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A New Computing Mathematical Model about Surge Links Capacity in Logistics Transportation System and its Solving Algorithm Fitted for Computer Programming

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Abstract: The surge bin is widely used in logistics transportation system. Theoretically it has many virtues, such as reducing the interacting of links ahead and behind bin, buffering different transporting flows, adjusting and processing materials. In practical application, bin capacity size has great influence on reliability and production efficiency of whole logistics transportation system. Studying optimum computing of surge bin capacity to fully realize its beneficial functions are very significance. By utilizing some existing outcomes, this paper presents a new computing mathematical model about surge bin capacity in logistics transportation system. Compared with some existed references, this presented model fully considers different influences of surge bin capacity on reliability and production efficiency of whole logistics transportation system and realizes reliability and production efficiency overall optimization decision. All kind of factors affecting designed surge bin capacity can be easily gotten by the presented model. In addition this paper also presents a set of detailed design computing formulas about surge bin capacity in logistics transportation system, and presents detailed solving algorithm and steps fitted for computer programming. These can offer the reference for capacity decision design computing of surge bin in logistics transportation system.

Keywords: Computing method, reliability, logistics, computer programming, transportation, bin

1 Introduction

In some logistics transportation system, surge bins are often set. By setting surge bin, links behind bin can continue transporting material of bin when links ahead of bin are in failure; on the other hand, links ahead of bin can continue transporting material to bin when links behind bin are in failure. Therefore setting surge bin can reduce the interacting of links ahead and behind bin to improve reliability of whole logistics transportation system. Theoretically surge bin have many virtues, such as buffering the interacting of links ahead and behind bin, buffering different Transporting flows, adjusting and processing materials, and etc. But in practice because the whole logistics transportation system will become very complex after setting surge bin, these theoretic virtues often can not be adequately reflected. In practical application, bin capacity size has great influence on reliability and production efficiency of whole logistics transportation system. So studying optimum decision design of surge bin capacity to fully realize its beneficial functions are very significance.

2 Analyzing the Function of Surge Bin

The function of surge bin can be discussed as follows: (1)Buffering the effect of failures. By setting surge bin, links behind bin can continue transporting materials of bin when links ahead of bin are in failure, on the other hand, links ahead of bin can continue transporting materials to bin when links behind bin are in failure. So setting surge bin can reduce the interacting of links ahead and behind bin. (2)Buffering different transporting flows. Setting surge bin can buffer transporting flows to keep uniformity of them, and can cut down high transporting flows and fill up low transporting flows. (3)Adjusting and processing materials. By setting surge bin, materials can be classi-fied and neutralized, so quality problems of materials can be solved.

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3 Some Existed Related Studying References

Until now there have been many references studying surge system, and many concepts about it have been set up. In 1950**s'**, the transportation system with surge bin was named as soft or flexibility connecting system by professor J.kerp that comes from Poland. He discussed the influencing function of surge bin for the transportation system, but lacked quantificational analyzing. In [1], a model to simulate the existing conveyor belt haulage system at an underground coal mine in Southern Utah, USA was presented, By recording spillage and belt stoppage statistics for the simulated flow, belt and surge capacities were evaluated, Comparison of results for the belt system with and without a surge bin showed that the addition of a surge bin to the system increased production 13.2%. In [2], computer simulation method was used to analyze how surge bin improve the validity of system, and the method calculating the validity of soft connecting system under mine well was also presented. In [3], stochastic process and linear extension methods were used to modeling and analyzing reliability of surge bin system. In [4], authors made use of the theory of queuing system with surge bin to analyze the rational capacity of surge bin, and etc [5]-[9]. Compared with some references, this presented control computing method fully considers different influences of surge bin capacity on reliability and production efficiency of whole logistics transportation system and realizes reliability, cost and benefit overall optimization decision [10]-[12].

4 Some Influencing Results of Designed Surge Bin Capacity on Reliability and Pro-duction Efficiency of Whole Logistics Transportation System

The block diagram of the logistics transporta-tion system with surge bin is shown as Figure 1.

