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TECHNOGENIC HAZARDS COEFFICIENT OF SAND-RESIN MIXTURES IN FOUNDRY MANUFACTURING

Purpose. To carry out a comparative quantitative assessment of environmental and sanitary-hygienic hazards of utilizing synthetic resins for manufacturing molds and rods in foundry production.

Methodology. Quarry quartz sand brand $1K_2O_202$, furan resin brand Permaset 839 and catalyst Permacat 128, aluminum alloy AL2, gray cast iron SCh200, carbon steel 30L, bronze BrA9Zh3L were used in the work. Chromel-alumel thermocouples completed with electronic potentiometer were used for thermography. Molds were made from quartz sand, furan resin and catalyst mixture. Casting mold heating depth determination from casting to temperatures above 400 °C was carried out by its thermogram graphical processing, which was obtained after casting mold pouring with aluminum alloy, bronze, gray cast iron and carbon steel.

Findings. Among those studied, the most dangerous are urea-phenol-formaldehyde, urea-formaldehyde and urea-furan resins, and the least dangerous are phenol-formaldehyde and phenol-formaldehyde-furan resins. Ecological and sanitary-hygienic hazard level when using resin mixtures increases with increasing resin amount in mixture, castings walls thickness, their surface area, as well as with increasing temperature of melt poured into the mold.

Originality. For the first time, in relation to foundry molds and rods in foundry production manufacturing, technogenic hazard coefficient (THC) has been developed and its value has been calculated. This, in fact, is air volume (m^3) containing maximum permissible concentration of carcinogenic or poisonous substances released as a result of mold organic binder material destruction when pouring aluminum alloy, bronze, cast iron or steel.

Practical value. The use of the research results makes it possible to increase the level of predicting accuracy of technogenic (sanitary, hygienic and environmental) hazards, accuracy level of calculating ventilation systems capacities in foundries, taking into account the serial castings production, castings structural features, as well as binding materials nature for foundry molds and rods for such castings.

Keywords: *coefficient of hazards, synthetic resins, foundry, casting, labor protection*

Introduction. Cast parts quality requirements level, their weight, overall dimensions, their material properties, production character, etc., have determined molds and rods manufacturing methods. Castings produced in the world main volume (more than 75 %) have been prepared in disposable sand molds. At the same time, according to UK Foundry and Casting Industry, the largest castings producers today are China – 49.2 %, European Union countries – 11.9 %, India – 10.7 % and the USA – 9.8 %, which follows from the data in Fig. 1.

According to UK Foundry and Casting Industry, about 62 % of foundries in Europe for castings production use disposable molds with cold-solidified mixtures (CSM), where binding material is synthetic resins.

That is, in the most economically developed countries' structure, CSM molding with synthetic resins modern methods occupy a prominent position (Fig. 2), despite the fact that such casting molds and rods are the most harmful from an ecological and sanitary-hygienic point of view, which already today causes many problems and questions regarding their further using expediency.

At present, for steel and iron castings manufacturing, whose mass share in Ukraine reaches more than 70 %, CSM, where binder is also synthetic resin, has mainly used. Steel and cast iron castings have produced in much smaller (tens of times) quantities in CSM molds based on inorganic binders, as well as in sand-clay, ceramic shell molds, etc. [1].

Therefore, the problem of gas waste emissions negative effect from foundry production on environment and, accordingly, on human health is inherent not only for Ukraine, but is relevant for all other economically developed countries as well. This problem successful solution requires, first of all, an emerging dangers adequate targeted assessment when using synthetic resins in castings manufacturing specific conditions.

Literature review. CSM on synthetic resins widespread using has been facilitated by molds and rods high strength and manufacturability, operating rate and convenience, easy knocking out, etc. Nevertheless, CSM on synthetic resins using has significant drawback – unsatisfactory sanitary and hygienic conditions, production toxicological and environmental hazards when using molds and rods. Implementation of modified synthetic resins, systems for resin destruction gaseous products capturing and utilization, ranging from catalytic afterburning to specially selected microorganisms- destructors strain, somewhat reduces harmful substances emissions into media, but, at the same time, significantly increases casting production costs and does not solve the problem in general, because sand-resin mixtures give up to 40 % of environmental pollution from foundries [2].

