Рассмотрение с теоретических позиций проблемы взаимодействия потока с каналом и бункером как абстрактными объектами, выражающими сущность основных транспортных устройств, поможет корректно выбирать расчетные и оптимизирующие модели на транспорте.

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FLOW AND BUNKER-CHANNEL IN THE TRANSPORT SYSTEM

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ABSTRACT

At an abstract level, the author estimates regularities of interaction between flow and structural elements of the transport system. Preassembled elements are channel (flow processing) and bunker (extinguishing and generating bursts of flow). It is shown that bunker converts a flow from random to partially controlled, thereby increasing the level of possible channel load. The author highlights the necessity to consider as a bound element not a channel, as it is usually done, but «bunker-channel».

ENGLISH SUMMARY

Background. *This issue has already been discussed to some extent in earlier journal publications [1,2]. In this article the author offers the further development of the proposed approaches.*

Objective. *The aim is to demonstrate different aspects of flow- channel interaction and to justify the necessity to use the parameter «flow- bunker-channel interaction».*

Method. *The author applies mathematical approach in justification of his position.*

Results. 1. Interaction of flow and channel

Any device processing flow can be represented as a channel. If the specific type of processing is ignored, then hump and cargo front are also channels. The main thing is to compare flow size and channel capacity.

Flow then has two options:

u_{cp} *– average flow size;*

ρ_n *- disorganization of flow.*

When considering the interaction of flow and channel in the abstract sense, parameter ρ_n *displays random fluctuations in the flow size, which leads to the need to have in a channel a reserve of channel capacity (Pic. 1). Here there is formula (1), where* ν_n *-variation coefficient of flow size fluctuations and* α *-some coefficient, and formula (2), where* $\tilde{u}$ *- the estimated flow size.*

In terms of organization theory, a flow has a «noise». And this must be taken into account.

But channel also has some own «noise» and disorganization. Due to random fluctuations of processing time for one flow unit, channel somewhat receives random fluctuations of capacity (Pic. 2).

The author provides an example of calculation. It is supposed, that the work of hump is considered. The hump can have 3 or maybe 20 cuts and there are cars, which cannot be dissolved from this hump. The dissolution time becomes to fluctuate. With respect to the hump there will generally be random fluctuations. In order to provide average capacity U_{cp} *, the channel must have a reserve. If, by analogy with the flow, channel disorganization is defined as* ρ_κ *, the estimated capacity will be calculated with formula (3).*

Quantitive parameters of interaction of flow and channel are determined by the author with formulas (4) – (6).

Thus, the channel must have dual reserve – for channel disorganization and for flow disorganization. Free reserve of capacity ΔU *will be determined by formula (7).*

Coefficient of potential channel utilization efficiency γ *can be defined as (8).*

If the channel is fully loaded: $\tilde{U} = U$ *and* $\Delta U = 0$ *(which often happens), then the relation (9) is applied. If* $U > \tilde{U}$ *, then (10) is taken.*

2. Interaction channel-channel

Average flow, going through the channels, is the same (Pic. 3). Then there are relations $\tilde{u}_1 = u_{cp}(1+\rho_{n1})$ *and* $\tilde{u}_2 = u_{cp}(1+\rho_{n2})$ *. Here the author assumes that channels do not have disorganization, i. e.* $\rho_{\kappa 1} = 0, \rho_{\kappa 2} = 0$ *, then* $\tilde{u}_i = \tilde{U}_i$ *.*

After calculations, made in (11) – (13), the author comes to the conclusion that proper interaction of channels will be (14).

In the chain of interaction, the more disorganized is the flow, which should be served by the channel, the greater reserve then should this channel have. But in accordance with the theory, disorganization itself only increases. Study of transport processes confirms the second law of thermodynamics. In general, when the flow passes, its disorganization increases. See (15) – (16).

Each subsequent channel should have a larger reserve associated with disorganization of the flow.

Here the author comes to another important conclusion. Widespread view that in an interacting chain of channels «bottleneck» will be the channel with the lowest capacity in general is not true. It is necessary to take into account, what kind of disorganization has the flow, approaching the channel. At the same own disorganization, the channel will be limiting by assumption (17).

