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TRIBOLOGY COMPATIBILITY OF STEEL AND CAST IRON IN ABRASIVE AND CORROSIVE ENVIRONMENT IN THE PRODUCTION OF BIOMASS BRIQUETTES

This article presents an idea of biomass compression that causes corrosive and abrasive wear on screw presses (sunflower husk, sawdust and straw). The present method allows determining the force of friction and wear rate of prototypes. The authors of the article designed some corrosive and abrasive environment where screw and extruder die (screw press) work for production of biomass briquettes. The article contains a tribology compatibility rating of materials for the manufacture of operating elements.

Key words: *Applied tribology, agriculture, friction, friction testing methods, wear, abrasive wear, corrosive wear, calculation, data receiving.*

Introduction. Searching alternative energy sources, one of the perspective areas is obtaining solid fuel from agricultural waste (biomass). These wastes include: straw, sunflower husks, rice husks, buckwheat husks, sheave of spinning plants, not feeder wastes of elevator production, stalks of sunflower and corn, wood waste. Solid fuel is produced from biomass by pressing in screw presses (extruders). Due to the fact that the pressed biomass has a significant level of acidity and abrasivity, mechanical wear of a screw and press die is supplemented by corrosion wear, which greatly reduces operating time of the presses.

Some works of the following scientists were devoted to study of mechanisms of wear of screw presses or extruders: Stambyrskui E.A., Beil A.I., Karlivan V.P., Bespalov Y.A. [1], Yastreba S.P. [2], Honchar V.A. [3], Derkach V.V. [4], Matviishyn P.V. [5], Vasylkiv V.V., Radyk D.L. [6], Lutsak D.L., Kryl Y.A., Prysiazhniuk P.M. [7] Berkovych I.I. [8]. The main achievement of the researchers was determining the factors that affect the wear, creating a classification of basic types and causes of wear, determining the negative effect of wear on the change of the basic characteristics of the equipment operation.

Wear mechanism of operating elements of screw press (extruder). Any tribosystem has its certain contacting peculiarities, which are defined by the nature of contacting materials, by contacting surface condition and by interaction terms. During pressing, raw material is subjected to temperature and mechanical influence, the shape of raw material varies by moving along the work area. The condition of the product is changed under the influence of temperature and pressure. In the hopper there is a contact of solid elements of raw material which has low bulk density (sawdust 200 kg/m^3, sunflower husk 120 kg/m^3) and the size of these solid elements doesn't exceed 8 mm [9]. In the area of compression, metal surfaces of operating elements are in contact with abrasive particles of the product, which gradually shrinks, deforms and increases bulk density. The particles of the product are heated by the heat energy released from friction and from the electric heater, they excrete lignin, thus they create viscous and supple medium. On the area of formation, the product contacts the die, namely surface of the die contacts ash, which appeared on the surface of the briquette under high temperature (processing temperature of sawdust is 320-350ºC, 240-290ºC of sunflower husk [9]). During sintering acrolein, nitrogen dioxide, dust of vegetable mater, silicon dioxide is extracted, [10] which come into molecular contact with a die material. Features of tribocontact on zones determine the value and type of wear.

Abrasive, adhesive, fatigue and corrosion-mechanical wear of extruder operating elements occur during pressing the biomass. Photos of a worn screw shank and die are presented on Fig. 1 and 2 respectively.

Fig. 1. Photo of a worn shank of extruder screw

a *b*

Fig. 2. Photo of a worn die: (*a*) in front and (*b*) behind

The raw material, which is used for production of biomass briquettes includes mineral particles (sand, soil and small stones) [11] and in contact with the operating elements they cause mechanical fracture of surfaces which rub against each other, as a result, cutting or scratching effect of solids and particles leads to abrasive wear [12; 13]. This type of wear is typical for all zones [3; 14]. Wear is typical for extruders on the area of compression [4]. The last two coils of an extruder shank are the most disposed to abrasive wear [15]. Abrasive wear happens when press efforts of worm crest is not high enough or there is no propensity of jamming. Metals of cylinder sleeve have a greater surface solidity after nitriding than metals of screw, thus microrelief of the die is capable for mechanical wear of screw coil surface. The more mineral impurities is in raw material, the stronger wear of surface of operating elements [1; 16]. During operating the screw, strengthening of the surface layer is observed, which is typical for mechano-chemical and abrasive wear form. On the surface of coil screw there are zones of supple deformation and secondary structures caused by abrasive particles of material [6]. Ash, which appeared during the oxidation product, consists of mineral substances, which lead to high abrasive wear [15].

Manufacturing biomass briquettes, the following chemical compounds as carbon dioxide, silicon dioxide, lignin due to adsorption, chemisorption and diffusion of atoms change chemical composition of the operating elements [2]. Under the influence of high temperature, moisture and poor acidic environment of biomass, a chemical reaction occur with the metal surface that provokes corrosive and mechanical wear [17]. Usually this wear happens in forming and melting zone, but it is the strongest one in compression zone. Corrosive-mechanical wear occurs only in the following pair of friction: pressed material – element of the construction [1].