This is related both to the nature of used resins genesis, and to the temperature at which their destruction begins. The fact is that at 250–500 °C, synthetic resins are destroyed with gaseous formaldehyde, phenol, furfural, styrene, carbon monoxide, etc. [3] releasing. Corresponding data, according to N. V. Sygarev with colleagues (2013), is presented in Table 1.

Above-mentioned harmful substances have the following toxicological characteristics [4]:

Class 2 danger:

1. Nitric oxide – has pronounced irritating and caustic effect on the respiratory tract, affects the alveolar tissue, which

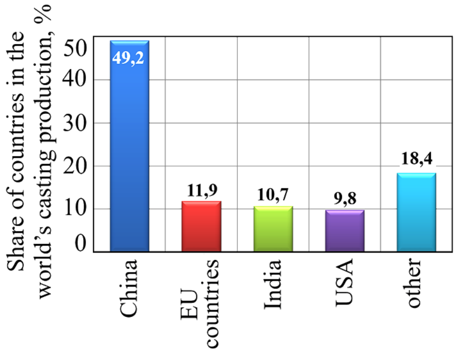
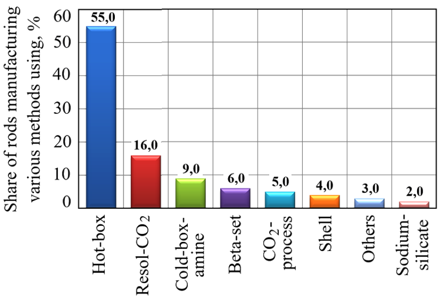


Fig. 1. Share of countries in the world's casting production according to UK Foundry and Casting Industry



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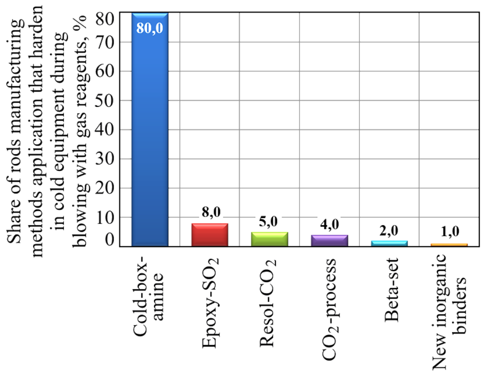

b

Fig. 2. Various molding processes with CSM in foundry industry prevalence — share of rods manufacturing various methods application (a); share of rods manufacturing methods application that harden in cold equipment during blowing with gas reagents (b) according to the data of UK Foundry and Casting Industry

leads to pulmonary edema; has an effect on arteries, causes vasodilation and blood pressure lowering.

2. Benzene — has narcotic (convulsive) effect on central nervous system, chronic poisoning can lead to death; contributes to leukemia formation [5].

3. Phenol — strong poison has general toxic effect, can be absorbed through the skin.

4. Formaldehyde — irritates the skin and mucous membrane, has general toxicity; can cause cancer of nasal cavity, sinuses, throat, leukemia — myeloid (lungs) [5].

5. Phosphoric anhydride — irritates the eyes, respiratory tract and mucous membranes.

6. Furfure alcohol — has depressing effect on central nervous system, breathing, lowers body temperature, causes dizziness, nausea.

7. Cyanides — cause tissue death due to formation with one of intracellular respiratory enzymes.

Class 3 danger:

1. Methanol — strong poisons with pronounced cumulative effect; has strong irritating effect on mucous membranes of respiratory tract.

2. Sulfuric anhydride — has strong irritating effect on respiratory tract, disrupts metabolic enzyme processes.

3. Furfural — poison that causes paralysis has weak irritating effect on mucous membrane.

Class 4 danger:

1. Ammonia — has narcotic effect; in high concentrations excites nervous system and causes convulsions.

2. Acetone — has narcotic effect; when inhaled for long time accumulates in the body; slow elimination from the body increases chronic poisoning risk.

3. Carbon monoxide — displaces oxygen from blood oxyhemoglobin, which prevents oxygen from lungs to tissues transfer, reduces oxygen content in blood, causes dysentery, has toxic effect on cells, disrupting tissue respiration and reducing tissue oxygen consumption.

