

## **Research Article**

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# Electromagnetic Super – Compressibility

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## Abstract

The dynamic emitter-a nozzle with a disposed along its axis central conic body-is a new engineering decision. The phenomena arising during its work are valuable and prospective both in fundamental science and practical application. During our experiments with this device we have discovered spiral-twisted non-ideal plasma wave structures arising in subsonic and supersonic gas jets flowing from the nozzle with a central cone. We consider very important and prospective the fact that the flow from the dynamic emitter remains almost stable both in shape and power with the distance from the nozzle outlet increasing. For example, the air jet from the nozzle with a central cone can deflect a steel plate of weight 2.55 kg, pending on the 120 mm wire, for about 45 mm at the distance of 400 mm. At this distance the power of the flow from the common conic nozzle is insignificantly low. Also in our experiments we registered phase transitions of air, argon and nitrogen to liquid and solid in the jets at room conditions (temperature of the jet was 285 K, humidity about 5-7%), which is very unusual and provides a lot of practical opportunities. Water vapor flowing from the dynamic emitter creates the mentioned non-ideal plasma structures with increased density of electrons that provides concentration of energy in small volumes (in the nodes of the structure) and high energy radiation (in the experiments there were detected electromagnetic fields up to 1 GHz). The received results can be explained with introducing the concept of electromagnetic super-compressibility which has been the primary aim of our work.

**Keywords:** Nozzle with a central cone; Spiral-twisted supersonic jet; Phase transitions; Electromagnetic super-compressibility

### Introduction

Invented in 1996, the dynamic emitter-a nozzle with a central conewas aimed to obtain gas jets of high kinetic energies with little power consumption [1]. It is a known fact that in classical nozzles (for example, of Laval type) loss of energy is high even at small distances from the outlet. A lot of energy is wasted on Mach shockwaves which arise in vicinity of the nozzle outlet. Therefore we started experimenting with the construction to avoid shockwaves and obtain better performance. Inspired by work of Abramovich [2], we created a nozzle composed of two cones-inner and outer-angled relative to each other. The first probes showed brilliant results-we did obtain jets of high power with little pressures in pre-chamber (about 0.15-0.2 MPa) whereas for the flow of such strength emitted by Laval nozzle we had to use 0.6-0.8 MPa pre-chamber pressure. Such success prompted us to continue our experiments with this device that we decided to call, as has already been mentioned, the dynamic emitter.

After long study we found a lot of interesting phenomena arising during the work of the nozzle with a central cone. This nozzle generates unusual spiral-twisted structured supersonic jets which we visualized using several methods [3-5]. Outflow of the gas from this nozzle is accompanied by adiabatic expansion that leads to gas cooling and forming of the channels with high degree of rarefaction in the jets [6]. The pressure difference between outer atmosphere and rarefied gas in the channels leads to the forming of rigid boundary layers of the flow at the output of the nozzle. Electric charges arise in the layers of the channels. The boundary layers radiate ultraviolet and visual light. The glow is a consequence of the formation of cold non-equilibrium plasma in the structured flows. This glow has an irregular character, where the maximal intensity is detected in the nodes of the structure [7,8]. We found that the boundary layers of gas flow are compressed and form spiral-twisted structures [5]. This compression we called "supercompression" since it is the result of three phenomena interacting: the pressure difference, the Coulomb interaction of separated electrical discharges and high frequency fields arising in the jets [8,9]. These fields interact with gas flow and form it into spiral-twisted structures. The radiation of high energy was studied during interacting of fields arising in the jets with gas and water vapor [10]. The high frequency field is found also by other methods in gas discharges in closed volume when the direction of the field was constant with respect to the gravity vector at the given point of space [9,11]. We observed progressing compression of the flow in the direction of its distribution when the volume of the structured part was decreased at a distance of 10-12 calibers of the nozzle without external pressure increasing.

In present paper we explore several phenomena found in supersonic jets flowing from the dynamic emitter and based on our experimental and theoretical background give them explanation using the concept of electromagnetic super-compressibility, after which we conduct one more experiment to confirm the existence this phenomenon. The main goal of this work was to introduce the concept of electromagnetic super-compressibility and to reveal its properties.

