Trend of Air Pollution during Electric Arc Welding and Oxyacetylene Cutting

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Abstract **– The present work comprises the unpublished results from the investigation of the air pollution caused by the electric arc welding and oxyacetylene cutting. These results have been obtained in the process of creating of the database, which contains information on the pollutants resulting from technological operations. In the present research the gained experience has been used. In the experiments the technological conditions and circumstances for carbon oxide, carbon dioxide, acrolein, nitric oxide and dust supply have been changed. During this research has bin made confrontation of other researcher's results.**

Keywords **– air, pollution, electric arc welding, oxyacetylene cutting.**

I. Introduction

Fire works such as electric arc welding, oxyacetylene cutting and cutting with angular grinder occur every day. So far they have been considered only in connection with their high degree of fire hazard. The preliminary research shows that these fire works generate a number of pollutants, which are intensively emitted in free air.

Air pollution caused by electric arc and oxy-acetylene welding are subjects of the scientific works of researchers as L. Vladimirov and V. Tomov [1,2,4].

The purpose of this work is to assess the risk of air pollution with substances released during electric arc welding and oxyacetylene cutting.

The main tasks, which have been solved to achieve the purpose include: 1. Selection of a method for studying pollution arising from fire works, which gives possibility to experiment 2. Carrying out experimental research; 3. Risk assessment; 4. Analysis and assessment of the obtained results.

II. Material and Methods

The method of physical modelling has been applied for the solution of the first task [2,3,4,9]. A system has been developed on which the specified types of technological operations are carried out subject to changing the controllable process factors. The methodical approach is based on experience of L. Vladimirov and V. Tomov [9], published in [1,3,5,6]. The purpose of these methods is to establish tooling for carrying out the research. Therefore it is necessary:

1) to justify a summarized approach for studying the risk of air pollution;

2) to select methods to simulate risk situations;

3) to provide arguments for the methods for establishment and measuring of parameters of pollution.

This study addresses critical situations from ignition of materials and pollution of air from their burning. Physical modelling includes execution of the technological operations of electric arc welding, oxyacetylene cutting and abrasive cutting with angular grinder. The method of the active experiment is applied, which enables direct identification of parameters of critical situations. Input controllable factors are the technological characteristics of the risk phenomena subject to this study: a) electric arc welding 1) angular profiles; 2) angular profile to the sheet metal; 3) sheet metal; 4) cutting plane P_L : horizontal; vertical; 5) type of weld seam: Butt weld; with overlapping; weld seam length L_{SHEV} -100, 200, 300*mm*; 6) welding direction $\rightarrow, \leftarrow, \uparrow, \downarrow$; 7) electrode type "Universe 51R"-rutile-coated – cellulose electrodes; "Boehler"-Fox OHV KE"- rutile-coated; "ESAB-OK 43.32"-rutile-coated; 8) electrode diameter De , depending on welded details -3,15; 4, 5mm; 9) current strength I_Z -140A; 10) welding height H_Z -1, 2, 3m; 11) welded details. b) Oxyacetylene cutting; 1) welded details – sheet metal; 2) thickness of cut Dp 15mm; 3) cutting plane P_L - vertical, horizontal; 4) cut length B_P -200, 300 and 400mm; 5) oxygen pressure P_P -300kPa; 6) cutting height Hp -1, 2 and 3m;

The following input factors of actions, which may incur risk of pollution are adopted: a) environment of distribution of risk effects: Air; reflecting surfaces; floor, cemented and asphalted, as surface of falling, reflection and establishment of risk elements – welding and cutting metal pearls. b) type of fire-catching material: Woodchips from the operation of smoothing planer, circular saw, grinder, manual grinder, mixed chips with dispersivity – 1; 2, 3mm from electric-arc welding; dry tree leaves; straw; Rondo fabric and Vitosha fabric, polyester type, for work clothes; cotton threads and cloths; paper – newspaper, cardboard, corrugated cardboard, poster and wrapping paper, packing cardboard; c) surface density G_{MAT} of the material on the floor -0,5; 1 and 1,5kg/m^2; d) additional processing of the flammable material by soaking with: I)diesel fuel and gasoline 50ml, 100 and 150ml/100g studied material; II) solvents for polyurethane systems; III) Keroselin thinner, thinner "AMB" 25ml, 50ml, 100ml/100g studied materials; IV) used and unused machine oil 100; 150 and 200ml/100g studied material; V) water 50; 100 and 150ml/100g studied material; e) position toward the source: I) in longitudinal direction, on axis X from 0 to 3m; II) crosswise, on axis Y from - 2 to + 2 m; f) air speed – up to 0,25m/s. Output parameters of critical situations are firing of materials and air pollution from their burning.