The release of these substances into the air and their adsorption on solid surfaces sharply worsens sanitary and hygienic working conditions and can cause people to develop chronic, professional diseases up to the death point [6, 7].

Using in foundries of various systems for catching gases released during synthetic resins destruction, with their subsequent neutralization, for example, by means of catalytic afterburning, is associated with significant financial expenditures. As a result, in Ukrainian foundries, in cases majority, there are no systems for gases emitted from cast molds utilization and processing.

No synthetic resin, including modified, for example, ethoxy groups, can be environmentally safe material in foundry technology. Synthetic resins developers and manufacturers declarations that at temperature more than 500 °C low-temperature destruction products decomposing into water and

Table 1

Harmful substances released from mixtures containing organic binders

Binding substances	Harmful substances released	
	Rods and molds manufacturing	Casting, cooling and knocking out from mold
Phenol formaldehyde	Methanol, formaldehyde, furfural, phenol, furfure alcohol	Carbon monoxide, ammonia, acetone, methanol, benzene, cyanides, sulfur dioxide, hydrocarbons
Phenol furan	Ammonia, acetone, methanol, formaldehyde, phenol	Carbon monoxide, methanol, formaldehyde, phenol, benzene, marginal carbons, furfural, furfure alcohol, sulfuric anhydride
Urea formaldehyde	Ammonia, methanol, formaldehyde	Carbon monoxide, methanol, formaldehyde, marginal carbons, furfural, ammonia, cyanides, nitrogen oxides, phosphoric anhydride
Urea furan	Methanol, formaldehyde, furfural, furfure alcohol	Carbon monoxide, methanol, formaldehyde, marginal carbons, ammonia, cyanides, nitrogen oxides, furfural, furfure alcohol, phosphoric anhydride
Phenol urea formaldehyde	Methanol, formaldehyde, phenol, ammonia	Carbon monoxide, methanol, formaldehyde, marginal carbons, ammonia, cyanides, nitrogen oxides

carbon dioxide are incorrect, since this process can only be implemented in closed space to which neither molds, nor rods, nor foundry shops belong to. At the same time, harmful substances into the air from sand-resin mixtures releasing occurs already at the stage of casting molds and rods manufacturing in quantities that can be compared with gases amount released during such casting molds filling (Table 2).

In this regard, it can be stated that resin developers declarations about their next new development of this or that resin ecological purity [9, 10] are nothing more than advertising deliberation to promote their products on the foundry materials market.

Table 2

Harmful substances content in foundries working areas air [8]

Synthetic resin as CSM part	Substance name	MPC, mg/m^3	Harmful substances pollution into air, mg/m^3	
			at molds and rods manufacturing	when filling forms with metal
Phenol-formaldehyde resin (Cold-box-amine[1], Cold-box-MF, Resol-CO_2, Alfa-set[2], Bets-set[2], Pep-set, Croving, No-bake)	Acetone	200,0	114.07	53.6
	Methanol	5.0	1.86–6.73	2.58–3.43
	Formaldehyde	0.5	0.53–0.99	0.37–0.94
	Phenol	0.3	0.41–0.66	0.34–0.59
	Carbon monoxide	20.0	–	22.6–24.7
	Benzene	15.0	–	4.22
	Triethylamine[1]	10.0	4.82	6.77
	Nefras[1]	100.0	64.0	29.8
	Methyl formate[2]	250.0	83.4	125.6
Furfure resin (Hot-box)	Formaldehyde	0.5	0.13	0.26
	Methanol	5.0	7.92	6.52
	Furfural	10.0	17.41	11.76
	Carbon monoxide	20.0	–	24.8
	Benzene	15.0	–	8.06
Epoxy resin (Epoxy-SO_2)	Sulfuric anhydride	10.0	0.52	0.63
	Epi-chlorohydrin	1.0	0.62	0.76
	Acrylic acid	5.0	1.21	0.89
	Toluene	150.0	32.4	18.3
	Aromatic hydrocarbons	50.0	38.6	27.6
	Carbon monoxide	20.0	–	22.7
Urea-furan resin	Methanol	5.0	9.86	6.77
	Formaldehyde	0.5	0.47	0.76
	Furfural	10.0	11.78	13.03
	Furfure alcohol	0.5	0.39	0.26
	Ammonia	20.0	–	5.78
	Carbon monoxide	20.0	–	25.8
Phenol-furan resins	Methanol	5.0	13.74	6.91
	Formaldehyde	0.5	0.32	0.58
	Phenol	0.3	0.67	0.85
	Furfural	10.0	10.68	9.66
	Furfure alcohol	0.5	0.42	0.37
	Carbon monoxide	20.0	–	26.9
	Benzene	15.0	–	4.76

Note[1, 2] – Harmful substances releasing refers to CSM solidification process

Currently, as a rule, hygienic, toxicological and epidemiological data analysis results are accepted for any production harmful environmental factors risk to public health estimation [11, 12].

