Pressure Fields Repeatability at Electrohydraulic Pulse Loading in Discharge Chamber with Single Electrode Pair

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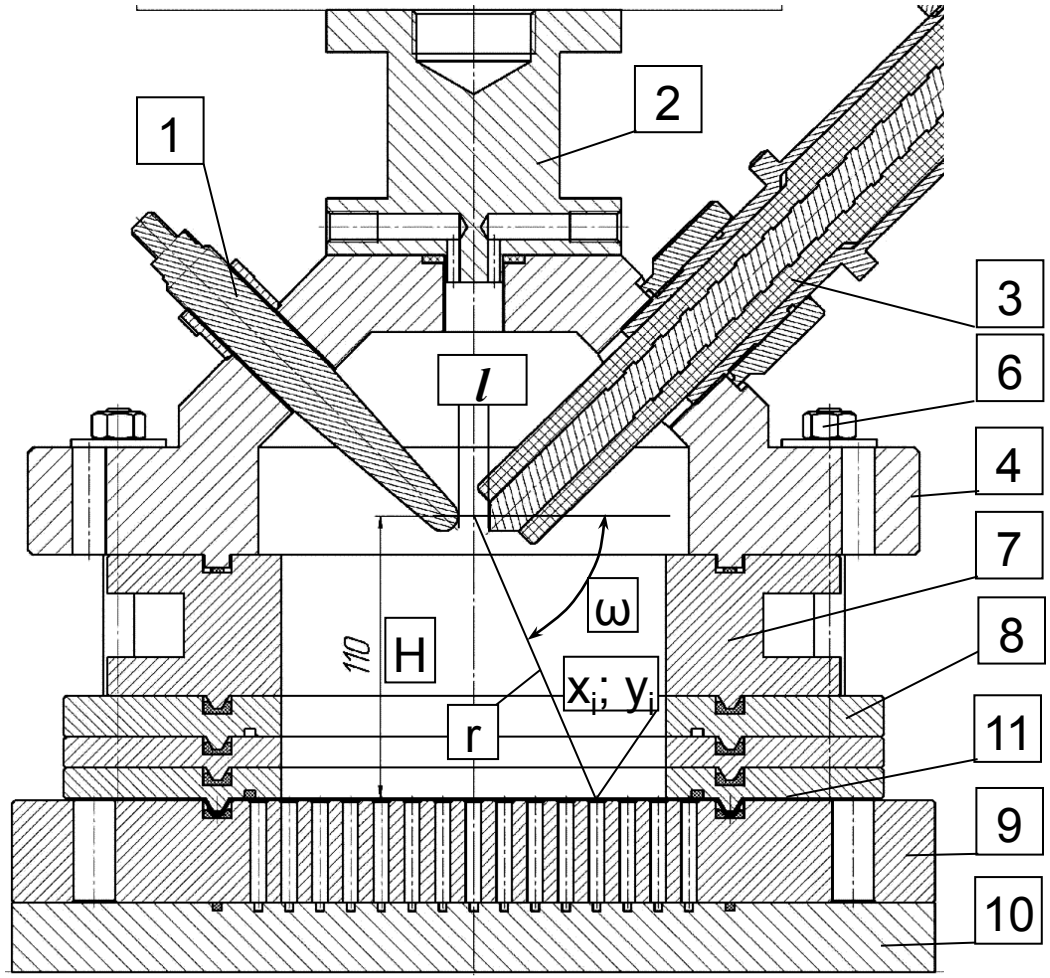
Purpose

The purpose of work is an experimental determination of electric and geometric parameters, at which stability (repeatability) of pressure fields will be the highest at non-initiated discharges

Vohnout, V.J.; Fenton, G.; Daehn, G. S.: Pressure heterogeneity in small displacement electrohydraulic forming processes. Proceedings of the 4th International Conference on High Speed Forming “ICHSF2010”, Columbus, Ohio, March 9-10, (2010), p. 65-74.
Homberg, W.; Beerwald, C.; Pröbsting, A.: Investigation of the Electrohydraulic Forming Process with respect to the Design of Sharp Edged Contours. Proceedings of the 4th International Conference on High Speed Forming “ICHSF2010”, Columbus, Ohio, March 9-10, (2010), p. 58-64.