The colorimetric method has been applied for measuring the emissions. Indicator tubes of Higitest AD and Castec Co. have been used. Sampling has been made at height 1,5 – 1,7m above the floor level and in the quadrants of firing by types of materials. For determination of dust emission the gravimetric method has been used. Samples have been aspirated by sampler AL-2.

The conditions for carrying out the study have been determined by the controllable factors – air temperature T_V and relative air humidity φ_V . In the course of study T_V changes from 22,5 to 28.8^{0}C, and V_V from 71,2 to 84,2%, have been measured by Asman's psychrometer.

Criteria for assessment of the risk of air pollution include: 1) type of pollutant, 2) emissions Izam, mg/m^3, 3) probability P_K for pollution within the range $E[K] \pm \sigma(K)$, where $E[K]$ is the average value of concentration of pollution, and $\sigma(K)$ -mean quadratic deviation; 4) number of exceedings N of the maximum concentration limits; 5) probability Рпр for exceedings of the maximum concentration limits within the range $E[N] \pm \sigma(N)$, where $E[N]$ is the average number of exceedings and $\sigma(N)$-mean quadratic deviation; 6) time Тпр of exceeding of maximum concentration limits; 7) probability $Рпр_T$ of the time of exceeding within the range $E[T] \pm \sigma(T)$, where $E[T]$ is the average value of time Тпр of exceeding, and $\sigma(T)$ - quadratic mean deviation [10,11,12].

Probability $P_{K,}$ characterizes the content of pollutant in air, and Рпр and $Рпр_T$ determine the degree of criticality. They may be used to assess the dynamics of change in pollution. These criteria reflect differential risks from exceeding the maximum concentration limit

Risk Rzam is established by multiplying Рпр and $Рпр_T$. It is a complex criterion of pollution.

Probabilities $P_{K,}$, Рпр , $Рпр_T$ are determined by verifying the hypothesis for the statistical law of distribution. The programme Risk 4.5 has been used. It is used to verify 12 laws of distribution. They are classified on programme basis. The first law in the classification is adopted. Parameters of law are defined; it helps to obtain the probability of occurrence of pollution within a specified range. This range may change depending on the degree of detailing of the influence of the interval of confidence. Times of pollution are handled in the same way.

During research proces uncertainty has been identified by the values of risk criteria, respectively their differential risks.

This problem has been avoided so far. Uncertainty has great significance, especially for such specific and sensitive criterion as risk. It is established through the parameters of diffusion of the random values of pollution - quadratic mean deviation σ ; dispersion σ^2 ; variation ratio V . Additional conclusions can be made based on the average value E and the mode M. Analysis of these results shows a number of clearly outlined trends [7,8].

Concentration of pollutants and time of exceeding of maximum concentration limits are distributed according to laws for continuous random values – normal and Weibull.

The number of exceedings is subject to the laws of discontinued random values – Poisson and binomial. Exceedings during abrasive cutting with angular grinder make exception, since they are distributed according to a normal law. It is explained with the fact that their number is higher than 9, therefore it may be approximated through the normal law of distribution. Poisson's law in this case turns into normal law. Uncertainty, assessed through dispersion, quadratic mean deviation, variation ratio, is highest for pollution with carbon dioxide and dust. It is lowest for nitric oxide. Concerning number of exceedings and their duration, great dispersion of results is established, respectively uncertainty within statistical meaning. There is significant difference in the values of parameters of the normal law and the Weibull's law, which are established for concentrations. Anomalies are observed concerning nitric oxide, where they are much bigger compared to other pollutants. Outlined trends are confirmed also by average value and mode.

Differential risks unite the average values and dispersion. The problem is to determine the range from $\pm\sigma$ to $\pm n\sigma$, where n is 2, 3 etc. The choice depends on the purpose of study. Range may be extended and narrowed depending on variations in concentrations of pollutants. Regardless of the subjective effect in selecting the scope, the introduced criteria $P_{K,}$, Рпр , $Рпр_T$ are more objective than using the absolute values of concentrations.

The same is noted for complex risk Rzam. It combines concentrations, number of exceedings and their duration. Comparative analysis shows that trends in change of differential risks Рпр и $Рпр_T$ are preserved. It is explained with the fact that it is a product of them and relative share of the higher value has effect because it is a multiplier.