In international practice, similar assessment uses the results of carcinogenic risk for health calculations (cancer cases increasing probability) and the danger index (all diseases types, except cancer, increasing probability) [13].

At present, danger index can be determined based on danger coefficient value, which is the ratio of carcinogenic substance average dose to its reference dose in $1m^3$ of air or the ratio of carcinogenic substance average concentration to its reference concentration in $1m^3$ of air [14, 15].

For non-carcinogenic risk to public health estimating the following formula has been proposed in [16]

$$HQ = C_i/C_{MPC},$$

where C_i is average concentration of the i^{th} pollutant, mg/m^3; C_{MPC} – maximum permissible concentration of the i^{th} pollutant, mg/m^3.

In work [17], in order to determine environmental protection measures implementation priority and to assess the total risk to population living in polluted areas or working in harmful industries health, it is recommended to use the method according to which carcinogenic risk of getting an oncological disease from carcinogenic pollutants presence in natural environment media has to be the sum of risks of getting an oncological disease from carcinogenic pollutants presence in: atmospheric air, soil, surface waters, drinking water, food products.

Today, the main danger indicator in most countries of the world is the risk to population health [14]. For public health risk from atmospheric air pollution estimation in Ukraine relevant methodological recommendations [17] exist.

The authors of the work [18] developed an improved method for population health in air pollution case comprehensive risk estimation. According to this method, carcinogenic risk indicators have been calculated for each pollutant according to the formula

$$CR = SF \cdot LADI,$$

where CR is getting cancer probability (dimensionless value – 1 : 1,000,000); SF – getting cancer probability in case of single LADDI dose taking, 1/mg/kg-day.

To discover atmospheric air pollution sources, the authors [18] propose to use the value of pollutant emissions from industrial enterprises danger index, which has to be calculated according to the following formula

$$I_B = \frac{B_{BJ} - B_B^{\min}}{B_B^{\max} - B_B^{\min}},$$

where I_B is pollutant emission hazard index, dimensionless quantity; B_{BJ} – pollutants emissions danger indicator into atmosphere (dimensionless value) from the j^{th} enterprise

$$B_{BJ} = \frac{\sum (B_J^i)^{m_i}}{(B_{CP}^i)^{m_i}},$$

where B_{IJ} is emissions volume of the i^{th} polluting substance into atmospheric air from the i^{th} enterprise, kt/year; B_{CP} – emissions of the i^{th} pollutant into atmospheric air average volume from enterprises of Ukraine, kt/year; B_J – degree indicator that takes into account the danger class of the i^{th} pollutant (for danger class I – 1.7; for II – 1.3; for III – 1.0; for IV – 0.8); $B_B^{\min}$ – pollutants from harmful permanent sources in Ukraine into the atmospheric air emissions danger indicator minimum value; $B_B^{\max}$ – pollutants from harmful permanent sources in Ukraine into the atmospheric air emissions danger indicator maximum value.

A large number of synthetic resins of various origins is known today which are used in foundries [20]. Such resins destruction takes place in their characteristic temperature ranges, with certain intensity, with gases different amounts and compositions releasing. At the same time, diverse in series castings production of various thicknesses from alloys with different pouring into sand-resin molds temperatures also leads to different levels of production hazards, for which evaluation methodology is currently absent. Therefore, methodology development for comparative quantitative assessment calculating of synthetic resins using for molds and rods manufacturing in foundry production environmental hazard is a relevant task.

Purpose. To carry out a comparative quantitative assessment of synthetic resins utilizing for molds and rods manufacturing environmental and sanitary-hygienic hazards in foundry production.