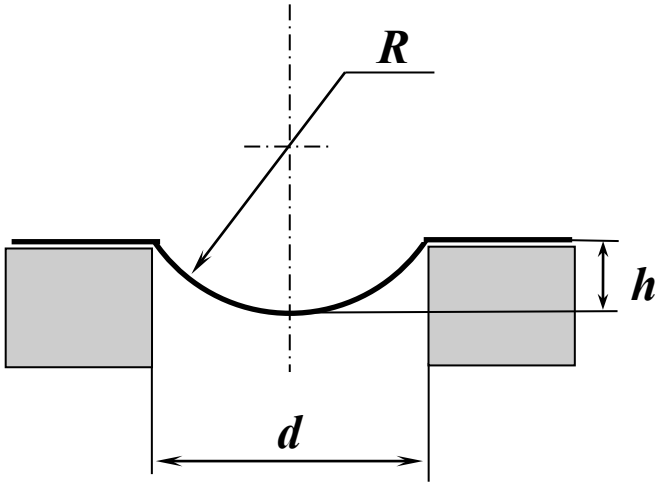
Test Diagram

$$l_n = \frac{4 \cdot l \cdot H}{\pi \cdot D^2}$$



1 – mass (negative) electrode;
2 – discharge chamber adaptor;
3 – insulated (positive) electrode;
4 – discharge chamber;
6 – studs, nuts, washers;
7 – spacer ring 55 mm in height;
8 – ring with ID of 150 mm;
9 – membrane pressure gauge;
10 – lower tooling adaptor;
11 – membrane;
l – spark gap;
H – distance between discharge channel and pressure gauge;
Voltage *V* = (10–30) kV,
Capacitance *C* = 33.2 μF,
Charged energy
E = (1.66–14.94) kJ,
Inductance *L* = 0.5 μH

