A method of parameter optimization of the equipment configuration with the help of neural net and finite element analysis

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Abstract. The authors have developed the procedure of optimization of the equipment configuration with the help of neural net based on the results of finite element analysis. The dismembrator’s characteristics for feeding slop production has been optimized. The results of the virtual experiment are displayed in diagrams of pressure and temperature of the liquid inside the operating devices. The equipment of the optimized configuration has demonstrated a number of advantages compared to the prototype.

1. Introduction
Dismembrators are a variety of flour mills, the operative parts of which are made as a rotor or stator with pegs on their surface. They are widely used in chemical and manufacturing industries and agriculture. In particular, they are used for production of highly efficient feeding slop [1].

There are different approaches to the construction of the operating devices. Numerous scientists (N S Sergeev, U N Kamyshov, S V Zolotarev, V M Cheryakov, U K Sabiev) [2-4] were engaged in objectification of the constructional features of a similar type of equipment, but no suitable procedure of the efficient structural calculations of dismembrators has been developed for now.

Consequently, the aim of the research is to develop a method of optimization of the design parameters of centrifugal-rotor dismembrators for feeding slop production.

2. Theory
An algorithm of optimization of the design parameters of a centrifugal-rotor dismembrator consists of several stages.

Stage 1 represents a computer-based experiment on the operating devices of the equipment. At this stage a procedure of the virtual experiment was developed, enabling us to estimate a module of grain milling, mixture temperature and the efficiency of the equipment.

The system of Navier-Stokes non-stationary equations in their conservative form underlies the mathematical model. In this case the authors examine the liquid, where the processes of heat transfer and internal friction take place. Therefore, the system includes a heat transfer equation and is concluded by density and specific heat capacity equations as a function of independent variables of pressure and temperature. The system of equations was solved by means of the finite element analysis software tool AnsysCFX.
Stage 2 includes optimization of the configuration with the help of neural net. At this stage, firstly, the rotor and the stator were parameterized. Secondly, the target values of the milling modulus indices, mixture temperature and efficiency of equipment were determined.

It is recommended to mill the grains before feeding. The desired size of the particles in pigs’ feed is considered to be 600...700 µm. The amount of particles less than 1 mm must be 75 % of the total mass. Consequently, fine grinding (0.2...1 mm) of feeding stuff is accepted as effective [5].

The appropriate temperature of the mixture is 40 °C, which is slightly higher than the temperature of a pig’s body. In case of using unheated feed, it is to be heated up in the pig’s stomach before being digested, thereby a part of the nutrients consumed by the pig is wasted. So, the acceptable range of the feed temperature should be 40...60 °C.

To formulate the aim of parameter optimization the authors have specified the following characteristics: the average diameter of the particles after milling (y1, mm); mixture temperature (y2, °C).

The conditions of the operability are the following: y1 = 0.5 ± 0.3; y2 = 40 ± 5.

The controlled characteristics are the following: Lr – width of the section of pegs of the rotor; Z – gap between the section of pegs of the stator and the rotor cavity; Kr – the amount of rotor sections; A – peg width along the outer side; B – cavity width along the outer side; Hp – height of the peg; Hd – depth of the cavity; G – sharpening angle of the peg; P – gap between the stator and the rotor (Figure 1).

Figure 1. The constructional features of a centrifugal-rotor dismembrator.

The following step is to obtain a training sample. Since it is impossible to conduct a natural experiment by the example of a large number of equipment options, a virtual experiment was preferred.

The authors developed the plan of experimentation, carried out the virtual experiment and obtained the results. Subsequently, on the basis of these results a regression model and the training sample were developed. After application of the neural net, the authors obtained the parameters of the optimized model of operating devices of the dismembrator, allowing one to reach specified target parameters.

3. Results and discussion
The analysis of the modeling results allowed revealing the following regularities:
– the diagrams (Figure 2) reflect the zones of the increased pressure and evacuation. The zones of the increased pressure are formed, when the liquid stream encounters the moving peg of the operating device. At that moment the fluid behaves as a compressible fluid and a pressure jump occurs. The conditions of hydraulic shock origination are created;
– as a result of the liquid compression, at the moment of stream collision with the peg, the temperature of the liquid increases (Figure 3), as the span between the liquid molecules reduces and kinetic energy increases.
After optimization of the design parameters, an optimized configuration of the operating devices of the dismembrator for feeding slop production was developed. Experimental comparison with the prototype revealed the advantages of the optimized configuration.

**Figure 2.** Contour diagrams of the liquid pressure inside the operating devices of the dismembrator.

**Figure 3.** Contour diagrams of the liquid temperature inside the operating devices of the dismembrator.

**Figure 4.** Dependence of the temperature of the mixture on the time of the process behavior.

Figure 4 shows the graphs of the average temperature values depending on time. The graph of dependence displays a sharp rise in heating in case of the optimized configuration. Such result is
evidence of a larger size of the pegs compared to the prototype. The mixture is ground by the rotor’s and the stator’s walls for a longer period of time and, consequently, it is heated more quickly.

One of the most important results of the experiment is that the mixture in the optimized configuration is heated to the specified temperature (40 °C is the recommended temperature of the liquid feed) by 4 min faster (in 19 min), than that in the prototype (in 24 min).

4. Conclusion
Summing up the study mentioned above, it is necessary to note that the authors have succeeded in the development of the optimization method of the dismembrator parameters configuration for feeding slop production. This method has allowed the authors to develop a configuration which is more beneficial than the prototype in terms of the heating rate of the grain mixture.

References
[1] Kamyshov U N 2012 Justification of working bodies’ design parameters of dismembrators for production of liquid feed mixture. Abstract of thesis cand. of tech. sci. (Barnaul: Altai State technical University Press.)
[2] Drjuk V A, Saleev F I, Kamyshov U N, Nefjodov K E, Pochter S V, Sitnikov A A, Nefjodov E N 2010 Dismembrator for preparing homogenized products. Patent RF 2466795
[3] Sabiyev U K, Pirozhkov D N, Sabiyev I U 2014 Bulletin of the Altai State Agricultural University 12(122) 132–137
[4] Sergeev S V, Reshetnikov B A, Gordeev E N, Sergeev U S 2007 Method for miling viscous materials. Patent RF 2365469
[5] Sitnikov A A, Kamyshov U N, Makarova N A, Pochter S V 2012 Bulletin of the Altai State Agricultural University 3(89) 85–88