The research of possibility to use the machine for biofuel production as a mobile device for poultry farm waste recycling

Andrei Nikolaevich Nikulin, Kirill Valerievich Epifancev, Stanislav Vyacheslavovich Kovshov, Gennady Ivanovich Korshunov

National Mineral Resources University, 21 Line, 2, St.-Petersburg, 199002, Russia

Abstract. At present, the problem of waste recycling becomes urgent for technologists and ecologists. There are many examples of developed devices which look like large workshop units with no ability to be moved easily. Thus they need much time for installation, the cost price per 1 kg of waste is high and it is hard to change it over quickly. A large number of staff also rises in the price of recycling. This article presents the existing machines for waste recycling. Besides, the authors describe the development of mobile recycling machine and ground the structure of its matrix.

[Nikulin A.N., Epifancev K.V., Kovshov S.V., Korshunov G. I. **The research of possibility to use the machine for biofuel production as a mobile device for poultry farm waste recycling.** *Life Sci J* 2014;11(4):464-467] (ISSN:1097-8135). http://www.lifesciencesite.com. 67

Keywords: chicken manure, fertilizer, draw die, matrix, moulding, agglomeration, briquetting.

Introduction

Currently, the increase in foodstuff prices is well grounded by soil depletion in some areas. Moreover, the majority of such enterprises as poultry farms and livestock farms increase the warehousing of waste products which are processed in a very small volume [1, 2]. So, the reduction of rich soils leads to problems in supplying the region with inexpensive food of high quality. All this gradually leads to an environmental problem because manure landfills pollute underground water and atmosphere [3]. In the article, we try to extend the list of products made of recycled chicken manure – fertilizers and fuel which can be used for heating the farm and reducing logistic costs.

Now we will compare indications of using chicken manure as a fertilizer (Table 1).

Table 1. The comparison of fertilizers made of chicken manure with other fertilizers

Element	Type of fertilizer			
	Cattle manure	Chicken dung	Kemira Comby	Ammonium nitrate phosphate fertilizer
N	0.41	2.8-4.17	14.0	17.0
P_2O_5	0.19	2.7-3.5	11.0	17.0
K_2O	0.41	1.5-1.7	25.0	17.0
Humidity	78.5	10.2	10.0	10.0
Mg	-	0.032	1.4	-
S	-	0.8	1.8	-
Fe	-	0.025	0.1	-
B	0.0005	0.01	0.02	-
Cu	0.0004	0.0059	0.01	-
Mn	0.005	0.5	0.1	-
Zn	0.002	0.03	0.01	-
Mo	0.00005	0.001	0.002	-
Co	0.00003	0.001	0.001	-
J	-	0.001	0.001	-
Cr	-	trace	0.001	-

The high indexes of chicken manure increase the ability of microelements to generate organo-mineral complexes with organic compounds. This plays a significant role in intracellular metabolism.

One of alternative renewable fertilizers is the waste products of poultry farms – chicken manure with litter (CML) of 4 hazard class. The calorific capacity of the CML is QpH = 2500±500 kcal/kg [4]. So this waste is on a par with other kinds of biofuel (straw, wood and some sorts of coal). When burning, 1t of the CML gives up to 2 gcal of heat in the form of hot water or up to 3 t of steam for process needs. It substitutes up to 270 m^3 of natural gas or up to 240 kg of liquid fuel (black oil or stove fuel) [5].

The equipment for chicken manure granulation

Taking into account the size of coal fuel, we can conclude that GOS diameter should change within limits $6 \leq d \leq 25$ mm with a glance to the size of the holes in fire grate. After we find the optimal parameter for the pellet, we move to choosing the matrix [6].

Round matrixes are made of three dimension types with height 22, 28 and 60 mm.

The draw die duct, the mass moves through, is made with the help of high-precision electroerosion computer-controlled machines.

The internal surfaces of duct are polished up to radius 0.05-0.2 μm. This makes it possible to reduce the adhesion of mass to draw die's walls and thus to accelerate extrusion, to reduce backpressure and to quicken tool cleaning.

In our computations, we accepted three forms of narrowing draw die's entry section.

Methods

In order to check the data of theoretical research, we conducted virtual tests for created model by means of open-source framework YADE for discrete numerical models, focused on Discrete Element Method and open-source visualization

application ParaView [7]. We studied the possibilities of virtually prescribed chicken manure particles with draw dies of different inclination (Figure 1) [8].