Impulse Pressure Estimation



Schematic diagram of spherical dimple in a hole of membrane gauge

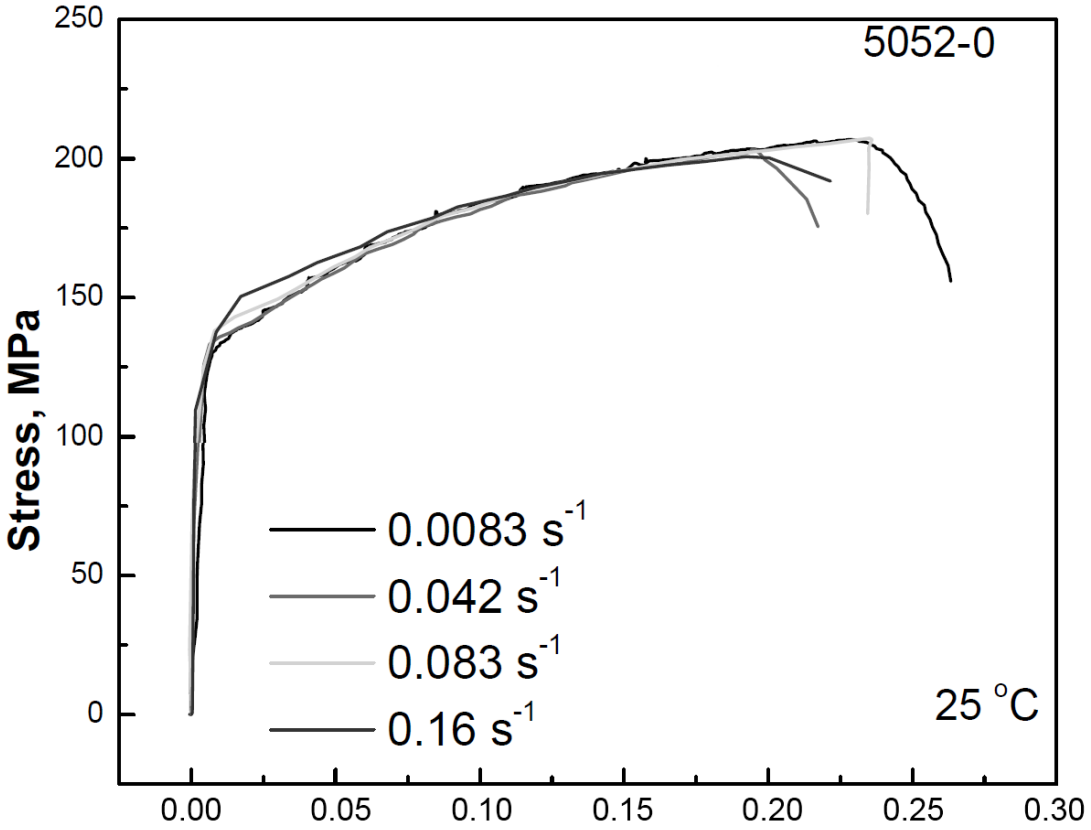
Laplace equation for spherical shell

$$P_L = \frac{2\sigma \cdot t}{R} \qquad R = \frac{(d/2)^2 + h^2}{2h}$$

where t – membrane thickness; R – radius of spherical segment; σ – stress, at which deformation occurs; h – depth of dimple

Membrane

$$\sigma = 0.0015\,\varepsilon^3 - 0.1667\,\varepsilon^2 + 7.1258\,\varepsilon + 92.802 \qquad R^2 = 0.9988$$