Investigation tasks are:

1. To establish casting mold depth heating dependence to temperatures exceeding 400 °C for flat castings with 10, 25 and 40 mm thickness from alloys based on aluminum, copper (bronze) and iron (gray cast iron and carbon steel).

To develop a problem-oriented criterion for synthetic resins in foundry production using environmental and sanitary-hygienic hazard assessing – coefficient of techno-genus hazard (CTH).

To carry out CTH calculation for various resins and alloys and to determine on its basis most and least dangerous modern synthetic resins brands used in foundry production.

Methodology. In this work the authors used:

- quarry quartz sand brand $1K_2O_202$, furan resin brand Permaset 839 and catalyst Permacat 128;

- aluminum alloy AL2; gray cast iron SCh200; carbon steel 30L; bronze BrA9Zh3L.

Casting mold heating depth determination to temperatures above 400 °C has been carried out by casting mold at different distances from casting graphical thermogram temperature changes processing.

Chromel-alumel thermocouples completed with an electronic potentiometer have been used for thermography. Thermocouples have been placed in casting mold at distance of 2, 8, 13, 20, 30 and 60 mm from casting surface according to scheme presented in Fig. 3.

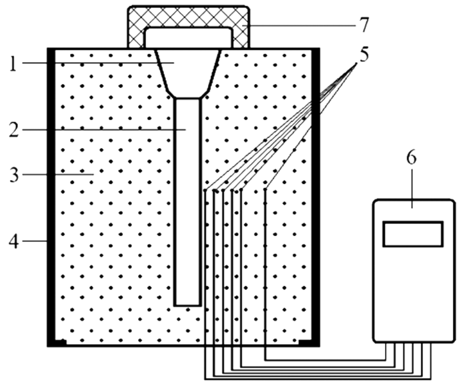

Fig. 3. Scheme of thermocouples location in casting mold:

1 – pouring basin; 2 – casting mold working cavity; 3 – compacted hardened molding mixture; 4 – flask; 5 – thermocouples junctions "hot"; 6 – electronic potentiometer; 7 – fireclay cover

Monolithic casting molds made from quartz sand, furan resin and catalyst mixture were used in research. Resin content in all casting molds mixtures was 1 % (by weight).

For thermography casting mold with initial temperature of 20–25 °C has been filled with AL2 aluminum alloy (11.8 Si, 88 % Al), BrA9Zh3L bronze (9 % Al, 3 % Fe, 87.5 % Cu), gray cast iron SCh200 (3.4 % C, 2.0 % Si, 0.9 % Mn, 0.1 % P, 0.1 % S, rest – Fe), carbon steel 30L (0.3 % C).

Casting molds thermography was performed for castings with dimensions of 10 × 110 × 110, 25 × 260 × 260 and 40 × × 410 × 410 mm. Melts were poured into casting molds with superheating by 100–150 °C above their liquidus temperature through a pouring basin, which, according to design, was located along the entire length of casting upper end (Fig. 3). During casting solidification, pouring basin of this design performed its open type riser function.

For quantitative environmental hazard assessment of specific synthetic resin implementation as binding material for casting molds and rods, parametric problem-oriented criterion has been proposed – technogenic danger coefficient (TDC)

Table 3

Substances mass fractions (φ_i) formed as resins high-temperature destruction result and their MPC

Resin brand	φ_i							
	Carbon monoxide	Methanol	Phenol	Benzene	Formaldehyde	Furfural	Ammonia	Cyanides
Urea-Formaldehyde resins								
М-3	0.069	0.110	–	–	0.071	–	0.585	0.165
ВК-1	0.145	0.098	–	–	0.093	–	0.486	0.178
Urea-Furan resins								
КФ-90	0.6943	0.0143	–	–	–	0.0002	0.2247	0.0665
БС-40	0.1369	0.0196	–	–	0.0001	0.0001	0.7642	0.0791
Phenol-Formaldehyde resins								
РСФ-3010	0.4039	0.0040	0.2856	0.3065	–	–	–	–
СФ-3042	0.4312	0.0137	0.1924	0.3627	–	–	–	–
Phenol-Formaldehyde-Furan resin								
«Фуритол-68»	0.8373	0.0105	0.0183	0.1327	0.0007	0.0005	–	–
Furan resin								
ПФС	0.2419	0.0075	–	0.7493	–	0.0013	–	–
Urea-Phenol-Formaldehyde resins								
КФФ-л	0.2238	0.0932	0.0320	0.0077	–	–	0.3050	0.3383
$MPC_i \cdot 10^{-6}$, kg/m^3	20	5	0.3	5	0.5	10	20	0.3