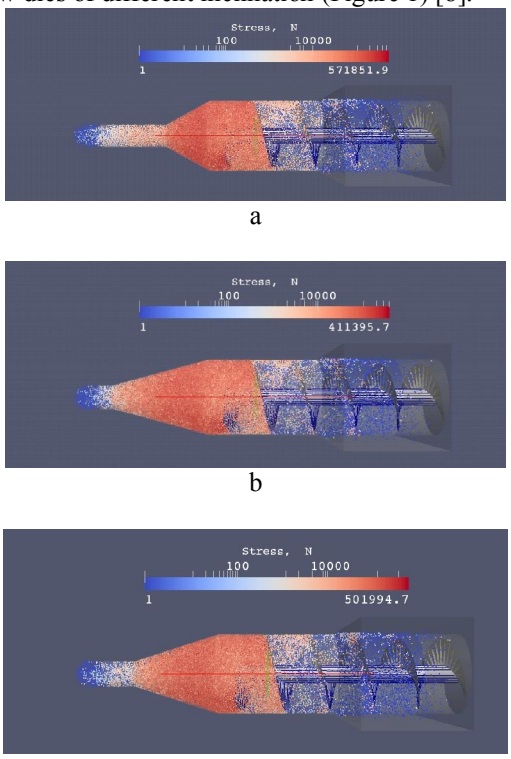

Figure 1. Agglomeration model
a – draw die inclination 65°, b – draw die inclination 55°, c - draw die inclination 45°

Main part

Tests allowed us to make a summary table containing indications of stress at the shaft connected with reducer and normal stress (Table 2).

Table 2. The results of tests for draw dies with different inclinations

Inclination	Angular velocity, rps	Shaft stress, kPa	Normal stress, Nwm
45°	1.42	571.8	7.6
55°	1.37	501.9	6.2
65°	1.33	411.3	5.1

So we can predict that normal stress will grow together with the inclination of matrix wall.

When stress concentrates in certain sections of auger's housing, there is a danger of overheating caused by the increase of internal friction and worsening of auger's rotatory power. If we study the most intensive variant of test (Figure 2) we can see that the maximum stress falls on the last blade of the auger.

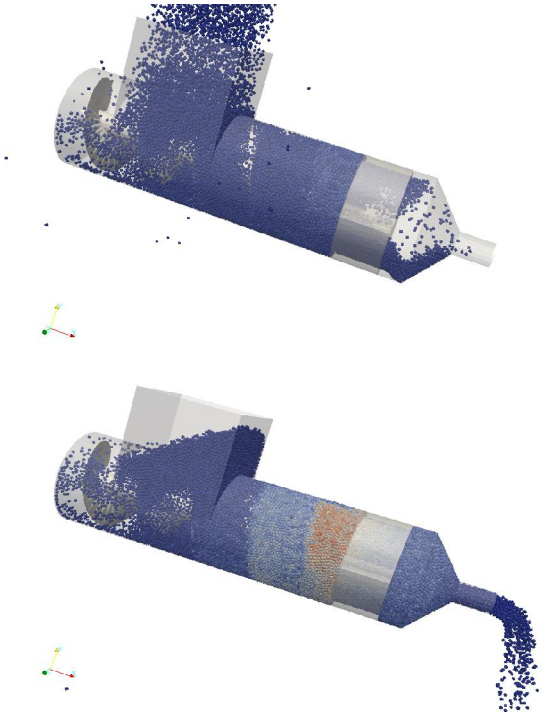

Fig. 2. The increase of internal friction by material stopping (marked in red).

There are many attendant useful substances in processed material. They cannot be processed in traditional moulders. This fact and the above-stated problems made us create a device for producing solid fuel with inclination 65° taken from Table 1 as the least stressed variant (Figure 3) [9].

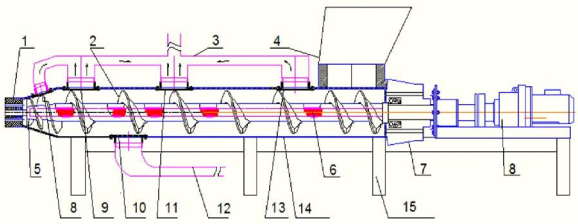

Fig.3. The plant consists of:
1 – matrix with moulding holes and ducts; 2 – augers; 3, 13 – suction hoses of the conditioning system; 4 – charging hopper; 5 – processing knifes; 6 – tubular heating element; 7 – reducer; 8 – motor; 9, 10, 11, 12, 14 – the grids of the conditioning system; 15 – housing; 16 – frame.