Laboratory equipment and methodology of experimental researches. A special friction machine (represented in Fig. 3) was used for studying wear rate of operating elements of extruder tribosystem using different environments of plant material and for determining the coefficient of friction. In order to reduce the costs and time necessary for study of tribotechnical characteristics of certain tribosystems, we used a method of physical modelling, which is represented in the works [18–22].

Fig. 3. Appearance of a friction machine

When using physical modelling, we resolved some tasks of dependencies detection of wear rate, friction force for full-scale tribosystem according to research data during the experiment. Modelling law is displayed in the form of calculated scale factor, which is a combination of large-scale conversion factors from the model to the full-scale parameters which are in criteria of resemblance [23].

The above stated friction machine is able to determine wear rate of all simulated scale reduced tribosystems taking into account construction features, materials of operating elements and environment. By using electronic strain gauge, the instrument that measures the force of the computer, the machine allows to define force of friction and to calculate a coefficient of friction. Researches on determining wear rate were made according to a «ring-ring» scheme. Dimensions and shape of samples for model tribotechnical tastings were in accordance with DSTU 30480-97, Fig. 4.

Control of acidity was carried out by the laboratory Microprocessor ionomer I-160 M, Fig. 5, which is designed for direct and indirect potentiometric measurement of activity of hydrogen ions (pH), activity and concentrations of other monovalent and divalent anions and cations (pX), oxidation-reduction potentials (Eh) and temperature of aqueous solutions with the presentation of results in digital form and as the same signal of direct-current voltage.

Results of experimental researches and their discussion. To determine the effect of active acidity pH, abrasivity and load, which are typical for plant material, on wear rate and friction force of operating elements of extruder for the production of biomass briquettes, there is a need in carrying out of experiment of three factors, solving an optimization problem and selection of compatible materials of screw and of extruder die.

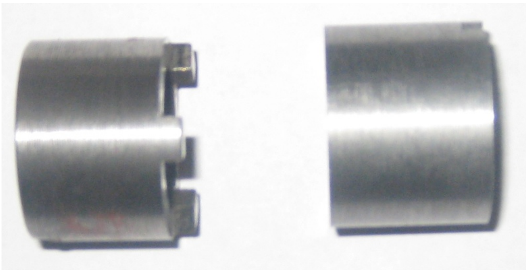

Fig. 4. Prototypes for tribology tests

Fig. 5. Laboratory microprocessor ionomer I-160 M

To solve the optimization problem, an experiment was carried out; its results are presented in the form of matrix in the table 1 and table 2.

Table 1

Matrix of planning and results of experiments on determining influence of active acidity level, abrasion and loading on tribosystem of steel with 28% High-Chromium cast iron

№ exp.	Factors			Response function of the tribosystem steel 41Cr4 and 28% High-Chromium cast iron		Response function of the tribosystem steel X102CrMo17 and 28% High-Chromium cast iron		Response function of the tribosystem steel X40CrSiMo10 and 28% High-Chromium cast iron	
	pH X_1	Abrsivity %, in a weight X_2	*P* (H) X_3	*I* (mcm/h) Y_1	$F_{fr.}$ (H) Y_2	*I* (mcm/h) Y_1	$F_{fr.}$ (H) Y_2	*I* (mcm/h) Y_1	$F_{fr.}$ (H) Y_2
1	8	0	800	171,22	141,65	73,38	84,71	61,15	106,58
2	8	10	800	195,69	252,82	144,61	148,70	195,69	149,63
3	8	0	1200	366,18	331,69	236,04	163,21	219,71	181,71
4	8	10	1200	402,80	361,28	316,18	184,52	256,33	172,01
5	4	5	800	291,30	239,18	203,54	152,95	195,69	153,60
6	11	5	800	366,92	271,47	227,92	158,99	220,15	189,67
7	4	5	1200	406,05	378,34	370,97	205,34	279,64	196,86
8	11	5	1200	659,14	387,08	397,74	270,64	347,88	234,38
9	4	0	1000	303,53	252,46	199,38	171,11	195,69	185,68
10	11	0	1000	391,37	279,94	266,92	193,47	244,61	206,32
11	4	10	1000	396,92	321,55	318,00	201,44	269,07	191,72
12	11	10	1000	562,60	346,49	438,15	217,12	293,53	217,83
13	8	5	1000	269,07	236,58	158,00	150,28	195,69	147,41
14	8	5	1000	267,12	234,13	155,17	145,23	204,23	142,12
15	8	5	1000	270,17	239,21	151,23	154,33	193,17	151,33

Table 2

Matrix of planning and results of experiments on determining influence of active acidity level, abrasion and loading on tribosystem of steel with 32% High-Chromium cast iron

