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Food packages grouping equipment cyclogram investigation

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1. Introduction

The food industry has always been one of the most developing industrial branches. The global market demands novelties, which would be not only attractive, but which would also be of high quality and could satisfy high hygienic norms. At present more and more daily food products (e.g. cheese, sausage, ham, fish) are packed into vacuum packages [1, 2], which look attractive and are practical both to producer and consumer. In order to use the transportation areas, shelves in shops as effectively as possible, and to satisfy the needs of consumers, the vacuum packages of food products, also called internal packages, are put into the boxes in certain number, i.e. group. In order to get consolidated in the market, more and more producers of food products automate putting the internal packages of food products so that the staff costs were reduced and higher efficiency of packing was ensured [2]. One of the fully automated grouping devices is the grouping device of internal packages for salmon fillet. It is integrated as a separate unit into the packing complex of salmon fillet.

2. Grouping equipment of packages for salmon fillet construction and principle of work

The geometric model of the grouping equipment of packages for salmon fillet is presented in Fig. 1.

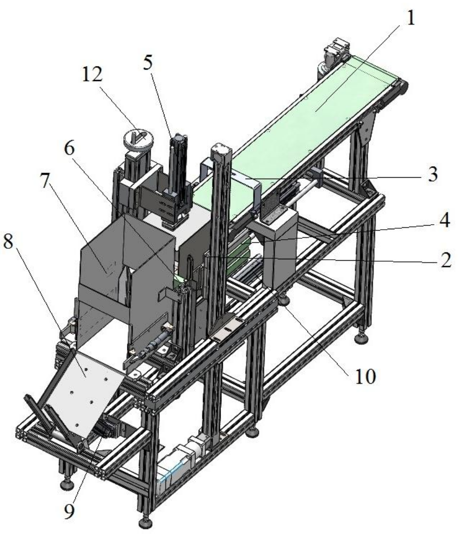

Fig 1 The geometric model of the grouping equipment of packages for salmon fillet

The internal packages of salmon fillet are moving by transporter *1*. The initial position of lifting system *2* is at the lower part of the shaft of transporter *1*. When the internal package passes sensor *3*, the lifting system moves downwards by one step, which size (motion of the lifting system) will be determined during the investigation. In such a way the lifting system makes 5 steps and goes until the dislodging position, which is by the lower part of the thruster *4*. When the pressing cylinder *5* descends, it presses the packages of the group present in the lifting system, and thus their height is measured. If the height is suitable, the thruster *4* pushes the package group of salmon fillet through the gates *6* to the box that is in the container of empty boxes *7*. The box is directed by the dislodging plane 8 to the rolling device *9*, which rolls the full box down onto the roller transporter of full boxes.

If the group's height is too big, the rejection is performed: the lifting system moves to the rejection position that is by the lower part of the plate *11* of rejection cylinder *10*. This cylinder pushes the group of packages of unsuitable height from the lifting system.

After rejection of the group or its dislodging to the box all the cylinders return to their initial positions (Fig. 1), and then the lifting system moves to its initial position, and the cycle is repeated.

3. Grouping equipment of packages cyclogram

As the total efficiency of the group packing complex of salmon fillet is known – 120 units of internal packages per minute, it is determined that the operating cycle of the grouping device cannot exceed 5 s. The cycle's modeling and investigation will be conducted, according to the parameters presented below:

- grouping and packing cycle – not more than 5 s;
- number of steps of lifting system – 5;
- time between the internal packages (time, during which the next package comes after the previous, as well as period of steps of the lifting system) – t_0 s;
- linear speed of the transporter (as well as of movement of internal packages) – 600 mm/s;
- displacement of one step – *a* mm (determined during investigation);
- motion time of one step of the lifting system – t_1 s;
- time of lifting system's movement to dislodging position – t_2 s;
- displacement of lifting system's movement to dislodging position – *b* mm;
- measurement of height of package group – t_3 s;
- dislodging time of package group – t_4 s;
- returning time of lifting system to the initial position – t_5 s;
- returning distance to the initial position – 250 mm.
- delay of time, after which the lifting system makes one step forward after the package passes the sensor (de-

termined during investigation) – u_t s.