Generally it appears that pollution with nitric oxide during electric arc welding and oxyacetylene cutting features the highest degree of risk. As the second the pollution with carbon oxide during electric arc welding is considered, followed by the pollution with dust during abrasive cutting. As to other pollutants Rzam changes from 0,1771 to 0,5832. Regardless of the small range of variation the criterion has great sensitivity and resolving ability. It may be verified by expression in percentages.

III. Results and Discussion

Tables 1-7 show results from studying air pollution upon variation of technological factors within the above specified limits.

IV. Conclusion

The author of the paper proposes that the method of physical modelling is applied for assessment of risk of air pollution during fire works. Air pollution is measured in different points in the space of distribution of pollutants within the range of the modelling system. Colorimetric method is applied to measure the concentrations of carbon dioxide, carbon oxide, acrolein, nitrogen oxide and acetylene. Dust concentration is measured by gravimetric method. These methods enable accurate practical measuring to a sufficient extent.

TABLE 1

NUMERICAL CHARACTERISTICS OF THE LAWS OF DISTRIBUTION OF IMMISSIONS IN AIR DURING EXPERIMENTAL STUDY OF ELECTRIC ARC WELDING

Pollutant	Law	Numerical characteristics							
		a	b	E[X]	σ	σ^2	V,%	M	P_K
Carbon oxide, mg/m^3	Normal	10,22	10,19	9,02	9,88	97,61	38,29	10,22	0,773
Carbon dioxide, mg/m^3	Normal	17,28	17,18	36,28	10,22	104,44	31,28	17,28	0,427
Acrolein, mg/m^3	Normal	8,43	7,22	4,66	1,72	2,95	37,82	8,43	0,729
Nitric oxide, mg/m^3	Weibull	24,22	3,82	62,81	12,56	157,22	28,11	73,81	0,812
Dust, mg/m^3	Weibull	267,22	45,11	332,71	36,77	8055,	20,77	133,29	0,822

TABLE 2

NUMERICAL CHARACTERISTICS OF THE LAWS OF DISTRIBUTION OF THE NUMBER OF EXCEEDINGS OF THE AVERAGE DAILY MAXIMUM CONCENTRATION LIMITS DURING EXPERIMENTAL RESEARCH OF ELECTRIC ARC WELDING

Pollutant	Law	Numerical characteristics					
		E[X]	σ	σ^2	V,%	M	Pпр
Carbon oxide, mg/m^3	Binomial	16,72	4,95	24,50	1632,1	9,35	0,372
Carbon dioxide, mg/m^3	Poisson	9,88	7,21	97,61	98,82	11,5	0,537
Acrolein, mg/m^3	Poisson	18,92	9,18	84,27	28,47	180,22	0,725
Nitric oxide, mg/m^3	Binomial	14,72	7,73	59,85	33,43	98,77	0,352
Dust,mg/m^3	Poisson	15,77	11,38	129,50	1577,7	12,44	0,633

TABLE 3

NUMERICAL CHARACTERISTICS OF THE LAWS OF DISTRIBUTION OF THE TIME OF EXCEEDINGS OF THE AVERAGE DAILY MAXIMUM CONCENTRATION LIMITS DURING EXPERIMENTAL RESEARCH OF ELECTRIC ARC WELDING

Pollutant	Law	Numerical characteristics							
		a	b	E[X]	σ	σ^2	V,%	M	$Pпр_T$
Carbon oxide, mg/m^3	Normal	7,88	4,52	7,88	5,63	31,69	57,36	7,88	0,637
Carbon dioxide, mg/m^3	Weibull	4,55	7,82	5,27	8,22	67,56	16,28	8,22	0,728
Acrolein, mg/m^3	Weibull	6,29	5,36	7,13	7,82	61,15	85,27	9,36	0,638
Nitric oxide, mg/m^3	Normal	3,22	3,44	3,22	6,27	39,31	106,7	3,22	0,722
Dust, mg/m^3	Weibull	9,11	5,66	11,81	15,61	243,67	62,12	12,74	0,627

TABLE 4

NUMERICAL CHARACTERISTICS OF THE LAWS OF DISTRIBUTION OF IMMISSIONS IN AIR DURING EXPERIMENTAL STUDY OF OXYACETYLENE CUTTING

Pollutant	Law	Numerical characteristics							
		a	b	E[X]	σ	σ^2	V,%	M	P_K
Carbon oxide, g/m^3	Weibull	9,83	11,88	10,99	12,72	161,79	120,4	10,11	0,738
Carbon dioxide, mg/m^3	Weibull	15,26	8,29	28,17	11,83	139,13	54,67	18,25	0,722
Acrolein, mg/m^3	Weibull	6,72	7,82	8,92	6,77	45,83	73,17	9,77	0,618
Nitric oxide, mg/m^3	Weibull	34,28	2,33	17,74	4,22	17,80	41,52	27,18	0,692
Acetylene, mg/m^3	Normal	9,18	6,72	9,18	6,72	45,18	73,62	9,18	0,526
Dust, mg/m^3	Normal	162,82	33,73	162,82	33,73	1137,1	20,37	162,82	0,667