№ exp.	Factors			Response function of the tribosystem steel 41Cr4 and 32% High-Chromium cast iron		Response function of the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron		Response function of the tribosystem steel X40CrSiMo10 and 32% High-Chromium cast iron	
	pH X_1	Abrasivity %, in a weight X_2	*P* (H) X_3	*I* (mkm/h) Y_1	$F_{fr.}$ (H) Y_2	*I* (mkm/h) Y_1	$F_{fr.}$ (H) Y_2	*I* (mkm/h) Y_1	$F_{fr.}$ (H) Y_2
1	8	0	800	60,38	47,61	56,05	74,05	54,46	139,9
2	8	10	800	145,15	218,87	108,15	134,08	195,69	200,5
3	8	0	120	140,08	126,04	152,23	147,19	122,31	225,0
4	8	10	120	243,33	324,68	169,13	222,34	269,07	231,3
5	4	5	800	162,69	176,47	125,47	130,09	146,77	193,9
6	11	5	800	187,07	176,47	153,68	195,37	225,69	238,9
7	4	5	120	341,17	269,55	276,78	247,69	256,48	262,2
8	11	5	120	373,04	370,80	281,49	308,41	347,87	322,9
9	4	0	100	152,15	192,41	84,91	119,01	117,84	214,8
10	11	0	100	253,92	247,82	255,60	162,23	186,76	216,2
11	4	10	100	244,38	271,75	175,75	237,42	293,54	253,2
12	11	10	100	302,84	363,37	328,85	281,12	317,99	257,7
13	8	5	100	138,23	169,93	100,56	147,29	134,54	190,8
14	8	5	100	142,42	162,35	101,43	143,43	128,17	188,1
15	8	5	100	137,89	171,54	99,65	151,36	142,12	182,6

Optimization parameters were: wear rate (Y1) and force of friction (Y2).

To check the possibility of using the least squares method during processing of the received results, we performed calculation of characteristics of random variables and we checked hypothesis of normal distribution. At the first stage we determined the average absolute deviation according to (Ω) the formula:

$$\Omega = \frac{\sum \left| y_i - \overline{y} \right|}{n}, \tag{1}$$

where: y_j – current value of responses; $\overline{y}$ – average value of responses; n – a number of tests.

The following representation must be fair for a selection, which has a normal distribution law:

$$\left| \frac{\Omega}{S} - 0{,}7979 \right| \langle \frac{0{,}4}{\sqrt{n}}, \tag{2}$$

where: S – root-mean-square deviation.

The results of hypothesis checking of values normal distribution of average absolute deviation are given in the Table 3. Analysis of the Table 3 shows that the hypothesis is confirmed according to the block of experimental data of the normal distribution law.

Table 3

Results of checking of normal distribution hypothesis

Tribology characteristics	$\left\lvert \frac{\Omega}{S} - 0{,}7979 \right\rvert$	$\frac{0{,}4}{\sqrt{n}}$
Steel 41Cr4 and 28% High-Chromium cast iron		
I	0,0577415	0,10328
F_{fr}	0,0227361	0,10328
Steel X102CrMo17 and 28% High-Chromium cast iron		
I	0,01821	0,10328
F_{fr}	0,0609	0,10328
Steel X40CrSiMo10 and 28% High-Chromium cast iron		
I	0,08829	0,10328
F_{rf}	0,01192	0,10328
Steel 41Cr4 and 32% High-Chromium cast iron		
I	0,03483	0,10328
F_{fr}	0,00266	0,10328
Steel X102CrMo17 and 32% High-Chromium cast iron		
I	0,0022	0,10328
F_{fr}	0,0356	0,10328
Steel X40CrSiMo10 and 32% High-Chromium cast iron		
I	0,03482	0,10328
F_{fr}	0,04912	0,10328

As a result of mathematical processing of experimental data, we obtained encoded regression equations that adequately describe the impact of pH active acidity, abrasion and loading on the wear rate and friction force:

– for steel 41Cr4 and 28% High-Chromium cast iron:

$$Y_1 = 268{,}7867 + 72{,}77875X_1 + 40{,}71375X_2 + 101{,}1288X_3 + 19{,}46X_1X_2 + \\ + 44{,}367X_1X_3 + 3{,}0375X_2X_3 + 145{,}8479X_1^2 - 1{,}02958X_2^2 + 16{,}21542X_3^2; \quad (3)$$

$$Y_2 = 236{,}639 + 11{,}6803X_1 + 34{,}55X_2 + 69{,}1584X_3 - 0{,}635X_1X_2 - \\ - 5{,}88848X_1X_3 - 20{,}395X_2X_3 + 55{,}31485X_1^2 + 8{,}156148X_2^2 + 27{,}06485X_3^2. \quad (4)$$