Table 4

Coefficient TDC_i calculated data for castings with 10 mm wall thickness from various alloys and synthetic resins

Alloy	TDC_i, m^3/m^2							
	Carbon monoxide	Methanol	Phenol	Benzene	Formaldehyde	Furfural	Ammonia	Cyanides
Resin М-3								
Aluminum	11.4	72.6	–	–	468.6	–	96.5	1,815
Bronze	45.5	145.2	–	–	1,874.4	–	386.1	7,260
Cast Iron	79.7	508.2	–	–	3,280.2	–	675.7	12,705
Steel	91.1	580.8	–	–	3,748.8	–	772.2	14,520
Resin ВК-1								
Aluminum	23.9	64.7	–	–	613.8	–	80.2	1,958
Bronze	95.7	258.7	–	–	2,455.2	–	320.8	7,832
Cast Iron	167.5	452.8	–	–	4,296.6	–	561.4	13,706
Steel	191.4	517.5	–	–	4,910.4	–	641.5	15,664
Resin КФ-90								
Aluminum	114.6	9.4	–	–	–	0.07	37.1	731.5
Bronze	458.2	37.8	–	–	–	0.3	148.3	2,926
Cast Iron	801.9	66.1	–	–	–	0.5	259.5	5,120.5
Steel	916.5	75.5	–	–	–	0.5	296.6	5,852
Resin БС-40								
Aluminum	22.6	12.9	–	–	0.66	0.03	126.1	840.1
Bronze	90.4	51.7	–	–	2.6	0.13	504.4	3,480.4
Cast Iron	158.1	90.6	–	–	4.62	0.2	882.7	6,090.5
Steel	180.7	103.5	–	–	5.3	0.3	1,008.8	6,961
Resin РСФ-3010								
Aluminum	66.6	2.6	3,141.6	67.43	–	–	–	–
Bronze	266.6	10.6	12,566.5	269.7	–	–	–	–
Cast Iron	466.5	18.5	21,991	472	–	–	–	–
Steel	533.2	21.1	25,133	539.5	–	–	–	–
Resin СФ-3042								
Aluminum	71.1	9.0	2,119.4	79.8	–	–	–	–
Bronze	284.6	36.26	8,465.5	319.2	–	–	–	–
Cast Iron	498.0	63.3	1,4815	558.6	–	–	–	–
Steel	569.2	72.3	1,6931	638.4	–	–	–	–
Resin «Фуритол-68»								
Aluminum	138.2	6.9	201.3	29.2	4.6	0.17	–	–
Bronze	552.6	27.7	805.2	116.8	18.5	0.7	–	–
Cast Iron	967.1	48.5	1,409.1	204.4	32.3	1.2	–	–
Steel	1,105.2	55.4	1,610.4	233.6	36.9	1.3	–	–
Resin ПФС								
Aluminum	39.9	4.9	–	164.8	–	0.4	–	–
Bronze	159.7	19.8	–	659.4	–	1.7	–	–
Cast Iron	279.4	34.7	–	1,153.9	–	3.0	–	–
Steel	3,19.3	39.6	–	1,318.8	–	3.4	–	–
Resin КФФ-л								
Aluminum	36.9	61.5	352.0	1.7	–	–	50.3	3,721.3
Bronze	147.7	246.1	1,408	6.8	–	–	201.3	1,4885
Cast Iron	258.5	430.6	2,464	11.9	–	–	352.3	26,049
Steel	295.4	492.1	2,816	13.6	–	–	402.6	29,770.5

$$TDC_i = \frac{m_i}{MPC_i}, \quad (1)$$

where m_i is gas mass released from binder material, the i^{th} substance upon contact with casting surface 1 m^2, kg; MPC_i – maximum permissible concentration of the i^{th} substance in air, kg/m^3.

