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ELECTRICAL CONTACT PROCEDURE FOR RECORDING x, t-DIAGRAMS

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UDC 531.761

In performing different gas dynamic studies the problem often arises of measuring the free surface velocity of projected bodies or the shock and detonation wave (SW, DW) velocities. The electrical contact procedure is the most used method for these purposes. With its use a record is made of the instant of closing wire or foil contacts with any surface (body, screen). The value of velocity sought is found as a result of treating x, t-diagrams of movement for the surface or wave being studied. In this work a short description is given of a modified electrical contact procedure developed by the authors for recording detailed x, t-diagrams using a miniature multicontact sensor.

Normally in measuring devices use is made of quite massive tubular sensors with screens protecting the contacts from premature closure by an air SW. Sensors of different levels are placed in different locations beneath the surface of the flying body (e.g., a plate), and therefore the measurement accuracy is affected by the shape of the surface closing the contacts (e.g., deviation of the plate surface from being flat in the measurement zone). Oscillation of the amplitude and duration of electric pulse fronts obtained with closure of contacts also reduces measurement accuracy.

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TABLE 1

Gas	T, K	w, km/sec
Air	3 000	2,5
Carbon dioxide	12 500	5,5
Helium	20 000	11
Propane	10 000	11

With the aim of improving the accuracy and reliability of measured results the electrical contact procedure has been improved. A miniature electrical contact sensor* (Fig. 1) has been developed, i.e., a cylinder of capacitor paper along whose generating line copper wires made of PEV insulated wire are glued. Each wire is trimmed together with the paper to a certain height (depending on the measurement base) so that the ends of the wires are in a spiral (whence the name spiral sensor). The sensor with ten contacts has a diameter of 2.3 mm. Previously on a specially constructed wiring bench flat blanks are prepared which are then covered with adhesive BF-2, turned into a cylinder, and in this form polymerized at 130°C. The wires are cut off by a template which makes it possible to prepare sensors with various measurement bases within the limits ±0.015 mm. The overall thickness of the paper and adhesive in the sensor does not exceed 0.04 mm, although the tubular shape gives the sensor sufficient stiffness.

Considerable attention was devoted to selecting the distance between the sensor wires including the reciprocal effect of contacts on each other. On reaction of the sensor with a moving body a crater forms in the latter from which a jet flies off containing materials of the moving body and the contact [2, 3]. It may contain a bridge of conductivity for neighboring contacts and disrupt their operation. A ridge forms along the crater edge, and therefore the neighboring contact should be sufficiently removed so that it falls in an undisturbed area of the surface.

Studies carried out for reaction of moving bodies with rods have shown that depending on the body material and the rod diameter the disturbed region reaches a value $d_d = 10d_0$ (d_0 is rod diameter, body velocity ~5 km/sec). Therefore, for a spiral sensor with contacts of wire 0.06 mm in diameter the distance taken between contacts is 0.6 mm, which is twice as large as the size of the disturbed zone ($r_d = 5d_0 = 0.3$ mm).

Tests have shown that the jet flying out of the crater cannot close or dislodge a neighboring contact since it is not continuous, but it consists of individual particles which do not form an electrical circuit and in size the particles are an order of magnitude less than the contact diameter. Thus, grouping of contacts in a single spiral sensor of small diameter reduces the measurement error connected with surface asymmetry (each sensor records a x, t-diagram for movement of practically a single point of the surface), it simplifies assembly of the measuring unit, and it increases the placement density of contacts.

Since the ends of contacts are not insulated (for more reliable closing with moving body), the work of the sensor depends on ionization of a gas medium in which the measurement is performed. For air the velocity of a body should not exceed 2.5 km/sec. With a greater velocity air behind the SW front moving ahead of the moving body is ionized so much that it

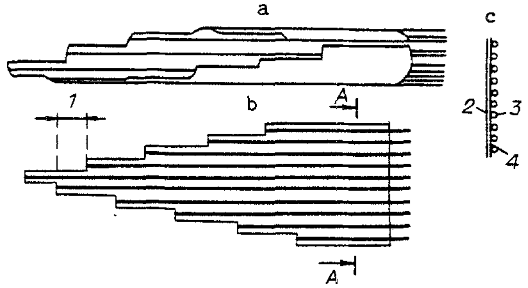

Fig. 1. Multicontact sensor. a) spiral; b) flat; c) section along AA. 1) measurement base; 2) capacitor paper 0.01 mm thick; 3) wire PEV-2 with diameter 0.06 mm; 4) adhesive BF-2.

*Sensor construction suggested by E. S. Antonevich.