– for steel X102CrMo17 and 28% High-Chromium cast iron:

$$Y_1 = 154{,}8 + 29{,}855X_1 + 55{,}1525X_2 + 83{,}935X_3 + 13{,}1525X_1X_2 + \\ + 0{,}595X_1X_3 + 2{,}2275X_2X_3 + 129{,}15X_1^2 + 21{,}6625X_2^2 + 16{,}09X_3^2; \quad (5)$$

$$Y_2 = 149{,}9467 + 13{,}67268X_1 + 17{,}40943X_2 + 34{,}79497X_3 - 1{,}67108X_1X_2 + \\ + 14{,}81679X_1X_3 - 10{,}6695X_2X_3 + 48{,}76812X_1^2 - 2{,}9263X_2^2 - 1{,}73486X_3^2. \quad (6)$$

– for steel X40CrSiMo10 and 28% High-Chromium cast iron:

$$Y_1 = 197{,}6967 + 20{,}76X_1 + 36{,}6825X_2 + 53{,}86X_3 - 6{,}115X_1X_2 + \\ + 10{,}945X_1X_3 - 24{,}48X_2X_3 + 65{,}32417X_1^2 - 12{,}2958X_2^2 - 2{,}18083X_3^2; \quad (7)$$

$$Y_2 = 146{,}9522 + 15{,}04191X_1 + 6{,}363165X_2 + 23{,}18582X_3 + 1{,}368736X_1X_2 + \\ + 0{,}363023X_1X_3 - 13{,}189X_2X_3 + 47{,}28798X_1^2 + 6{,}143798X_2^2 - 0{,}6109X_3^2. \quad (8)$$

– for steel 41Cr4 and 32% High-Chromium cast iron:

$$Y_1 = 139{,}5133 + 27{,}06063X_1 + 41{,}14625X_2 + 67{,}79063X_3 - 10{,}8275X_1X_2 + \\ + 1{,}87125X_1X_3 + 4{,}62X_2X_3 + 108{,}784X_1^2 - 9{,}97479X_2^2 + 17{,}69646X_3^2; \quad (9)$$

$$Y_2 = 167{,}9411 + 31{,}03444X_1 + 70{,}59868X_2 + 58{,}95596X_3 + 9{,}054X_1X_2 + \\ + 25{,}31205X_1X_3 + 6{,}84403X_2X_3 + 84{,}96038X_1^2 + 15{,}93834X_2^2 - 4{,}578X_3^2. \quad (10)$$

– for steel X102CrMo17 and 32% High-Chromium cast iron:

$$Y_1 = 100{,}5467 + 44{,}58875X_1 + 29{,}13625X_2 + 54{,}535X_3 - 4{,}3975X_1X_2 - \\ - 4{,}3975X_1X_3 - 8{,}8X_2X_3 + 99{,}34792X_1^2 + 11{,}38292X_2^2 + 9{,}460417X_3^2; \quad (11)$$

$$Y_2 = 147{,}3595 + 26{,}6156X_1 + 46{,}56031X_2 + 49{,}00559X_3 + 0{,}121031X_1X_2 - \\ - 1{,}13859X_1X_3 + 3{,}78033X_2X_3 + 64{,}28027X_1^2 - 11{,}6936X_2^2 + 8{,}748633X_3^2. \quad (12)$$

– for steel X40CrSiMo10 and 32% High-Chromium cast iron:

$$Y_1 = 134{,}9417 + 32{,}96X_1 + 74{,}365X_2 + 46{,}64X_3 - 11{,}1175X_1X_2 + \\ + 3{,}12X_1X_3 + 1{,}3825X_2X_3 + 88{,}95417X_1^2 + 5{,}136667X_2^2 + 20{,}30417X_3^2; \quad (13)$$

$$Y_2 = 187{,}2024 + 13{,}93813X_1 + 18{,}34474X_2 + 33{,}53038X_3 + 0{,}78208X_1X_2 + \\ + 0{,}782076X_1X_3 - 13{,}5798X_2X_3 + 51{,}82697X_1^2 - 3{,}49755X_2^2 + 15{,}504X_3^2. \quad (14)$$

Having analysed the regression equations (3) – (14), we can make a conclusion about influence of factors on the response function.

From equations (5), (9), and (11) it follows that first of all it is loading that affects the rate of wear of most quantities of tribosystems, then a little less - abrasivity, and the least effect makes active acidity. Except tribosystem steel 41Cr4 with 28% High-Chromium cast iron and steel X102CrMo17 with 28% High-Chromium cast iron of equations (3) and (7): first of all wear rate is affected by loading, then active acidity and abrasivity in a less extent. The tribosystem steel X40CrSiMo10 with 32% High-Chromium cast iron is also an exception, (13): first of all abrasivity affects the wear rate, then a little less loading and finally the least effect has active acidity.