The cyclogram of one cycle of grouping device of salmon fillet is made, according to the aforementioned parameters. It is presented in Fig. 2

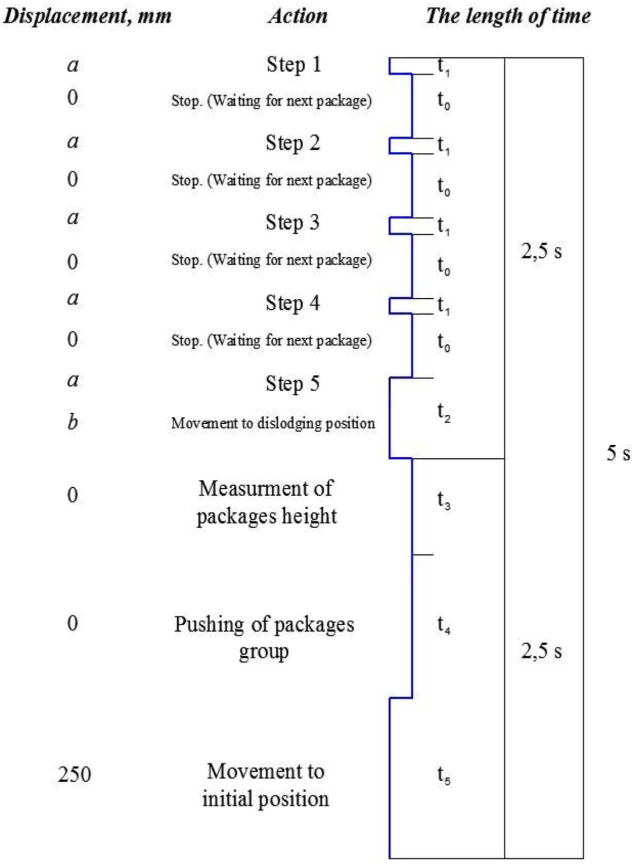

Fig. 2 The cyclogram of one cycle of grouping device of salmon fillet

The total duration of the cycle is 5 s – the grouping device collects the group for 2.5 s and pushes it down to the box or rejects it in 2.5 s. The cyclogram given in the Fig. 2 was made for the main function of grouping device, i.e. dislodging of the group to the box.

4. Compiling of cyclogram research methodology

Following the cyclogram given in Fig. 2 and the system SolidWorks Motion [3-6], the operation cycle of the grouping device is modeled. The calculated model is formed on the basis of the model of the geometric grouping device of packages of salmon fillet. As the dislodging of the full box lasts for relatively short time in the total grouping cycle, and the box is rolled down regardless the work of the lifting system, it is not taken into account in the investigation of the cyclogram.

The actual weight of cart is taken into account in the calculation model – 4.79 kg. The dimensions of the package of salmon fillet correspond to the dimensions of internal package of ideal form – 220×190×10 mm and the real weight of the internal package – 200 g. The movement speed of the package corresponds to the linear speed of the complex transporters – 600 mm/s. The real gravitation force affects the entire equipment, including the packages (9.81 m/s^2).

The calculation model of the grouping device is made using geometric model basis of grouping device, presented in Fig. 1.

The modeling is conducted, according to the methods presented below.

Five geometrical models of real weight and dimensions of the packages of salmon fillet are used to model the cycle. When the packages are moving on the transporter, they are recorded by virtual sensor, which location and seeing area correspond the real one (Fig. 2). When the package passes the sensor, the delay of time starts to be calculated before the first step of the lifting system. When the packages reach the end of the transporter, they fall freely on the cart of the lifting system. When the set delay time passes, the cart makes one step downwards. When the 5th package passes the sensor, the cart moves to the unloading position after the set delay, and it also corresponds the real one. When the group of packages is in the unloading position, the pressure of group is modeled, and it is virtually determined that the group of packages is good, the group is dislodged. When the thruster returns, the cart returns to the initial position within the set period and the modeling is completed.

In order to assess the possible delay of signals, the time delays are entered before the operations, and they are equal to 0.1 s [6]. As the possible delays of components (sensors, valves, links) do not exceed 0.5 ms, the reserve of delay time is received in the calculated model of such delay.

It should be noted that the full cycle is considered to be the time from fixing the first package until the cart's return to the initial position.

5. Grouping equipment of packages for salmon fillet operation cycle numerical analysis

One cycle of packing of grouping device is modeled using the methodology presented above. For this purpose, cyclogram presented in Fig. 2 receives real values, which are received proportionally to the duration of operations when the total time of the cycle is segmented , presented in Table 1 (model No. 1).

