect of washing dirt increases significantly. The effect of the initial amount of dirt and the amount of water available on the solution of Problem 2: When the amount of water is sufficient, or the initial amount of dirt is relatively small, then the number of washings can be selected according to the curve of D_k .

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