From equation (4), (6), (8), (12) and (14) it follows that force of friction of most tribosystems is influenced primarily by loading, then by abrasivity and then by active acidity. Except tribosystem steel 41Cr4 and 32% High-Chromium cast iron, equation (10), where force of friction is influenced mostly by abrasive, then by loading and then by active acidity.

Optimization task, concerning choosing the most optimal active acidity (pH) where there is the lowest wear rate and friction, was solved using a programme Mathad 15. The basis of the optimization task solution is the following:

$$I \to \min \begin{cases} 5 \le X_1 \le 11 \\ 0 \le X_2 \le 10 \\ 800 \le X_3 \le 1200; \end{cases} \quad F_{fr} \to \min \begin{cases} 5 \le X_1 \le 11 \\ 0 \le X_2 \le 10 \\ 800 \le X_3 \le 1200. \end{cases}$$

After some calculations of optimal pH determination where there is the lowest rate of wear and friction, we received some results which are presented in the Table 4.

Table 4

The optimal level of active acidity, pH of the lowest wear rate and friction

Steel 41Cr4 and 28% High-Chromium cast iron	*I* min	X_1=7,908	X_2=0	X_3=800
	$F_{fr.}$ min	X_1=7,506	X_2=0	X_3=800
Steel X102CrMo17 and 28% High-Chromium cast iron	I min	X_1=7,813	X_2=0	X_3=800
	$F_{fr.}$ min	X_1=7,984	X_2=0	X_3=800
Steel X40CrSiMo10 and 28% High-Chromium cast iron	I min	X_1=7,634	X_2=0	X_3=800
	$F_{fr.}$ min	X_1=7,578	X_2=0	X_3=800
Steel 41Cr4 and 32% High-Chromium cast iron	I min	X_1=7,503	X_2=0	X_3=800
	$F_{fr.}$ min	X_1=8,059	X_2=0	X_3=800
Steel X102CrMo17 32% and High-Chromium cast iron	I min	X_1=7,172	X_2=0	X_3=800
	$F_{rf.}$ min	X_1=7,355	X_2=0	X_3=800
Steel X40CrSiMo10 and 32% High-Chromium cast iron	I min	X_1=7,309	X_2=0	X_3=800
	$F_{fr.}$ min	X_1=7,733	X_2=0	X_3=800

By finding the arithmetic mean value, based on the values presented in Table 4, we can receive the optimal level of active acidity, pH for the tribosystem:

– steel 41Cr4 and 28% High-Chromium cast iron– 7,71pH;
– steel X102CrMo17 and 28% High-Chromium cast iron – 7,90 pH;
– steel X40CrSiMo10 and 28% High-Chromium cast iron – 7,78 pH;
– steel 41Cr4 and 32% High-Chromium cast iron – 7,78 pH;
– steel X102CrMo17 and 32% High-Chromium cast iron – 7,26 pH;
– steel X40CrSiMo10 and 32% High-Chromium cast iron– 7,52 pH.

We may conclude that that the lowest wear rate and friction is in a slightly alkaline environment, close to the neutral one.

After selecting the optimal level of active acidity, we carried out a research to determine tribology characteristics. The results are shown in the Table 5.

Table 5

Tribology characteristics: wear rate and friction, depending on the active acidity, abrasivity and load

Tribosystem	Wear rate I, mcm/h.	Friction $F_{fr.}$, H
Steel 41Cr4 and 28% High-Chromium cast iron	144,786	146,285
Steel X102CrMo17and 28% High-Chromium cast iron	55,03	82,649
Steel X40CrSiMo10 and 28% High-Chromium cast iron	66,923	108,812
Steel 41Cr4 and 32% High-Chromium cast iron	38,396	56,557
Steel X102CrMo17 and 32% High-Chromium cast iron	21,671	49,65
Steel X40CrSiMo10 and 32% High-Chromium cast iron	36,301	133,594

The analysis of values which are presented in the Table 5, allows making a conclusion that the most compatible tribosystem is steel X102CrMo17 and 32% High-Chromium cast iron which exceeds 41Cr4 steel 28% High-Chromium and iron by its tribology characteristics. That means that it has 6.68 times less wear rate and 2.94 times less friction force, with minimal abrasiveness, load and slightly alkaline acidity, close to neutral.

Based on the experimental data in the Table 5, we may conclude that the selected steel X102CrMo17 and 32% High-Chromium cast iron is the most compatible tribosystem according to their tribology characteristics.

Fig. 3 shows the dependences of wear rate and friction force. The research was conducted at a constant loading of 1000 N, 0% of abrasivity in the mass and a certain level of active acidity. Under such circumstances, the smallest value of wear rate refers to the following tribosystem: steel X102CrMo17 and 32% High-Chromium cast iron; a little bigger value refers to the tribosystem steel X102CrMo17 and 32 High-Chromium cast iron; then tribosystem steel 41Cr4 and 32% High-Chromium cast iron; and the biggest value refers to steel 41Cr4 and 28 High-Chromium cast iron.