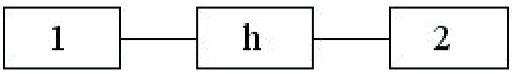

Fig. 1 The block diagram of the logistics transportation system with surge bin

Where 1 is links ahead of bin, h is surge bin, and 2 is links behind bin. The influence of designed surge bin capacity on reliability and production efficiency of whole logistics transportation system can be discussed from following two aspects:

The influence of designed surge bin capacity on reliability and production efficiency of whole logistics transportation system can be discussed from following two aspects:

(1)When links ahead of bin 1 are in failure, links behind bin 2 can continue Transporting materials of bin, The maximum value of materials of bin is designed bin capacity, supposed as Q tons. After a certain time if links ahead of bin 1 are still in failure, empty bin will occur, and then whole logistics transportation system will stop working.

(2)When links behind bin 2 are in failure, links ahead of bin 1 can continue Transporting materials to bin by rest capacity of surge bin. The maximum value of rest capacity of surge bin is also designed bin capacity Q tons. After a certain time if links behind bin 2 are still in failure, full bin will occur, and then whole logistics transportation system will stop working.

5 The Integrated Considered Method about Reliability and Cost-Benefit Optimization

Supposing fluctuation pattern of inputting materials quantity and outputting materials quantity are negative exponential distributions, failure rule of links ahead of bin, links behind bin are also negative exponential distributions. Steps of presented design computing method are as follows.

(1)When links ahead of bin 1 are in failure, links behind bin 2 can continue Transporting materials of bin, The maximum value of materials of bin is designed bin capacity Q tons. Here only considering a kind of having influence case of designed surge bin capacity and maximum possible case of outputting materials quantity (tons/minutes) of links behind bin 2, when the duration time t_1 (minutes) of that links ahead of bin 1 are in failure satisfied following equation, empty bin will occur, and then whole logistics transportation system will stop working.

$$t_1 \geq t_{01} = \frac{Q}{E_2} \quad (1)$$

Where t_1 (minutes) is the duration time of that links ahead of bin 1 is in failure, Q (tons) is de-signed surge bin capacity, t_{01} (minutes) is the duration limit time of that links ahead of bin 1 are in failure, and E_2 (tons/minutes) is mathematical expectation of outputting materials quantity of links behind bin 2.

The reliability function of negative exponential distribution is

$$R(t) = P(T \geq t) = 1 - F(t) = e^{-\frac{t}{\mu}} \quad (2)$$

The reliability function of negative exponential distribution is

$$P_1 = n_1 \cdot P(T \geq t_{01}) = n_1 \cdot e^{-\frac{1}{\mu_1} t_{01}} = n_1 \cdot e^{-\frac{1}{\mu_1}\frac{Q}{E_2}} \quad (3)$$

Where n_1 (numbers) is failure number of links ahead of bin 1 in a year, **U**3bc$_1$ (minutes/numbers) is mean value of failure time of links ahead of bin 1, definitions of Q(tons), t_{01}(minutes),E_2 (minutes) are as above.

Above formula (3) is derived from reliability function, it reflects reliability characteristic of surge bin system.

The loss profit caused by one-time above empty bin s_1 (dollars) is

$$S_1 = \mu_1 \cdot E_2(h_1 - h_2) \tag{4}$$

Where h_1 (dollars/tons) is the selling price of per ton material, h_2 (dollars/tons) is per ton ma-terial cost, definitions of **U**3bc$_1$ (minutes/numbers), E_2 (tons/minutes) are as above. Above formula (4) reflects cost-benefit characteristic of surge bin system. The loss profit l_1 (dollars/year) caused by above empty bin in a year is

$$l_1 = P_1 \cdot S_1 = \mu_1 \cdot E_2 \cdot n_1 \cdot e^{-\frac{1}{\mu_1}\frac{Q}{E_2}}(h_1 - h_2) \tag{5}$$

Above formula (5) is derived from formula (3) which reflects reliability characteristic and formula (4) which reflects cost-benefit characteristic, so it reflects integrated considered about reliability and cost-benefit optimization of surge bin system.