$$\varepsilon = 1 - (A_0 / A_d)$$

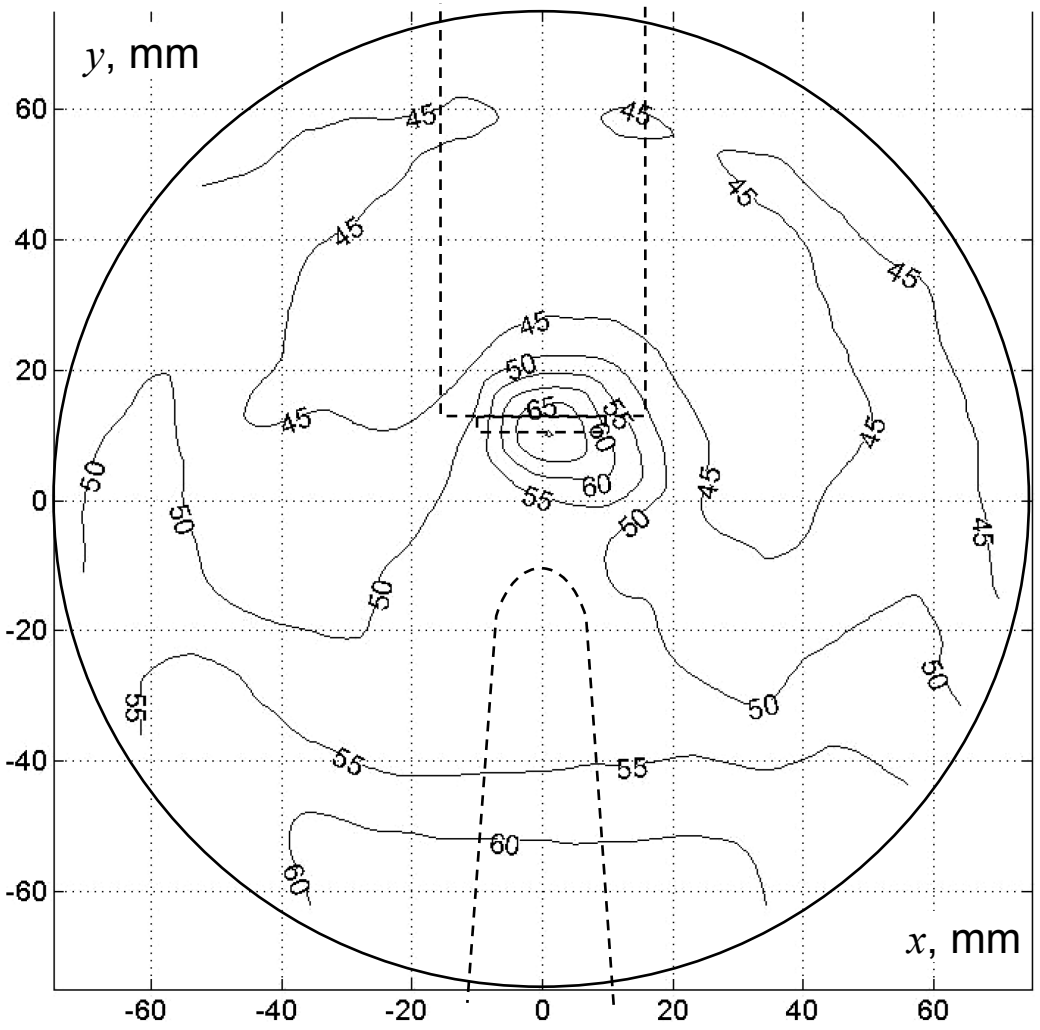
$$A_0 = \pi d^2/4$$

$$A_d = 2\pi R h$$

At d/t < (6…8) - linear proportionality between equivalent static pressure P_L and peak pressure of shock wave P_m

http://products.asminternational.org/datasheets/metaview.do?record=8555&database=datasheets

Tests Results



Representative pressure map (MPa) for test conditions No. 13 at l = 20 mm and V_0 = 20 kV

P_{max} = 69.84 MPa

P_{min} = 40.69 MPa

Data Processing

- Average pressure for each *i* point (*i* = 1…127) of MPG membrane for the *m* quantity of pressure fields under the same test conditions (*m* = 3-6)