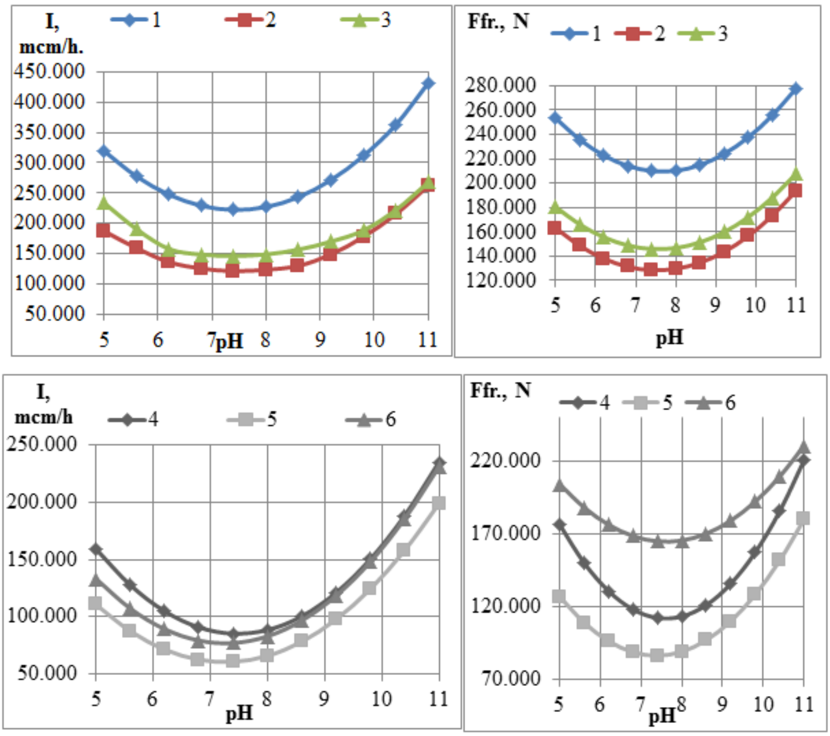

Fig. 3. Dependences of wear rate and friction force of tribosystems from the level of active acidity under constant load and abrasivity: *1* – steel 41Cr4 and 28% High-Chromium cast iron; *2* – steel X102CrMo17 and 28% High-Chromium cast iron; *3* – steel X40CrSiMo10 and 28% High-Chromium cast iron; *4* – steel 41Cr4 and 32% High-Chromium cast iron; *5* – steel X102CrMo17 and 32 High-Chromium cast iron; *6* – steel X40CrSiMo10 and 32 High-Chromium cast iron

The plant raw material for the production of solid fuel has a slightly acidic environment and active acidity (pH5). The smallest value of the friction force refers to the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron, a little bigger value refers to steel X102CrMo17 and 28% High-Chromium cast iron, then tribosystem steel 41Cr4 and 32% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron.

Friction force and wear rate become smaller when adding lye (sodium hydroxide up to pH7.4) to the raw material. The smallest value of the friction force refers to the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron, a little bigger value refers to steel 41Cr4 and 32% High-Chromium cast iron, then tribosystem steel X102CrMo17 and 28% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron.

Further addition of lye causes highly alkaline environment pH11, and a reverse process occurs, in which the wear rate and friction force is increased. The smallest value of the friction force refers to tribosystem steel X102CrMo17 and 32% High-Chromium cast iron, a little bigger value refers steel X102CrMo17 and 28% High-Chromium cast iron, then tribosystem steel X40CrSiMo10 and 28% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron.

The smallest value of wear rate and friction force for all tribosystems is at pH7.4.

Fig. 4 shows the dependences of the wear rate and friction force at constant load of 1000 N, neutral level of active acidity from abrasiveness. Plant raw material for the production of solid fuel has about 10% of abrasivity. In such circumstances, the smallest value of wear rate refers to the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron, a little bigger value refers to steel X102CrMo17 and 28% High-Chromium cast iron, then tribosystem steel X40CrSiMo10 and 32% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron.