TDC physical meaning is an air largest volume (m^3) containing carcinogenic or toxic substance (phenol, formaldehyde, carbon monoxide, etc.) MPC, which was released as organic binding material (synthetic resin) destruction result from 1 m^2 mold surface in cases aluminum casting alloy, bronze, cast iron or steel.

Gas mass of the i^{th} substance released from binder material of $1m^2$ casting surface has been calculated by formula, kg

$$m_i = k \cdot \delta \cdot \rho \cdot M \cdot n \cdot \varphi_i, \quad (2)$$

where k is the molding mixture heating-through coefficient to temperature 400 °C; δ – casting wall average thickness, m; ρ – apparent density of foundry mold material, kg/m^3; M – binder material mass fraction in molding mixture content; m – binder material mass fraction that turned into gas as destruction result; n – casting mold binder substance mass fraction that has turned into gas; φ_i – gaseous i^{th} substance mass fraction in mass of gases released from casting mold.

Findings. Based on thermography data processing results, it has been established that for each specific alloy coefficient k value depends exclusively on alloy nature and does not depend on casting wall thickness. For alloys used in this work, molding mixture heating-through to temperature 400 °C coefficient was established as: 0.2 – for aluminum alloy, 0.8 – for bronze, 1.4 – for gray cast iron, 1.6 – for carbon steel.

If we assume that casting mold material apparent density value is ρ = 1,650 kg/m^3, binder material in molding mixture mass fraction is M = 0.01, binder material that turned into gas as destruction result mass fraction is n = 0.1, then formula (1) will have the form, m^3/m^2

$$TDC_i = \frac{k \cdot \delta \cdot \rho \cdot M \cdot n \cdot \varphi_i}{MPC_i} = \frac{1.65 \cdot k \cdot \delta \cdot \varphi_i}{MPC_i}. \quad (3)$$

From [9] data analysis, as result of gaseous i^{th} substance conversion mass fraction in gases mass released from the mold, as product of high-temperature resins destruction, and their MPC are presented in Table 3.

Assuming conditional casting average wall thickness is equal to δ = 0.01 m, TDC_i coefficients were calculated for mold and rod mixtures synthetic binder components, when aluminum, bronze, cast iron and steel alloys was poured into them. Calculations results are presented in Table 4.

Table 3 analysis shows that urea-formaldehyde (ВК-1, М-3), phenol-formaldehyde (РСФ-3010, СФ-3042) and urea-phenol-formaldehyde (КФФ-л) resins are most dangerous. That is because these resins have the largest formation of gas substances belonging to the 2^{nd} class of danger, namely phenol, benzene, cyanides. This is also evidenced by the histogram (Fig. 4) analysis, which shows TDC_i maximum values for casting molds with different resins when steel casting with wall thickness of 10 mm pouring.

Therefore, the use of synthetic resins as binder material for molding and core-rod mixtures in foundries leads to a large number of carcinogenic and poisonous substances releasing into environment. As a result, this not only has an extremely negative effect on environment, but also significantly worsens sanitary and hygienic working conditions in foundry shops, which contributes to professional diseases development among workers (silicosis, leukemia, central nervous system damaging, respiratory tract oncological diseases, etc.).

For this problem to protect foundry workers from such emissions radical solving, it is necessary either to carry out technological (sanitary and technical) procedures for carcinogenic and toxic gases from molding and rod mixtures synthetic resins released into surrounding and foundry shop air extracting, or synthetic resins replacing with inorganic origin binding materials (liquid glass, water, clay, etc.).

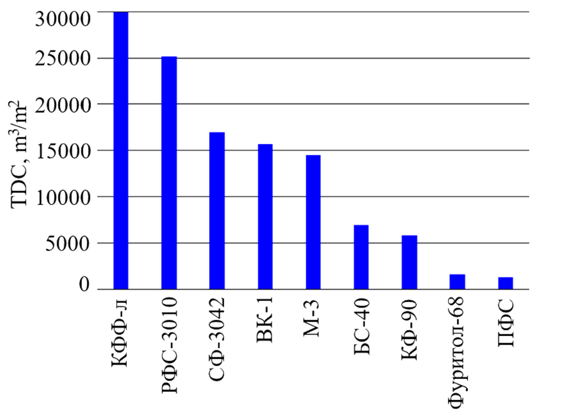

Fig. 4. TDC_i total value for casting molds with different resins in steel casting with wall thickness of 10 mm production

Conclusions.