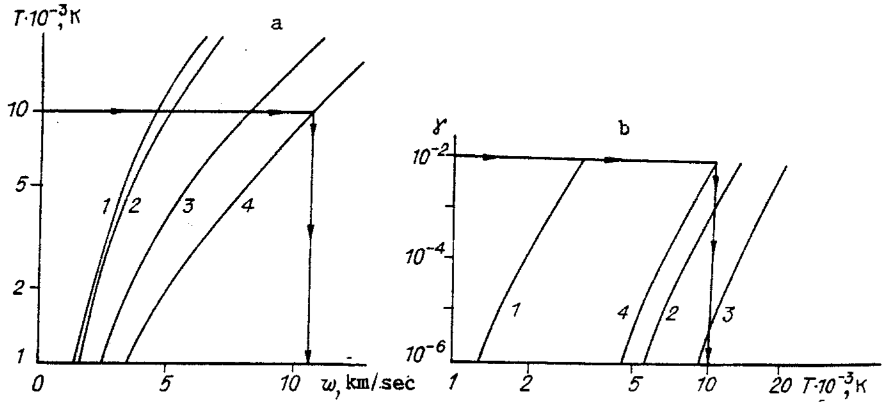

Fig. 2. Calculation of dependences for temperature behind the SW front in gases on plate velocity (a) and γ(T) (b). 1) air; 2) CO_2; 3) helium; 4) propane.

disturbs the normal contact operation (they are closed by the air SW and not by the body surface).

For measurements with high velocities gas protection of the spiral sensor is used including substitution of air ahead of the moving body by another gas with a reduction in the degree of ionization behind the SW front [4, 5]. It is possible to use helium (with a high ionization potential) or multiatomic gases (carbon dioxide, methane, propane, etc.) which have a high heat capacity and they warm up less than air in the SW [6, 7, 8]. For air, carbon dioxide, helium, and propane estimates have been made of the temperature and degree of ionization γ of gas behind the SW front in relation to the movement velocity of the object being studied in the gas. The dependences obtained are given in Fig. 2. In carrying out measurements in air without protecting the contacts for the maximum permissible body velocity of 2.5 km/sec behind the SW front, T = 3000 K, γ = 0.01. By assuming that in other gases measurements are permissible with open contacts, if $\gamma \leqslant 0{,}01$, we obtain values of T and limiting velocities w given in Table 1 which may be measured by a spiral sensor. In fact, in experiments the space around the sensors is made closed (but not hermetically) and propane—butane is blown through continuously.

For measurements by means of spiral sensors a multichannel measuring complex was developed (Fig. 3) having the following parameters: number of measurements in a test (number of

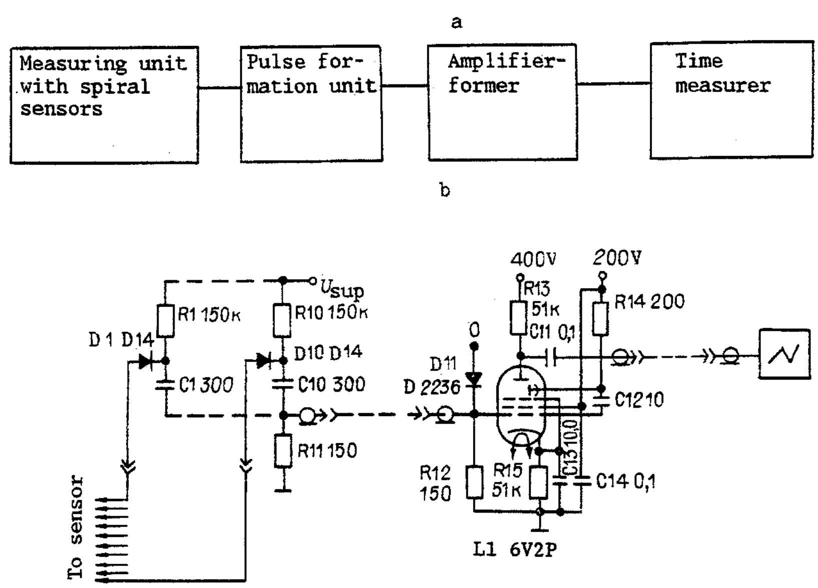

Fig. 3. Block diagram (a) and electric circuit (b) of a single channel of the measuring complex.