$$P_{ave.i} = \frac{1}{m}\sum_{j=1}^{m} P_{ij}$$

- Standard deviation of pressure value in each *i* point

$$S_i = \sqrt{\frac{1}{m}\sum_{j=1}^{m}\left(P_{ij} - P_{ave.i}\right)^2}$$

- Coefficient of variation in each *i* point

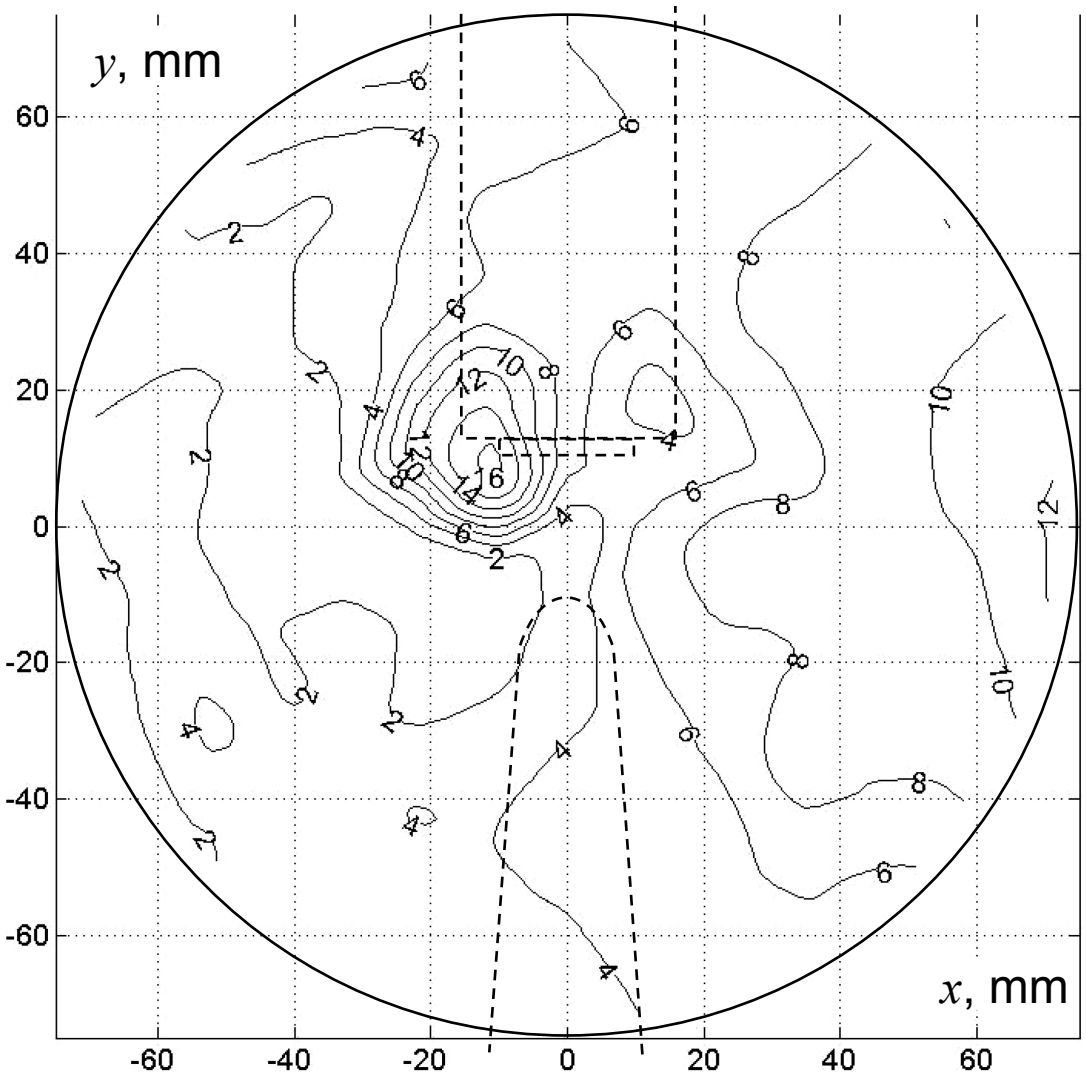
$$C_{Vi} = \frac{S_i}{P_{ave.i}} \cdot 100\%$$

- Maximum C_{max} and minimum C_{min} values
- Average value of variation coefficient among *n* = 127 points