Table 1

Values for modeling

Parameter	Model No.1	Model No.2	Model No.3
displacement of one step a, mm	20	15	12
time of one step t_1, s	0.1	0.1	0.08
displacement to dislodging position b, mm	170	190	202
movement time to dislodging t_2, s	0.5	0.5	0.5
measurement time of package group t_3, s	0.7	0.7	0.7
dislodging time of package group t_4, s	1.0	0.8	0.8
returning time to the initial position t_5, s	0.7	0.4	0.3
delay of time u_t, s	0.7	0.7	0.75

When the simulation of grouping device was done using cycle's parameters, presented in Table 1 (model

No. 1), it was determined that the full cycle lasts 5 s. The received modeling results on the time axis are presented from the moment when the first package is recorded by the sensor (0.61 s from the beginning of modeling) until the lifting system returns to the initial position.

The diagram of the displacement of weight centre of each internal package in the vertical direction is presented in Fig. 3.

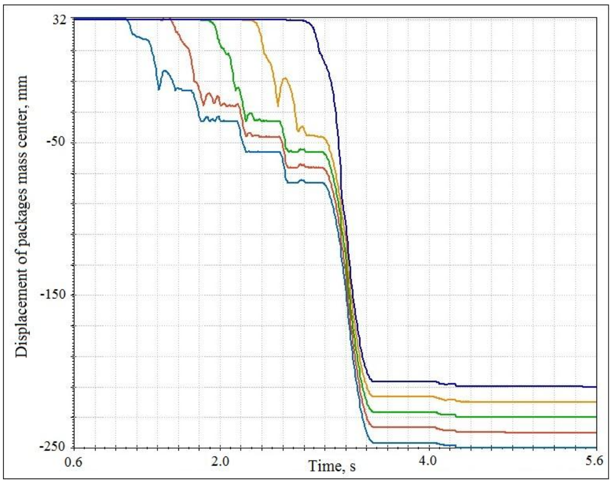

Fig. 3 The diagram of the displacement of weight centre of each internal package in the vertical direction (model No. 1)

The diagram of reaction force of the lifting system is presented in Fig. 4.

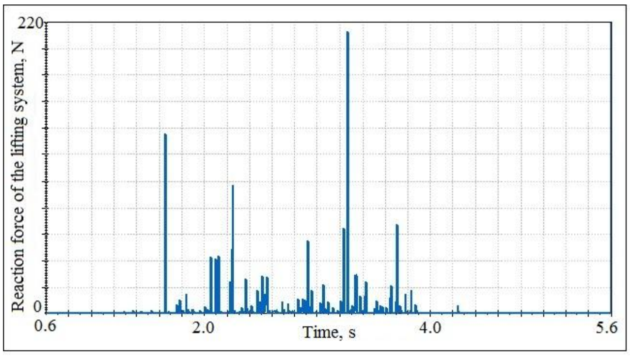

Fig. 4 The diagram of reaction force of the lifting system (model No. 1)

The view of the modeling of operation cycle of the grouping device 2.54 s after the beginning of the cycle is presented in Fig. 5.

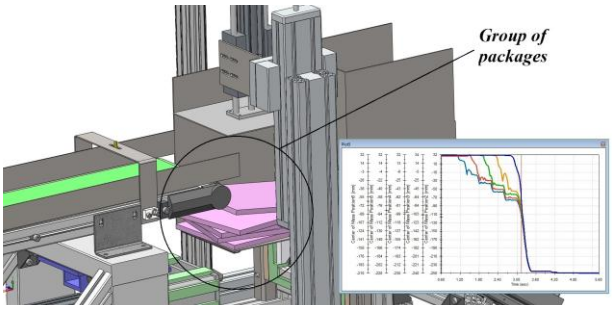

Fig. 5 The view of the modeling of operation cycle of the grouping device 2.54 s after the beginning of the cycle (model No. 1)

The modeling results of grouping device presented in Figs. 3-5 helped to determine that when the grouping device is working by the parameters, presented in Table 1 (model No. 1), the big fluctuation of weight centers of internal packages is received, which reaches 20 mm when the fourth internal package gets onto the lifting system (the package rebounds). The maximal reaction force of the lifting system received is 212 N. It exceeds the maximal allowable load of the gear of linear motor (150 N), thus the modernized grouping device cannot work in such a regime.

In order to find rational work regimes, the modeling of operation cycle of the grouping device is done using the values set for cyclogram presented in Table 1 (model No. 2).

When the simulation of grouping device was done using the aforementioned cycle's parameters, it was determined that the full cycle lasts 4.57 s.

The diagram of the displacement of weight centre of each internal package in the vertical direction is presented in Fig. 6.