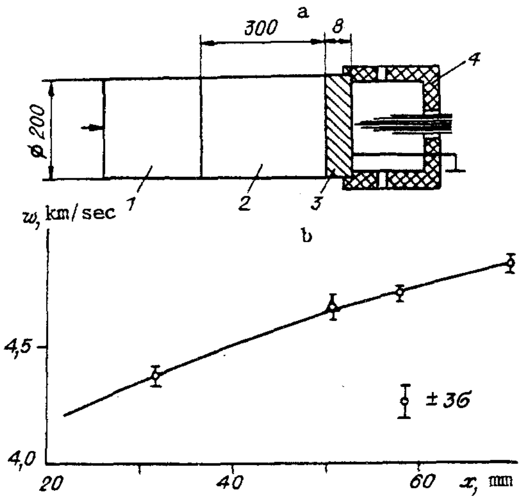

Fig. 4

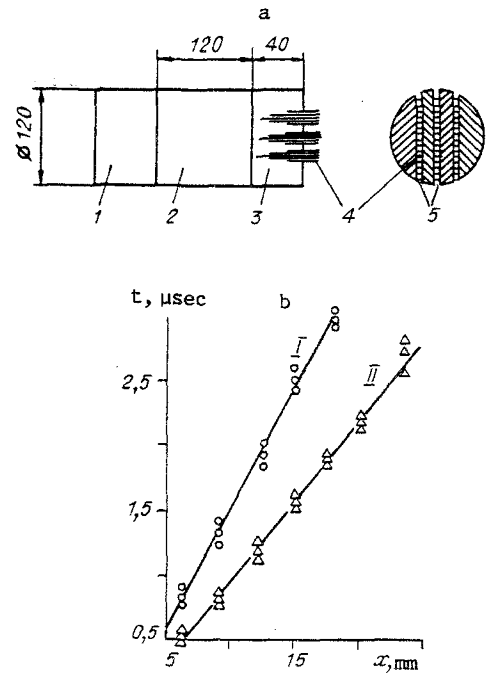

Fig. 5

Fig. 4. Arrangement of the experiment (a) and dependence of aluminum plate velocity on the flight base (b). 1) Plane wave lens generator; 2) charge of TG 40/60; 3) aluminum plate; 4) measuring unit with a spiral sensor; o) measurements of eight spiral sensors in a single test; Δ) average velocity value obtained in a standard procedure with tubular contacts (five tests).

Fig. 5. Diagram of the experiment (a) and experimental x, t-diagrams for a shock wave in steel and aluminum (b). 1) Plane wave lens generator; 2) charge of TG 30/70, 120 × 120 mm; 3) specimen; 4) flat sensor; 5) cellulose nitrate varnish; I) steel (D = 5.4 km/sec); II) aluminum (D = 7.4 km/sec).

contacts) 200 (20 sensors of ten contacts each or ten sensors of 20 contacts each); voltage in the contacts 50 V; time resolution 50 nsec.

The pulse formation unit (PFU) provides short output pulses of almost constant amplitude independent of the number of contacts used up in the sensor. The short pulse duration (50 nsec) is achieved by using capacitors of low capacity (150-300 pF), and a constant amplitude is achieved by introducing diodes D1-D10 which separate the positive half-wave of oscillations arising due to parasitic capacitance and inductance in the circuit on closing the contact, and they avoid the effect of previously used contacts on the amplitude of the pulses formed. In order to improve the shape of pulses the PFU is placed behind armored protection as close as possible to the sensor.

With a low supply voltage for sensors and considerable damping of short pulses during transfer along the cable the sensitivity of the oscillographs IV-30M used in the complex is low for recording pulses from the PFU. Therefore, an amplifier-former is introduced into the measuring channel which generates a pulse with an amplitude of 150 V and a leading front duration of 10 nsec. A trigger circuit in a 6V2P lamp with secondary emission is used as the former [9]. A zero pulse is fed through diode D11 in relation to which the time for sensor contacts to be used up is varied.

Measurement errors for time intervals depend on the time measurer used and the accuracy of preparing the sensor base. In using sensors prepared by templates and IV-30M oscillographs the random error for time intervals is not more than ±20 nsec.

In order to reveal the systematic error under identical test conditions measurements by means of spiral sensors were compared with measurements by the generally accepted electrical contact procedure (with screening of tubular sensors [1]). Results of this comparison shown in Fig. 4 point to the absence of a marked systematic error in measurements by means of the procedure developed. An example of measurements in the complex developed is shown in Fig. 5.

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STABILIZATION OF WAVE FORMATION AT THE CONTACT BOUNDARY OF METAL LAYERS IN AN EXPLOSIVE WELDING REGIME

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In a number of cases oblique impact of metal layers is accompanied by wave formation at the interface [1]. In order to develop wave formation it is necessary to fulfill limiting conditions for the impact angle γ and the velocity of the contact point v_C, which are connected with criteria of jet formation with oblique impact [2, 3]. Currently several ideas have been developed for the mechanism of wave formation [1, 2, 4-9]. A review of the majority of these is given [1]. In a number of studies wave formation is explained by development of disturbances of the Kelvin—Helmholtz type of instability with realization of tangential flows of material along the contact boundary behind the point of impact [6-9].

Processes of wave formation and reciprocal displacement of materials are used extensively in explosive welding of metals [1, 10, 11]. However, in a number of cases (profiled explosive welding, etc.) wave formation and displacement of metal layers with oblique impact are undesirable.

Oblique impact of flat layers of metals (copper, brass, aluminum, magnesium, and combinations of them) in an explosive welding regime and the effect of different protective interlayers on the state of the contact boundary after loading have been studied by experiment. A traditional scheme of plate projection has been used in a sliding detonation regime for an explosive charge. A diagram of the tests carried out and notations of the characteristic projection parameters are presented in Fig. 1. A fixed plate 5 with Δ = 4 mm is placed on a massive steel base 6. Over it the projected plate 3 with Δ = 4 mm is set up which is in-

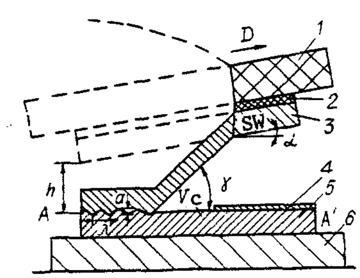

Fig. 1. Diagram of the test procedure.

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