$$C_{V.ave} = \frac{1}{n}\sum_{i=1}^{n} C_i$$

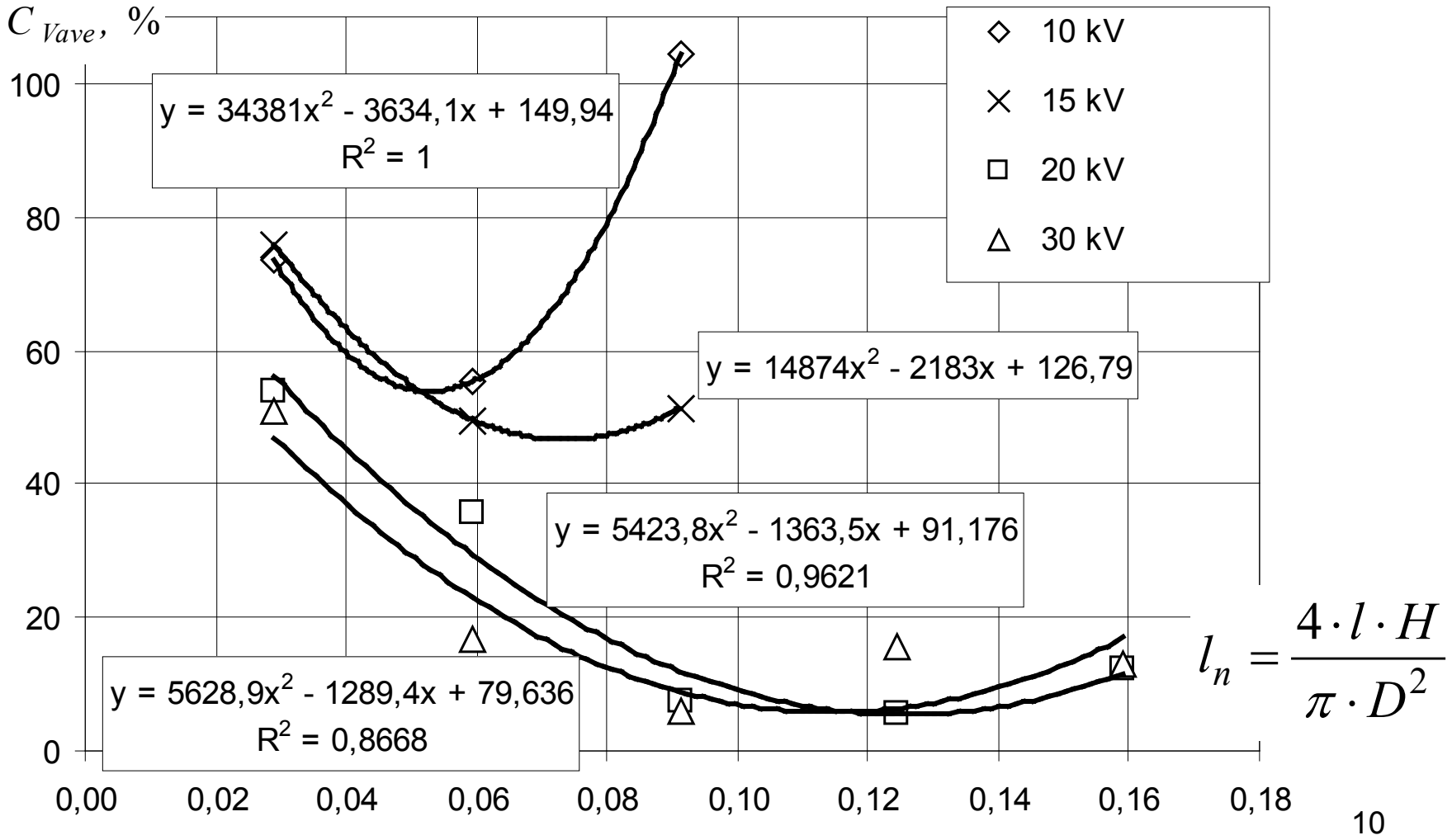
Tests conditions						Tests results				
No.	l, mm	V_0, kV	E_0, kJ	H, mm	m	$P_{max\text{-}ave}$, MPa	S_{ave}, MPa	C_{Vmax}, %	C_{Vmin}, %	C_{Vave}, %
1.	5	10	1.66	102.5	6	10.65	1.99	105.69	34.68	73.46
2.	5	15	3.73	102.5	3	29.04	5.05	112.16	35.58	75.99
3.	5	20	6.64	102.5	3	22.18	3.87	79.50	35.02	53.72
4.	5	30	14.94	102.5	5	57.71	7.13	72.18	35.89	50.74
5.	10	10	1.66	105.0	3	32.75	6.44	79.43	37.96	55.39
6.	10	15	3.73	105.0	3	49.41	8.06	60.30	33.09	49.60
7.	10	20	6.64	105.0	4	69.46	8.79	46.27	26.26	35.62
8.	10	30	14.94	105.0	3	78.53	9.18	41.99	11.92	16.63
9.	15	10	1.66	107.5	3	12.64	1.77	117.76	80.65	104.60
10.	15	15	3.73	107.5	3	46.91	5.25	57.56	43.56	51.45
11.	15	20	6.64	107.5	3	84.09	8.82	15.67	1.02	7.38
12.	15	30	14.94	107.5	3	89.93	7.94	26.45	2.01	6.12
13.	20	20	6.64	110.0	3	71.44	6.63	15.52	0.57	5.49
14.	20	30	14.94	110.0	3	86.36	6.69	21.07	6.47	15.58
15.	25	20	6.64	112.5	3	80.81	9.69	23.87	1.64	12.25
16.	25	30	14.94	112.5	5	101.15	7.27	21.27	5.38	13.00