Material conditioning provides the following steps of process: drying and moulding. This sequence ensures the absence of drying unit in manufacturing process. Grids mounted on the upper part of the housing and hoses placed above the grids remove evaporating moisture generated by wet material processed by heated auger. When a blade turns over through these vapor extracting systems, the arising pressure will push out both steam and some smells.

The collected moisture rich in humic acids can be further used in chemical and perfume industry.

If we increase the length of the auger up to 200 m, the material will be inside the heated zone for a longer period of time. Thus the material is conditioned.

Conditioning system consists of grids 9, 10, 11, 12, 14, mounted in housing 15, and suction hoses 3 and 13 connected with workshop exhaust system.

The plant operates the following way. The material (prepared charge) is received by charging hopper 4; then augers 2 process it and moves it to the moulding holes of matrix 1. While the moulded material moves through the housing by auger 2, it loses moisture, gases and smells by means of the conditioning system which consists of grids 9,10, 11, 12, 14, mounted in housing 15, and suction hoses 3 and 13, connected with workshop exhaust system. Besides, the heat energy impulse created by heating element 6 influences the processed material. Before the motor starts, heating element 6 is turned on in auger 2.

So, the research conducted makes it possible to choose the optimal form of matrix for the plant. Experiments show that when manure mass moves through the draw dies of auger machine with entry section inclination 65°, the pressure in the material changes exponentially and the energy content declines by 28%.

Selected draw die has less material resistance. Consequently the machine spends less energy (Figure 1 a). This promotes the improvement of fuel granules quality including solidity and humidity enough for the delivery of granulated fuel without drying.

Here one can see economic calculations for the payback of the project. They will to understand in details the economic efficiency of granulated biofuel and fertilizer production. Payback is always a decisive factor in investment activity (Tables 3-5) [10].

Table 3. Payback

The cost for 1 t of product	3 800	rubles
Annual output	3 305	t/year
Annual product sales income	12 558 240.00	rub/year
Sales profit	8 037 484.80	rub/year
Payback period	0.7 of the year	

Table 4. Total start-up costs

Position	Ninst, kW	Cost with VAT, rub.
Basic manufacturing equipment	56.00	4 855 700.00
Transport and custom expenses		454 396.66
Supervised installation and commissioning		241 800.00
		5 551 896.66

Table 5. The economic efficiency calculation for a miniplant of fertilizing and fuel pellets (3 shifts).

Initial data:			
Load factor		0.85	
Output capacity	G =	450	kg/h
		9.18	t/day
Raw material consumption	G_{st} =	450	kg/h
		9.18	t/day
Raw material humidity	w_0 =	75	%
Calorific capacity of finished product	Q =	4000	kcal/kg
Installed capacity of electric motors	N =	56	kW
Electric energy consumption	W =	42	kW*h/h
Electric power costs	p_e =	2.4	rub/kW*h
Investment costs	p_a =	5 551 896.66	thousand rubles
Wholesale factory price for finished product	p_p =	3800	rub/t
Raw material cost	p_r =	100	rub/t
Workshop area	S_w =	150	m^2
Renting of 1 m^2	c =	250	rub/month
Number of labour days in a month	n =	30	days/month
Quantity of staff		8	men
Average salary (including taxes)	AS =	25 000	rub

Conclusion

The worked out plant makes it possible to increase the quality of moulded granules and make the solidity and humidity enough for delivery without drying. Besides, the density of granules increases by an order. All this allows us to conclude that the worked out technical solution is of significant efficiency and good prospects.

Findings

The research conducted allowed us to choose the optimal form for the matrix. Experiments showed that when manure mass moves through the draw dies of auger machine with entry section inclination 65°, the pressure in the material changes exponentially and the energy content declines by 28%.

Corresponding Author:
Dr.Nikulin Andrei Nikolaevich
National Mineral Resources University
21 Line, 2, St.-Petersburg, 199002 , Russia

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4/20/2014