#### **Experimental Part**

#### Description of gas dynamics part

We conducted a series of experiments on a special annular nozzle with a conic central body as in patent [1]. The nozzle is constructed with two cones (external and internal) with different angles (Figure 1). The inner cone can be disposed along the axis of the jet either in the nozzle pre-chamber or outside it. During our experiments we altered

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**Figure 1:** The scheme of the dynamic emitter. Here *a* is the pre-chamber, *b* is the central cone.



**Figure 2:** The dimensions of the cells in spiral-twisted configurations at two different positions of the central cone. The structure is visualized using Toepler method.

gas pressure and geometry of pre-chamber. Filtered argon, air and nitrogen were used for the study. Using a reducer we obtained gas pressure from the gasbags equal to (0.2-0.8) MPa. In present paper we provide the results of four experiments.

When the gas is flowing out into the atmosphere from the nozzle with a central cone it acquires a configuration of strong pronounced compressed flow of spiral-twisted radiating wave structures (Figure 2). These structures consist of the cells of certain size. The type of the structure and size of its cells depend on the position of the central cone. Linear dimensions of the cells decrease when we move the central cone out of the nozzle (Figure 2). On the left in Figure 2 the central cone was 2.5 mm inside the nozzle and on the right it was 2.5 mm outside. As seen from Figure 2, diameter 6 mm had become 5 mm, distance between the nearest nodes 10 mm had become 8.5 mm and diameter 4 mm at the distance of 13 calibers of the nozzle had become 3 mm. The super-compression of cell dimensions occurs instantly (in no more than 20 ns) [12].

In the first experiment we observed supersonic spiral-twisted air

jets radiating in wide range during their flowing from the nozzle with a central cone moved out of the nozzle for b=3 and b=5 mm (Figure 3).

The glow of the submerged jet has irregular character. Maximal intensity was detected in the nodes of the structure (Figure 4).

The flow temperature was 285 K measured with probe temperature sensor, and pre-chamber pressure was (0.4-0.6) MPa. The radiation was registered with monochromator of diffractive-grating type (MDR12) which operating range lies in 350-950 nm band. The flow of the jet is accompanied by the radiation within the ultraviolet, visible and infrared spectrum [5,7,8]. It is noteworthy that structure remains stable at long distances from the nozzle.

#### Comparison of power distribution in the submerged jets for two types of nozzles

Unusual stability of the jet structure at long distances prompted us the idea for our next study. Experiment 2 was conducted to compare power distribution along the axis of the flow in submerged jets during their flow from the dynamic emitter with a central cone and from a common conic nozzle of Laval type. Using filtered air jet, we made



**Figure 3:** Structure of supersonic jet flowing from dynamic emitter when b=3 mm, annular nozzle diameter is 3 mm, pressure in pre-chamber is 0.6 MPa. Toepler method of visualization is used.



**Figure 4:** Structure of supersonic jet flowing from dynamic emitter when *b*=5 mm, annular nozzle diameter is 5 mm, pressure in pre-chamber 0.6 MPa. Laser shadow method of visualization (632 nm wavelength) is used. Scattering. High density nodes.

several measures of the deviation of a steel plate of weight 2.55 kg with height of 113 mm, pending on 120 mm wire deflected by the jet at different distances from the nozzle and with different pressures in pre-chambers [13]. Both nozzles were fixed in horizontal position perpendicular to the pended plate initially in equilibrium position (Figure 5).

We can see that for the common conic nozzle the deviation becomes insignificant for the same distance L=250 mm in all cases (Figures 6a-6d). In the same conditions the dynamic emitter can deflect the pendulum noticeably enough (from 7 to 50 mm for pressures from 0.2 to 0.8 MPa respectively) even at the distance L=500 mm.

It is seen from the graphs that the jet flowing from the dynamic emitter remains almost stable both in shape and power with the distance increasing which confirms our previous conclusions based on the jet visualization. Using higher pressures in pre-chamber we acquire more stable jets from the dynamic emitter (compare graphs a-b and c-d).