TABLE 5

NUMERICAL CHARACTERISTICS OF THE LAWS OF DISTRIBUTION OF THE NUMBER OF EXCEEDINGS OF THE AVERAGE DAILY MAXIMUM CONCENTRATION LIMITS DURING EXPERIMENTAL RESEARCH OF OXYACETYLENE CUTTING

Pollutant	Law	Numerical characteristics					
		E[X]	σ	σ^2	V,%	M	Рпр
Carbon oxide, mg/m^3	Binomial	9,28	2,59	10,27	35,62	8,22	0,238
Carbon dioxide, mg/m^3	Binomial	6,72	3,02	14,26	25,28	16,28	0,119
Acrolein, mg/m^3	Poisson	11,02	2,80	11,02	11,027	22,10	0,198
Nitric oxide, mg/m^3	Poisson	8,29	4,71	8,29	82,92	9,83	0,727
Acetylene, mg/m^3	Poisson	8,19	5,89	8,19	81,92	8,22	0,801
Dust, mg/m^3	Poisson	10,37	2,60	10,37	100,37	12,84	0,277

TABLE 6

NUMERICAL CHARACTERISTICS OF THE LAWS OF DISTRIBUTION OF THE TIME OF EXCEEDING OF THE AVERAGE DAILY MAXIMUM CONCENTRATION LIMITS DURING EXPERIMENTAL RESEARCH OF OXYACETYLENE CUTTING

Pollutant	Law	Numerical characteristics							
		a	b	E[X]	σ	σ^2	V,%	M	$Рпр_T$
Carbon oxide, g/m^3	Weibull	8,71	5,62	7,22	6,37	40,57	67,28	5,28	0,722
Carbon dioxide, mg/m^3	Normal	7,28	4,02	7,28	4,02	16,16	55,21	7,28	0,783
Acrolein, mg/m^3	Weibull	6,22	1,53	9,03	2,37	5,61	24,29	7,28	0,739
Nitric oxide, g/m^3	Weibull	6,22	3,82	7,17	1,83	3,34	60,11	8,12	0,693
Acetylene,mg/m^3	Weibull	6,56	5,66	4,28	4,03	16,24	84,55	3,29	0,622
Dust,mg/m^3	Normal	8,29	6,81	8,29	6,81	43,37	81,97	8,29	0,733

TABLE 7

RESULTS FOR DIFFERENTIAL AND INTEGRAL RISKS

Technologic operation	Pollutant	Рпр	$Рпр_T$	Rzam	Results of L. Vladimirov [2,3,4]; L. Vladimirov and V. Tomov [4,6,8]		
					Рпр	$Рпр_T$	Rzam
electric-arc welding	Carbon oxide	0,218	0,811	0,1771	0,130	0,836	0,1086
	Carbon dioxide	0,693	0,802	0,5521	0,753	0,838	0,6310
	Acrolein	0,188	0,769	0,1444	0,113	0,835	0,0943
	Nitric oxide	0,169	0,883	0,1496	0,131	0,839	0,1627
	Dust	0,622	0,877	0,5394	0,592	0,836	0,4949
oxyacetylene cutting	Carbon oxide	0,188	0,883	0,1584	0,148	0,844	0,1249
	Carbon dioxide	0,166	0,888	0,1408	0,131	0,835	0,1093
	Acrolein	0,172	0,898	0,1526	0,139	0,832	0,1156
	Nitric oxide	0,729	0,811	0,5832	0,800	0,836	0,6688
	Acetylene	0,693	0,763	0,5244	0,784	0,794	0,6224
	Dust	0,178	0,829	0,1394	0,148	0,839	0,1241

Risk assessment is made applying a new method. It is based on determination of the laws of distribution exceeding the maximum concentration limits. Then probabilities of occurrence of changes within the specified ranges around the average value are established. In the same way the ignition time is handled. The complex risk is a product of probabilities for the number of exceeding of the maximum concentration limits and their duration.

The analysis of results show, that the applied criteria for risk assessment reflect objectively the levels, variations and dynamics of pollution. Uncertainty in terms of statistics is reflected.

It is also important that the method of physical modelling allows carrying out a wide range of planned experiments which otherwise would be impossible in normal production conditions.

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