(2) When links behind bin 2 are in failure, links ahead of bin 1 can continue Transporting materials to bin by rest capacity of surge bin. The maximum value of rest capacity of surge bin is designed bin capacity Q tons. Here also only considering a kind of having influence case of designed surge bin capacity and maximum possible case of inputting materials quantity (tons/minutes) of links ahead of bin 1, when the duration time t_2 (minutes) of that links behind bin 2 are in failure satisfied following equation, full bin will occur, and then whole logistics transportation system will stop working.

$$t_2 \geq t_{02} = \frac{Q}{E_1} \tag{6}$$

Where t_2 (minutes) is the duration time of that links behind bin 2 are in failure, Q (tons) is de-signed surge bin capacity, t_{02} (minutes) is the duration limit time of that links behind bin 2 are in failure, and E_1 (tons/minutes) is mathematical expectation of inputting materials quantity of links ahead of bin 1.

Likewise, the occurring number of above full bin in a year is

$$P_2 = n_1 \cdot P(T \geq t_{02}) = n_2 \cdot e^{-\frac{1}{\mu_2}t_{02}} = n_2 \cdot e^{-\frac{1}{\mu_2}\frac{Q}{E1}} \tag{7}$$

Where n_2 (numbers) is failure number of links behind bin 2 in a year, **U**3bc2 (minutes/numbers) is mean value of failure time of links behind bin 2, definitions of Q (tons), t_{02} (minutes), E_1 (tons/minutes) are as above. Above formula (7) is derived from reliability function, it reflects reliability characteristic of surge bin. The loss profit caused by one-time above full bin s_2 (dollars) is

$$S_2 = \mu_2 \cdot E_1(h_1 - h_2) \tag{8}$$

Where definitions of h_1 (dollars/tons), h_2 (dol-lars/tons), **U**3bc$_2$ (minutes/numbers), E_1 (tons/minutes) are as above. Above formula (8) reflects cost-benefit characteristic of surge bin system. The loss profit l_2 (dollars/year) caused by above full bin in a year is

$$l_2 = P_2 \cdot S_2 = \mu_2 \cdot E_1 \cdot n_2 \cdot e^{-\frac{1}{\mu_2}\frac{Q}{E1}}(h_1 - h_2) \tag{9}$$

Above formula (9) is derived from formula (7) which reflects reliability characteristic and formula (8) which reflects cost-benefit characteristic, so it reflects integrated considered about reliability and cost-benefit optimization of surge bin system.

(3)Building surge bin need certain expenses, allocate these expenses to a year, then per year cost l_3 (dollars/year) is

$$l_3 = (b_1/T + b_2) \tag{10}$$

Where b_1 (dollars/tons) is the building cost of per ton surge bin capacity, T (years) is life of surge bin, b_2 (dollars/tons) is maintenance cost of per ton surge bin capacity.

6 Building the Integrated Mathematical Model of Reliability and Cost-Benefit Optimization

For getting the optimization value l of designed surge bin capacity, the following programming model can be established.

$$\begin{aligned} MIN(l &= l_1 + l_2 + l_3) \\ &= \mu_1 \cdot E_2 \cdot n_1 \cdot e^{-\frac{1}{\mu_1}\frac{Q}{E_2}}(h_1 - h_2) + \\ &\quad \mu_2 \cdot E_1 \cdot n_2 \cdot e^{-\frac{1}{\mu_2}\frac{Q}{E1}}(h_1 - h_2) + (b_1/T + b_2) \end{aligned} \tag{11}$$

According to extreme value principle, the necessary condition of that l achieve its extreme value is

$$\frac{dl}{dQ} = 0 \tag{12}$$

$$\frac{d^2l}{dQ^2} = \frac{n_1}{\mu_1 E_2}(h_1-h_2)e^{-\frac{1}{\mu_1}\frac{Q}{E_2}} + \frac{n_2}{\mu_2 E_1}(h_1-h_2)e^{-\frac{1}{\mu_2}\frac{Q}{E_1}} \quad (13)$$

$\because n_1, n_2, \mu_1, \mu_2, E_1, E_2, (h_1-h_2), e^{-\frac{1}{\mu_1}\frac{Q}{E_2}}, e^{-\frac{1}{\mu_2}\frac{Q}{E_1}} > 0$
$\therefore \frac{d^2l}{dQ^2} > 0$

Therefore l have minimum value.