3. Interaction flow-bunker-channel

If in the channel with its own «noise» comes the flow with visible random fluctuations, capacity utilization of this channel will be extremely low. Therefore, a bunker usually appears in front of the channel. It should be emphasized that the bunker is just reserve tracks. Functional track is the channel with its own capacity and disorganization ρ_κ *.*

Bunker arises as a necessary complement to the channel. Its mission is to increase the rate of possible channel load γ. It is made by lowering the flow disorganization ρ_n, first to zero (up to a uniform flow), and then to negative values (to the controlled flow) (Pic 4). In the bunker naturally appears sequential queue of flow units. General queue is clearly divided into two parts – the first queue arises because of the disorganization of the channel and the second arises because of the disorganization of the flow (Pic. 5). These functions were obtained by the simulation model.

Blue line shows the dynamics of the queue with increasing loading of the channel ψ, when the flow is uniform $\nu_n = 0$, and the service correlation coefficient is $\nu_{об} = 0,5$. That is, the dynamics of the queue created by channel disorganization. Red line shows the dynamics of the queue created by flow disorganization ($\nu_n = 0,5$) at uniform service ($\nu_{об} = 0$).

Yellow line shows total queue, when the flow with random scatter ($\nu_n = 0,5$) enters the channel with the «noise» ($\nu_к = 0,5$). Pic. 6 shows a comparison of the total queue from Pic. 5 (yellow line) and the sum of the two individual queues (red line). The total queue is obtained by composition of queues, shown on Pic. 5- the blue and red lines. The two curves practically coincide. The experiment clearly demonstrates that the queue in the channel splits into two parts. See (18), where

M – general queue in the bunker (mathematical expectation),

$M(\rho_n)$ – queue, generated by flow disorganization,

$M(\rho_к)$ – queue, generated by channel disorganization.

Thus, bunker allows increasing possible channel capability due to the fact that the in flow, coming into the channel, random component decreases and the controlled component increases (Pic. 7).

If the processes in a bunker are considered with a system approach, then it can be found out that there is an active effect of $\Delta\tilde{\rho}$, which at first lowers the disorganization of the flow, and then gives it an organized form.

There are three possible boundary cases.

1) Random flow. Bunker capacity is zero.

$\rho_n > 0;\ \Delta\tilde{\rho} = 0$;

$\rho_n^к = \rho_n - \Delta\tilde{\rho} = \rho_n$,

$M(\rho_n) > 0$,

where $\rho_n^к$ – parameter of the flow, going from the bunker into the channel.

2) Bunker converts a random flow into a uniform one.

$\rho_n > 0;\ \Delta\tilde{\rho} = \rho_n$;

$\rho_n^к = \rho_n - \Delta\tilde{\rho} = 0$,

$M(\rho_n) = 0$

3) Bunker converts the flow into a fully controlled one.

$\rho_n > 0;\ \Delta\tilde{\rho} = \rho_n + \rho_к$;

$\left|-\rho_n^к\right| = \left|\rho_n - \Delta\tilde{\rho}\right| = \rho_к$.

Thus, the bunker increases possible level of possible channel load. The greater is capacity of the bunker, the greater is its ability $\Delta\tilde{\rho}$ to convert a flow and the channel can be used fuller (Pic. 8). And the coefficient of possible load will be (19), where $\Delta\tilde{\rho}$ – active action of the bunker (reserve tracks) on the reduction of disorganization.

4. «Bottleneck» and bound element

Using the simulation model it is possible to determine the delays arising from occupancy of the structural element. The «bottleneck» is an element that causes the greatest delay. This element is usually a channel. And of course this channel should be «expanded». The author states that as a minimum functional element should be considered channel with its bunker.

The well-known problem is determination of which element in the chain of channels is a bound element. The author believes that the main mistake is to consider channels without accompanying bunkers (Pic. 9a). In this case, as a bound element should be considered the second channel because it has the smallest maximum capacity (as it is calculated in the instructions – in a uniform flow and uniform service). But if bunkers are included in the chain, the situation may be different (Pic. 9b). In front of the second channel, there is a large bunker, and therefore the coefficient γ_2 is the largest. If then channels are compared by actual capacity and criterion $\gamma \cdot \mathrm{U}$, the bound element is the first channel.

Thus, the bound element should be determined not by the criterion $\min\limits_i \mathrm{U}_i$, but by the criterion $\min\limits_i \gamma_i \mathrm{U}_i$.

Conclusion. The author makes a conclusion that considering from theoretical positions the problem of interaction of flow with channel and bunker as abstract objects, expressing the essence of the main transport devices, will help to choose the correct calculation and optimization models on the transport.

Keywords: transport system, flow, channel, bunker, interaction, disorganization.

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