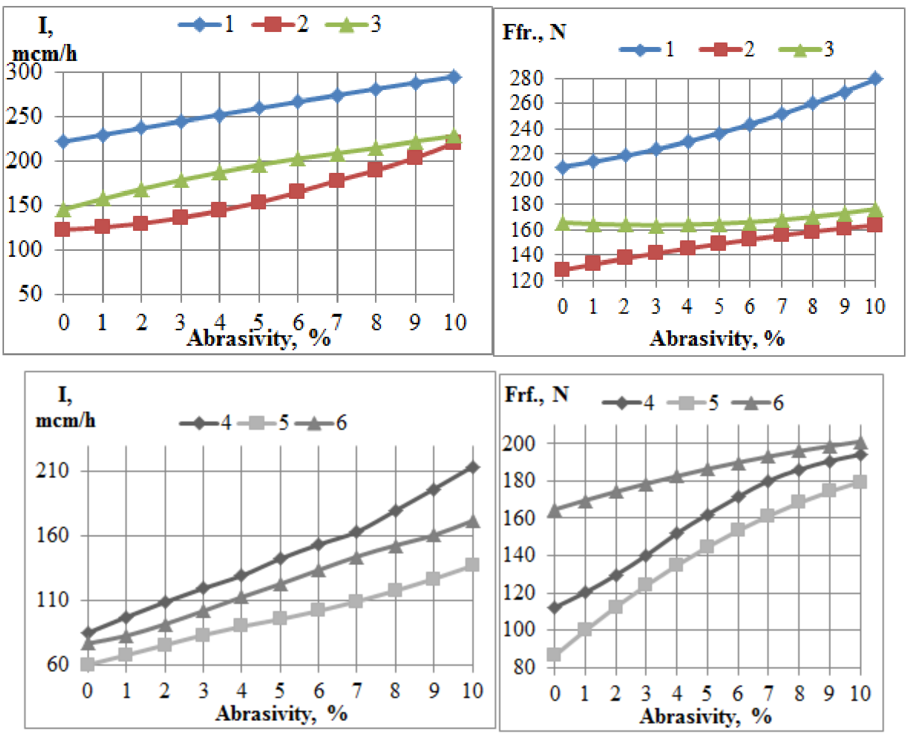

Fig. 4. Dependences of wear rate and friction force of tribosystems from the level of abrasivity under constant load and active acidity level: *1* –steel 41Cr4 and 28% High-Chromium cast iron; *2* – steel X102CrMo17 and 28% High-Chromium cast iron; *3* – steel X40CrSiMo10 and 28% High-Chromium cast iron; *4* – steel 41Cr4 and 32% High-Chromium cast iron; *5* – steel X102CrMo17and 32% High-Chromium cast iron; *6* – steel X40CrSiMo10 and 32% High-Chromium cast iron

The smallest value of friction force refers to the tribosystem steel X102CrMo17 and 28% High-Chromium cast iron, a little bigger value refers to steel X40CrSiMo10 and 28% High-Chromium cast iron, then the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron.

After removal of abrasive contaminants from the raw material at the amount of 5%, frictional force and wear rate become smaller. The smallest value of wear rate refers to the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron, a little bigger value refers to steel X40CrSiMo10 and 32% High-Chromium cast iron, then the tribosystem steel 41Cr4 and 32% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron. The lowest value of the friction forcerefers to tribosystem X102CrMo17 steel and 32% High-Chromium cast iron, a little more - X102CrMo17 steel and 28% High-Chromium cast iron, then tribosystem X40CrSiMo10 steel and 32% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron.

Upon further removal of abrasivity from the raw material to 0%, it causes wear rate and friction forcereducing. With no abrasivity the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron has the smallest value of wear rate. The tribosystem steel X40CrSiMo10 and 32% High-Chromium cast iron has a bigger value of wear rate, then the tribosystem steel 41Cr4 and 32% High-Chromium cast iron, and the biggest value refers to the tribosystem steel 41Cr4 and 28% High-Chromium cast iron. The tribosystem steel X102CrMo17 and 32% High-Chromium cast iron has the smallest value of friction force. The tribosystem steel 41Cr4 and 32% High-Chromium cast iron has a little bigger value of friction force, then the tribosystem steel X102CrMo17 and 28% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron.

The smallest value of wear rate and friction force for all tribosystems is at abrasivity of 0%.

Fig. 5 presents dependences of wear rate and friction force, at constant abrasivity of 0% and neutral level of active acidity (pH7), from loading. In such circumstances, the smallest value of wear rate refers to the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron, a little bigger value refers to steel X40CrSiMo10 and 32% High-Chromium cast iron, then to the tribosystem steel 41Cr4 and 32% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron. The smallest value of friction force refers to the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron, a little bigger value refers to steel 41Cr4 and 32% High-Chromium cast iron, then to the tribosystem steel X102CrMo17 and 28% High-Chromium cast iron, the biggest value refers to steel 41Cr4 and 28% High-Chromium cast iron.

The optimal values of wear rate and friction force are stated in the following three conditions:

– With no abrasivity and continuous loading of 1000 N, the tribosysytem steel X102CrMo17 and 32% High-Chromium cast iron has the smallest value of ware rate 60,46 mcm/h. and the friction force 86,38 N;

– In a neutral environment and continuous loading of 1000 N, the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron has the smallest value of wear rate 77,50 mcm/h. and the friction force 87,42 N;

– With no abrasivity and neutral environment, the tribosystem steel X102CrMo17 and 32% High-Chromium cast iron has the smallest value of wear rate 21,67 mcm/h. and the friction force 50,56 N.