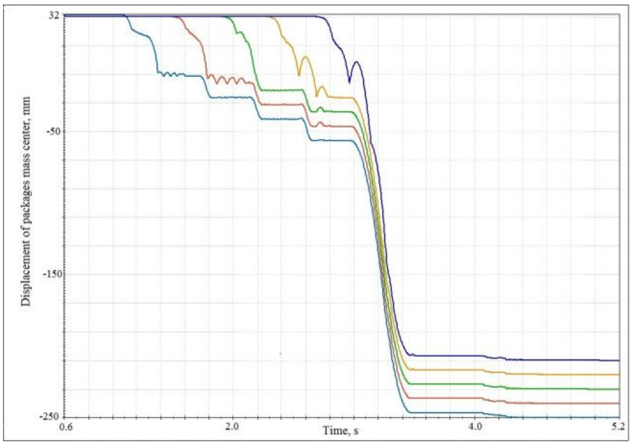

Fig. 6 The diagram of the displacement of weight centre of each internal package in the vertical direction (model No. 2)

The diagram of reaction force of the lifting system is presented in Fig. 7.

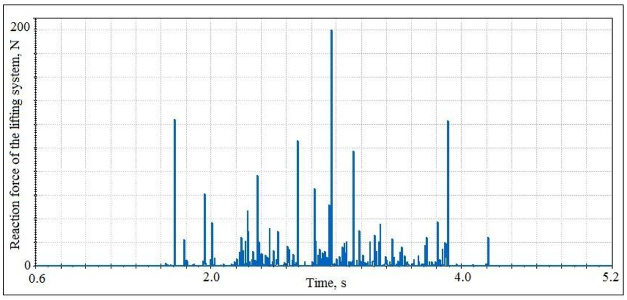

Fig. 7 The diagram of reaction force of the lifting system (model No. 2)

The view of the modeling of operation cycle of the grouping device 2.45 s after the beginning of the cycle is presented in Fig. 8.

According to the modeling results of grouping device presented in Figs. 6 – 8, when the grouping device is working using the parameters provided above (Table 1, model No. 2), the smaller fluctuation of weight centers of internal packages is received. The maximal reaction force of the cart received is 198 N. It exceeds the maximal allowable load of the gear of linear movement (150 N), thus the modernized grouping device cannot work in such a regime.

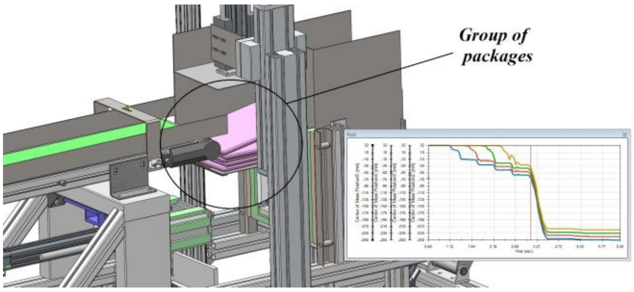

Fig. 8 The view of the modeling of operation cycle of the grouping device 2.45 s after the beginning of the cycle (model No. 2)

In order to find rational work regime, the modeling of operation cycle of the grouping device is done using the values set for cyclogram presented in Table 1, model No. 3.

When the simulation of grouping device was done using the aforementioned cycle's parameters, it was determined that the full cycle lasts 4.77 s.

The diagram of the displacement of weight centre of each internal package in the vertical direction is presented in Fig. 9.

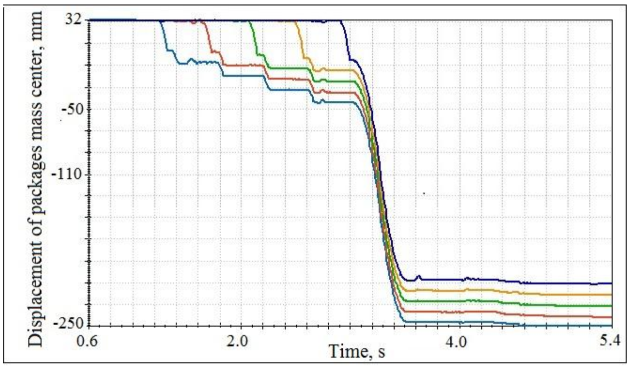

Fig. 9 The diagram of the displacement of weight centre of each internal package in the vertical direction (model No. 3)

The diagram of reaction force of the lifting system is presented in Fig. 10.