## Condensation of gases in spiral-twisted jets to liquid and solid

During our experiments with the pendulum we discovered that after interaction of the jet with the steel plate there was a noticeable amount of fluid on it. We decided to conduct an accurate study of this phenomenon. In the next step of research (Experiment 3) we used filtered air, argon and nitrogen. For the reasons of clarity the dynamic emitter was set in a chamber filled with the same gas which was used in a current test. After jet interaction with the quadratic quartz plate  $100 \times 100$  mm of thickness 5 mm located at a distance of 30-40 mm from the nozzle outlet perpendicularly to the direction of the jet for the case of vertically-fixed dynamic emitter (as in the Experiment 1) we obtained condensed matter which we studied with a microscope. The results are provided at Figures 7-10.

It is noticeable that the temperature of the jet was 285 K, temperature of the chamber was 293 K, the humidity in the chamber was 5-7%. Condensation of gases to liquid and even solid state in such thermodynamic conditions is very unusual.

## The concept of electromagnetic super-compressibility and its experimental confirmation

To explain phenomena arising in supersonic jets flowing from the nozzle with a central cone which we studied in our experiments we conducted a theoretical research. We have created the necessary theoretical background for this in several of our previously published papers. These phenomena can be explained with introducing the concept of electromagnetic super-compressibility.

High energy density in the nodes of the jet is a result of decreasing of internal energy during adiabatic expansion of the gas. This leads to high electron density in the nodes which causes powerful electromagnetic fields appear in the jet and its radiation. In such conditions there arises the electromagnetic super-compressibility: very strong self-compression-a sharp decrease in the volume of the gas in self-inducted electromagnetic field without impact of any external compressing forces. The super-compressibility is found in the nodes of the spiral-twisted jet flowing from the dynamic emitter and explains the phenomena which were observed in our experiments [6,12,14].

Taking into account the results of experiments 1-3 and our theoretical estimations we decided to use water vapor in the dynamic emitter to increase the energy density and therefore to



**Figure 5:** Pendulum experiment. Here L is the distance from the nozzle outlet to the equilibrium position of pendulum and d is its deviation from equilibrium position.



d) Pre-chamber pressure is 0.8 MPa.

**Figure 6:** The deviation d versus distance L for different gas pressures in prechamber for dynamic emitter with central cone and for common conic nozzle. a) Pre-chamber pressure is 0.2 MPa. b) Pre-chamber pressure is 0.4 MPa. c) Pre-chamber pressure is 0.6 MPa. d) Pre-chamber pressure is 0.8 MPa.

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study the phenomena of super-compressibility in better conditions. In Experiment 4 water vapor jet was emitted into the atmosphere from the nozzle with a central cone. The pressure of water vapor in the pre-chamber was (0.2-1.2) MPa, the temperature of vapor was



Figure 7: The result of the argon jet interaction with the plate. Condensate is obtained. Exposure is 30-40 sec. Zoom is 400x.



Figure 8: The result of nitrogen jet interaction with the plate. Condensate is obtained. Exposure is 30-40 sec. Zoom is 100x.



Figure 9: The result of air jet interaction with the plate. Condensate is obtained. Exposure is 30-40 sec. Zoom is 100x.



Figure 10: Air solid condensation. Fragments of Figure 8 Solid matter is obtained. Exposure is 30-40 sec. Zoom is 1000x.

393°K and decreased to 333°K at the output of the dynamic emitter, the environment temperature was 293°K. Beginning from pressure of 0.4 MPa, we detected the emergence of electromagnetic field from 1.4 MHz up to 1 GHz in spiral-twisted supersonic jets [5]. The field arose both in and around the jet. In case of supplying water vapor supersonic jets start glowing in violet and in other short electromagnetic waves regions. We observed glowing in violet region with the naked eye in darkness.

As is clearly seen from Experiment 4 water vapor in the jet creates plasma with increased density of electrons that provides concentration of energy in small volumes (particularly in the nodes of the jet) and high energy radiation. This result confirms our theoretical estimations and explanations of the experimentally observed phenomena on which we have been working in a number of our previously published papers.

### Conclusions

- The existence of electromagnetic super-compressibility phenomenon in submerged supersonic jets flowing from the dynamic emitter is confirmed.
- Due to super-compressibility structured jets which maintain stable configuration and retain their energy at long distances from the nozzle outlet can be obtained.
- Super-compressibility causes the condensation of gases in liquid and solid state.
- Electromagnetic super-compressibility is accompanied by significant energy release.

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