1. All synthetic resins considered in this work, without exception, are environmentally hazardous substances when used as binding material for casting molds and rods.

2. Most dangerous are urea-phenol-formaldehyde, urea-formaldehyde and urea-furan resins, in which the main harmful substances are cyanides. The least dangerous (with an order of magnitude lower technogenic danger coefficient – TDC) are phenol-formaldehyde and phenol-formaldehyde-furan resins, which do not release cyanides.

3. Ecological and sanitary and hygienic danger level when using synthetic resins increases with increasing: their quantity in mixtures, castings walls thickness, their surface area, melt pouring into the mold temperature, that is – from aluminum alloys castings to bronze, cast iron and steel castings.

4. Casting mold layer thickness, which is heated from the melt poured into casting mold to temperatures above 400 °C, does not depend on casting wall thickness within the boundaries of its changes from 10 to 40 mm. It is 0.2 of aluminum made casting wall average thickness, 0.8 – for bronze casting, 1.4 – for gray cast iron casting and 1.6 – for carbon steel casting.

5. Despite synthetic resins high technological properties and modern equipment wide variety availability for their using in foundries, synthetic resins implementation for casting molds and rods manufacturing should be recognized as an environmentally unacceptable technical solution.

6. An alternative to synthetic resins as binding materials for casting molds and rods involves binding materials of inorganic origin, including liquid glass, water, clay, etc. and materials of organic origin, in which all destruction stages are accompanied by only water steam, carbon and/or carbon dioxide releasing.

7. For the first time, problem-oriented criterion for synthetic resins in foundry production using environmental and sanitary and hygienic hazard assessing has been elaborated – technogenic danger coefficient (TDC).

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Коефіцієнт техногенної небезпеки піщано-смоляних сумішей у ливарному виробництві

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Мета. Порівняльна кількісна оцінка екологічної й санітарно-гігієнічної небезпеки використання синтетичних смол для виготовлення форм і стрижнів у ливарному виробництві.

Методика. У роботі використовували кар'єрний кварцовий пісок марки $1K_2O_202$, фуранову смолу марки Permaset 839 і каталізатор Permacat 128, алюмінієвий сплав АЛ2, сірий чавун СЧ200, вуглецеву сталь 30Л, бронзу БрА9Ж3Л. Для темографування використовували хромель-алюмелеві термопари в комплекті з електронним потенціометром. Ливарні форми виготовляли з суміші кварцового піску, фуранової смоли й каталізатору. Визначення глибини прогріву ливарної форми від виливка до температур більше 400 °С проводили шляхом графічної обробки її термограм, що отримували після заливання ливарної форми алюмінієвим сплавом, бронзою, сірим чавуном, вуглецевою сталлю.

Результати. Із числа досліджених, найбільш небезпечними є карбамідофенолформальдегідні, карбамідоформальдегідні й карбамідофуранові смоли, найменш небезпечними – фенолформальдегідні та фенолформальдегіднофуранові смоли. Рівень екологічної та санітарно-гігієнічної небезпеки при використанні смоляних сумішей підвищується зі збільшенням кількості смоли у суміші, товщини стінок виливків, площі їх поверхні та зі збільшенням температури розплаву залитого у ливарну форму.

Наукова новизна. Уперше, стосовно виробництва ливарних форм і стрижнів у ливарному виробництві, розроблено коефіцієнт техногенної небезпеки (КТН) і розрахована його величина. По суті, КТН – обсяг повітря ($м^3$), що містить гранично допустимі концентрації канцерогенної або отруйної речовини, яка виділяються в результаті деструкції органічного сполучного матеріалу форми при заливці алюмінієвого сплаву, бронзи, чавуну або сталі.

Практична значимість. Використання результатів досліджень дозволяє підвищити рівень точності прогнозування техногенної (санітарно-гігієнічної та екологічної) небезпеки, рівень точності розрахунку потужностей вентиляційних систем ливарних цехів з урахуванням серійності виробництва литва, конструкційних особливостей виливків, а також природи сполучних матеріалів для ливарних форм і стрижнів для цих виливків.

Ключові слова: *коефіцієнт небезпеки, синтетична смола, ливарне виробництво, виливок, охорона праці*

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