Processing results

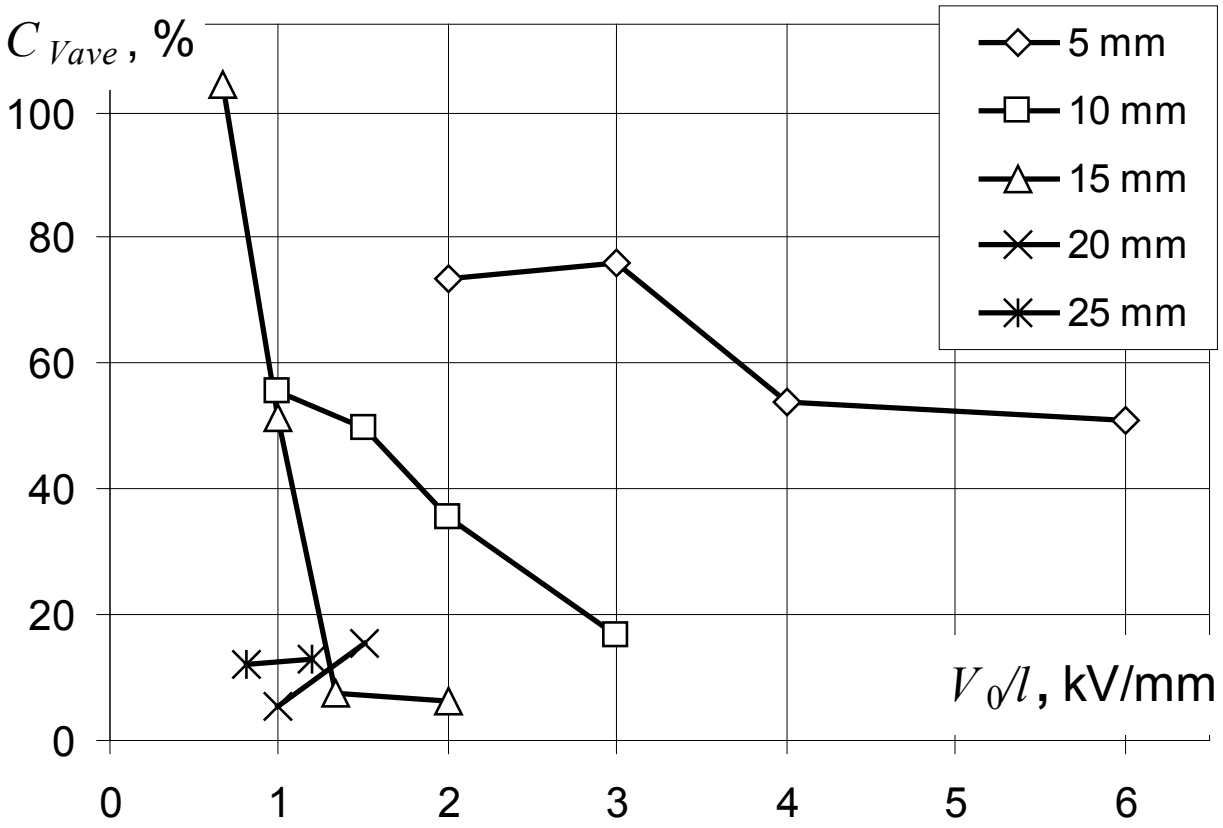


Map of variation coefficient (%) for test conditions No. 13 with 3 pressure maps processed