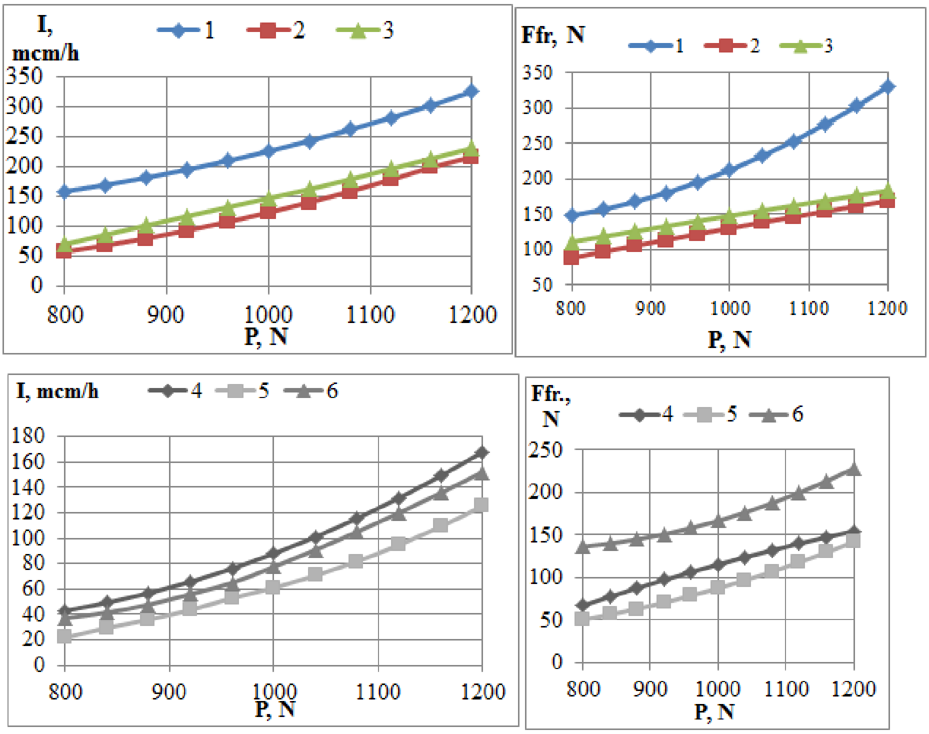

Fig. 5. Dependences of wear rate and friction force of tribosystems from loading under constant abrasivity and level of active acidity: *1* – steel 41Cr4 and 28 High-Chromium cast iron; *2* – steel X102CrMo17 and 28 High-Chromium cast iron; *3* – steel X40CrSiMo10 and 28 High-Chromium cast iron; *4* –steel 41Cr4 and 32 High-Chromium cast iron; *5* – X102CrMo17 and 32 High-Chromium cast iron; *6* – steel X40CrSiMo10 and 32 cast iron High-Chromium

Conclusion

1. During carrying out experimental studies, we found out that the following types of screw and extruder die wear happens during pressing biomass abrasive, adhesive, fatigue and corrosion-mechanical. The main ones are abrasive and corrosive.

2. The rating of tribology compatibility of steels and cast iron in abrasive and corrosive environments, where screw and extruder die work, was carried out for the first time. The most compatible tribosystem is steel X102CrMo17 and 32% High-Chromium cast iron, which exceeds the tribosystem steel 41Cr4 and 28% High-Chromium cast iron by its tribological characteristics, and it has 6,68 times lower wear rate and 2,94 times less friction force, with minimal abrasiveness, loading and weakly alkaline environment close to neutral.

3. When developing new equipment and knowing the wear rate and the friction force of steel and cast iron in abrasive and corrosive (acidic) environment, it will allow making the right choice of material of operating elements of equipment that is in contact with the product during manufacture of biomass briquettes and pellets from biomass.

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ТРІБОЛОГІЧНА СУМІСНІСТЬ СТАЛЕЙ ТА ЧАВУНІВ У АБРАЗИВНОМУ ТА КОРОЗІЙНОМУ СЕРЕДОВИЩІ, ПРИ ВИРОБНИЦТВІ ПАЛИВНИХ БРИКЕТІВ

Показано, що при пресуванні біомаси (лузги соняшнику, деревинної тирси та соломи) відбувається абразивне та корозійне зношування. Приведена методика дозволяє визначити сили тертя та швидкості зношування дослідних зразків. Змодельоване корозійне та абразивне середовище в якому працюють шнек та філь'єра екструдера (шнекового преса) для виробництва паливних брикетів. Наведений рейтинг трибологічної сумісності матеріалів для виготовлення робочих органів.

Ключові слова. Прикладна трибологія; сільське господарство; тертя; методи випробування на тертя; знос; абразивний знос; корозійний знос; розрахунок; отримання даних.

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