# Features of the powder spheroidization process and structure formation of the plasma-arc sputtering of powder wires with nanoscale refractory additives

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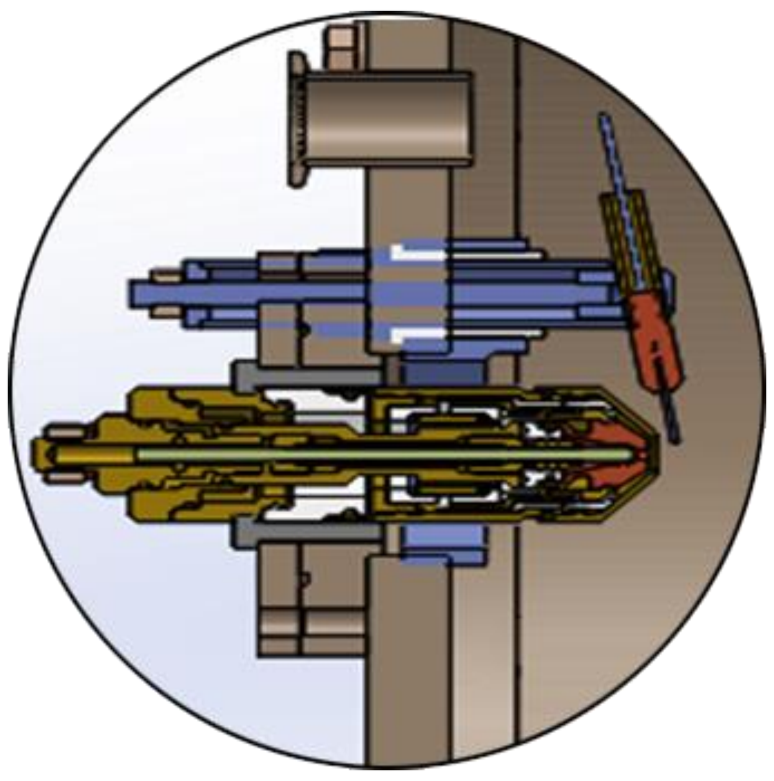
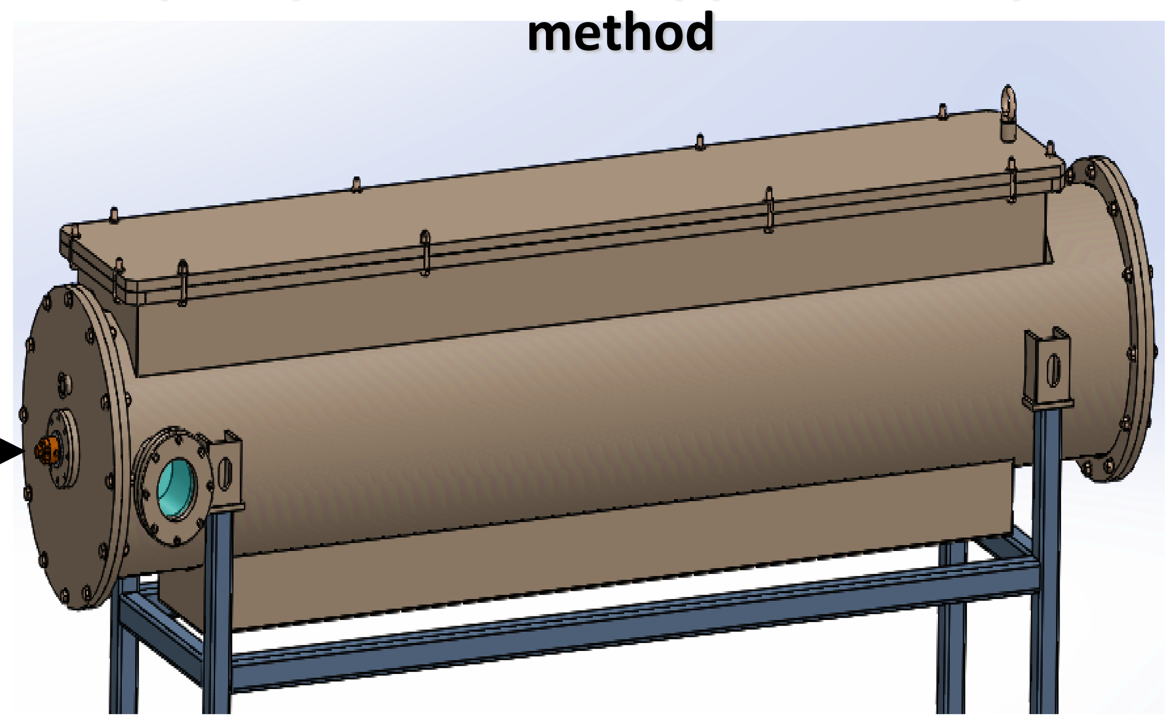
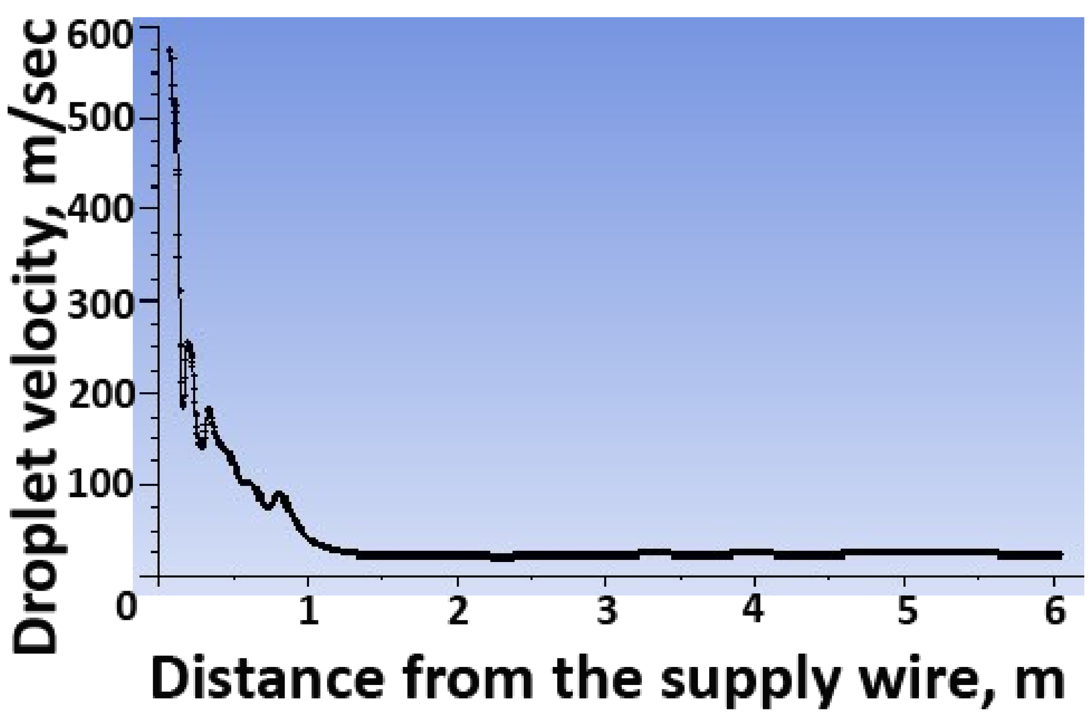
With the development of 3D printing technologies and layer-by-layer formation of bulk products, the most particularly important area is the production of metal spherical particles with a non-porous and composite structure. It is perspective for obtaining of such materials to use plasma-arc spraying of flux-cored wire process using argon arc with additional intense accompanying air flow. In the plasma-arc spraying process of a wire material the melting and formation of fine particles occurs either by energy released in the anode spot of the arc, closed on the wire, and due to the energy introduced into the wire by the transverse flow of arc plasma. As a result, the efficiency of the wire melting process increases in comparing, for instance, to the traditional method of electric arc metallization.