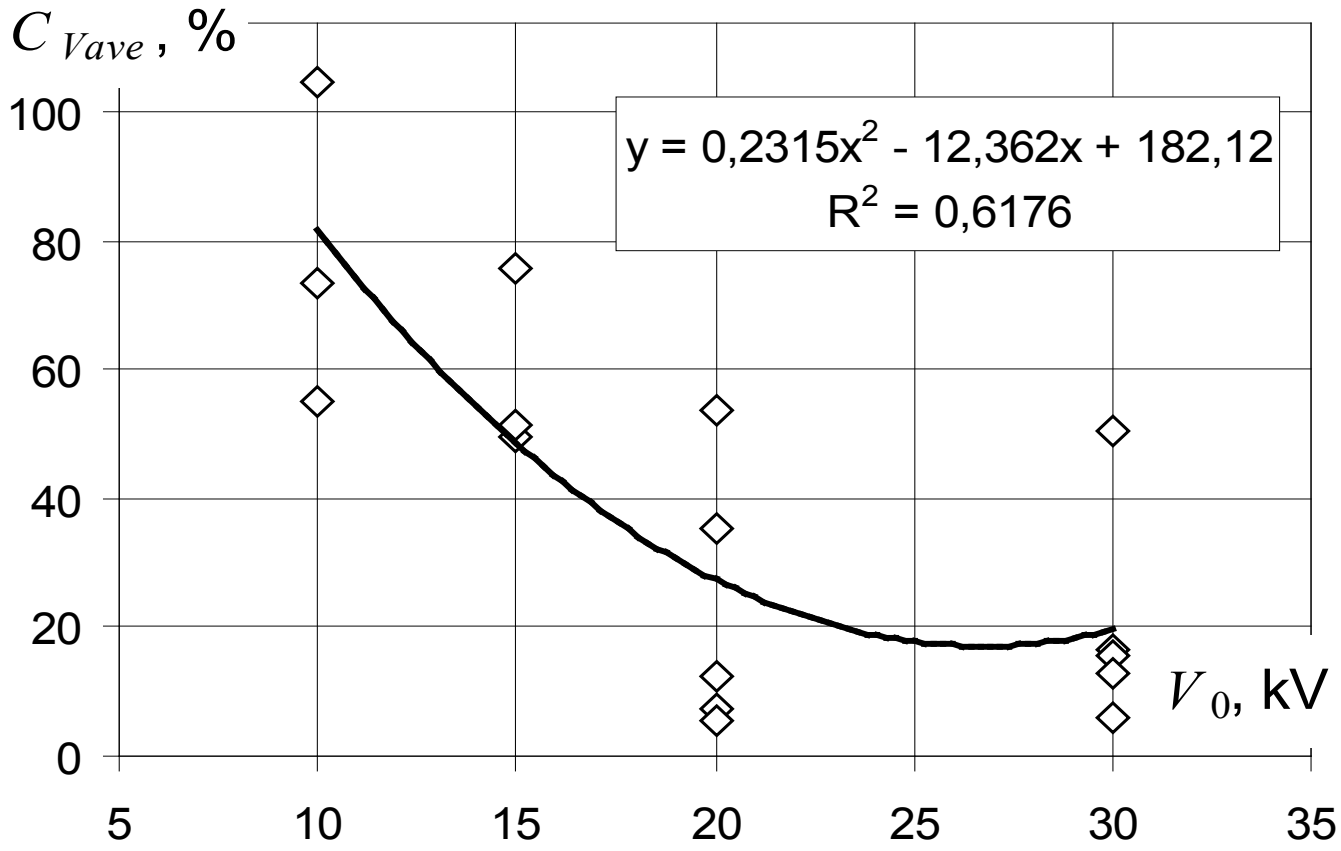
Dependences of average variation coefficient C_{Vave} from normalised spark gap l_n at specified values of charged voltage V_0



Dependences of average variation coefficient C_{Vave} from electrostatic intensity V_0/l at specified values of spark gap l



Dependency of average variation coefficient C_{Vave} from charge voltage V_0 for all tests



Conclusions

- The investigation results showed strong influence of geometric parameters of discharge work volume and electric parameters of discharge circuit on repeatability of pressure fields

- The spark gap value should be in severe correlation with distance to a sheet blank and dimensions of a loaded area

- Voltage and energy of discharge have optimal values. All deviations of their values from the optimums result in increasing instability of discharge channel position and, hence, low repeatability of pressure fields

- For the specified geometric parameters of discharge chamber at the condition of average variation coefficient value being of up to 10 % the following electric parameters are recommended: range of spark gap is 17 to 22 mm, voltage range of 20 to 30 kV and charge energy range of 6.64 to 14.94 kJ

- The further investigations with discharge chambers of other geometric parameters for verification of the proposed method are planned