Solve the equation (11), get the equation (14) and the equation (15).

$$\frac{dl}{dQ} = -n_1\cdot(h_1-h_2)e^{-\frac{1}{\mu_1}\frac{Q}{E_2}} - n_2\cdot(h_1-h_2)e^{-\frac{1}{\mu_2}\frac{Q}{E_1}} + (b_1/T+b_2) = 0 \quad (14)$$

$$\frac{dl}{dQ} = -n_1\cdot(e^Q)^{-\frac{1}{\mu_1}\frac{Q}{E_2}} - n_2\cdot(e^Q)^{-\frac{1}{\mu_2}\frac{Q}{E_1}} + (b_1/T+b_2) = 0 \quad (15)$$

The equation (15) only has an unknown variable Q.

7 Detailed Solving Algorithm Fitted For Computer Programming

For the equation (15), supposing

$$\begin{pmatrix} C_1 = -n_1\cdot(e^Q)^{-\frac{1}{\mu_1}\frac{Q}{E_2}} \\ C_2 = -n_2\cdot(e^Q)^{-\frac{1}{\mu_2}\frac{Q}{E_1}} \\ C_3 = b_1/T+b_2 \\ e^Q = x \\ m_1 = -\frac{1}{\mu_1 E_2} \\ m_2 = -\frac{1}{\mu_2 E_1} \end{pmatrix} \quad (16)$$

Then the equation (15) can be transformed into the equation (17).

$$C_1x^{m_1} + C_2x^{m_2} + C_3 = 0 \quad (17)$$

Where c_1, c_2, c_3, m_1, m_2 are all some known parameters. Detailed steps of solving algorithm are as follows.

(1) Firstly given a guess x_0 as initial value, a better approximation x_1 is gotten by

$$x_1 = x_0 - \frac{C_1x_0^{m_1} + C_2x_0^{m_2} + C_3}{C_1m_1x_0^{m_1-1} + C_2m_2x_0^{m_2-1}} \quad (18)$$

Repeats the following process of the formula (18) until the formula (19) or the formula (20) is satisfied

$$x_{k+1} = x_K - \frac{C_1x_k^{m_1} + C_2x_k^{m_2} + C_3}{C_1m_1x_k^{m_1-1} + C_2m_2x_k^{m_2-1}} \quad (19)$$

$$|x_{k+1} - x_k| \le \zeta_1 \quad (20)$$

$$|f(x_{k+1})| \le \zeta_2 \quad (21)$$

Where **U**3b6$_1$, **U**3b6$_2$ is given enough small positive number which is related with required accuracy, such as 10^{-6}, k=1, 2...

(2) Above process can be realized by relevant computer program. Supposing final equation solution value is x_{kk}, so designed surge bin capacity Q (tons) is

$$Q = \ln(x_{kk}) \quad (22)$$

8 Conclusions

It can be seen from the formula (15) that fluctuation rules of inputting materials quantity and outputting materials quantity (such as parameters E_1, E_2), failure rules of links ahead of bin 1 and links behind bin 2(such as parameters n_1, n_2, μ_1, μ_2) the building cost and maintenance cost of per ton surge bin capacity(such as parameters b_1, b_2), life of surge bin(such as the parameter T) , selling price and cost of per ton material(such as parameters h_1, h_2) should be all considered on designing surge bin capacity. Generally, the logistics transportation system with surge bin is widely used in mines, power plants, port terminals; material yards; grain depot, and etc. In practical application, bin capacity size has great influence on reliability and production efficiency of whole logistics transportation system. This paper presents a new control computing method for surge bin capacity in logistics transportation system. This presented control computing method fully considers different influences of surge bin capacity on reliability and production efficiency of whole logistics transportation system and realizes cost and benefit overall optimization decision design. All kind of factors affecting designed surge bin capacity can be easily gotten by the presented method. So the presented method can offer the reference for capacity optimization decision of surge bin in logistics transportation system.

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