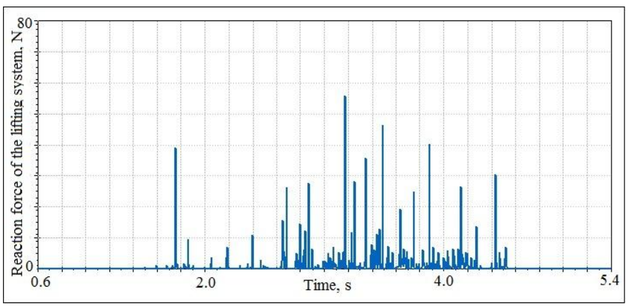

Fig. 10 The diagram of reaction force of the lifting system (model No. 3)

The view of the modeling of operation cycle of the grouping device 3.65 s after the beginning of the cycle is presented in Fig. 11.

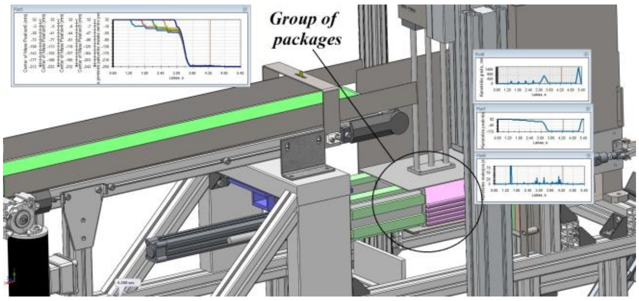

Fig. 11 The view of the modeling of operation cycle of the grouping device 3.65 s after the beginning of the cycle (model No. 3)

According to the modeling results of grouping device presented in Figs. 9-11, when the grouping device is working using the parameters provided above (table 1, model No. 3), the small fluctuation of weight centers of internal packages is received. The displacements of weight centers of internal packages presented in the Fig. 9 show, that during the cycle of the grouping device with the aforementioned parameters no bouncing of packages is noticed, thus when the grouping device is working in such regime, the group is collected qualitatively and it is pushed to the box (Fig. 11). The maximal reaction force of the cart received is 56 N (Fig. 10). It does not exceed evidently the maximal allowable load of the gear of linear movement (150 N), thus the grouping device may work in such regime.

6. Conclusions

The investigation of the cyclogram of grouping device of packages of salmon fillet allowed finding the rational parameters of working cycle of the grouping device, in presence of which the group of internal packages is formed and pushed to the box correctly. Rational parameters presented in Table 1, model No. 3.

The maximal reaction force of the lifting system was determined as it rises 3.18 s from the cycle's beginning and is equal to 56 N. This does not exceed evidently the maximal allowable load of the gear of linear motor (150 N).

The methodology of investigation of work cycle of the grouping device was formed that enables to determine the rational working parameters.

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PAKUOČIŲ SU VAKUUMUOTAIS MAISTO PRODUKTAIS GRUPAVIMO ĮRENGINIO VEIKIMO CIKLOGRAMOS OPTIMIZAVIMAS

R e z i u m ė

Straipsnyje pateiktas modernizuoto lašišų filė pakuočių grupavimo įrenginio veikimo ciklogramos optimizavimas. Naudojant Solidworks Motion sistemą geometriniu grupavimo įrenginio pagrindu sudarytas skaičiuojamasis modelis. Atlikta skaitinė analizė, rasti optimalūs grupavimo įrenginio darbo ciklo parametrai.

Nustatyta maksimali vežimėlio reakcijos jėga, lygi 56 N, susidaranti po 3.18 s nuo ciklo pradžios. Tai labai neviršija maksimalios leistinos tiesiaeigio judesio pavaros apkrovos (150 N).

Sudaryta grupavimo įrenginio darbo ciklo tyrimo metodika, leidžianti nustatyti racionalius veikimo parametrus.

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VACUUMED FOOD PACKAGES GROUPING EQUIPMENT CYCLOGRAM INVESTIGATION

S u m m a r y

The article presents the investigation of the operating cyclogram of grouping device of packages of salmon fillet. The system Solidworks Motion helped to create a calculative model using the geometric basis of grouping device. The numeric analysis revealed rational parameters of working cycle of grouping device.

The maximal reaction force of the cart was determined as it rises 3.18 s from the cycle's beginning and is equal to 56 N. This does not exceed evidently the maximal allowable load of the gear of linear motor (150 N).

The methodology of investigation of work cycle of the grouping device was formed that enables to determine the rational working parameters.

Keywords: vacuumed packages, primary packages, grouping equipment, packing equipment.

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