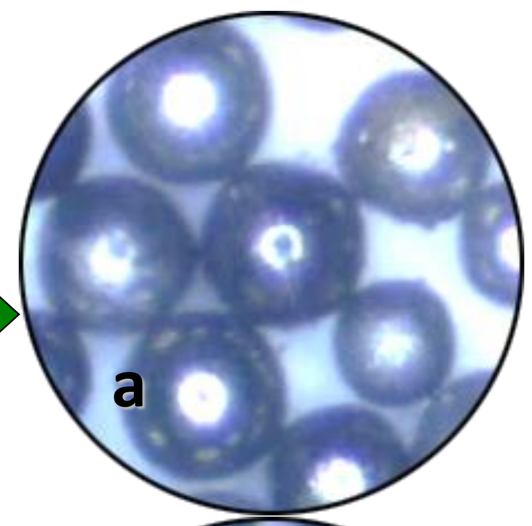
**Wire supply and spraying unit (plasmatron)**



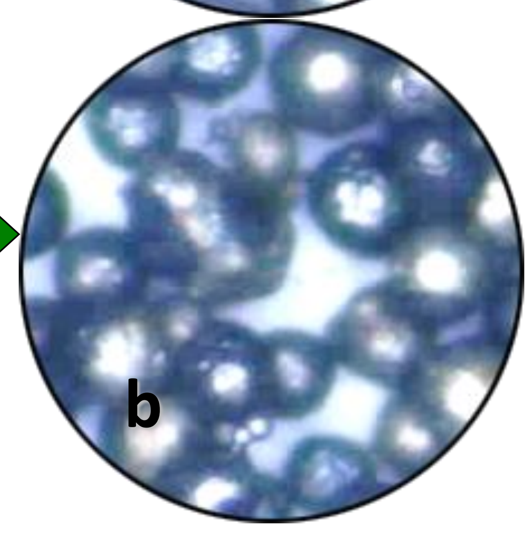
**Main view of the experimental unit used to study of droplet spherodization by plasma-arc sputtering method**






**a - powder obtained from Fe - WC flux-cored wire (WC powder filler without nanoadditives**




**b - powder obtained from Fe - WC flux-cored wire with nanoadditive (powder filler: WC + 0.5 wt.% nanopowder $ZrO_2$)**

Experimental studies were done at the original equipment of plasma arc spraying of wire feeders and showed that increasing of cathode current without a proportional increase in the wire feed rate increases the share of a large fraction of powder due to the wire melting mainly in the peripheral part of the plasma flow, where the dynamic gas pressure of the jet lower then on the axis.

The crushing of molten particles in the plasma flow is facilitated by the increase of pressure and rate of the associated gas flow up to the point of turbulence emergence in the plasma flow, farther increase of additional gas flow rate disrupts stability of the entire spraying process. Increasing of the cathode-anode distance and the flow rate of the plasma-forming gas contributes to a slight increase in the voltage of the plasma arc, which increases the effective thermal power of the plasma jet and formation of more fine powder fractions.

The regularities of the granulometric composition formation of spherical powders obtained by plasma-arc sputtering of flux-cored wires, a tubular steel shell type with fillers based on carbides WC, $Cr_3C_2$, $B_4C$ with nanoadditives NbC and $ZrO_2$, with particle size up to 120 nm, in amount 5 wt.% were discovered. Particles size distribution of powder wire spraying products with WC filler were studied. It is stated that addition of nanoscale powders of NbC and $ZrO_2$ promotes the average size reduction of the sprayed particles in 2.1 ... 2.5 times. At the same time, the number of the fine fractions ($0,14^{+0.1}$; $0,1^{+0,045}$; $0,045^{+0}$ μm) increases significantly.

## Conclusions

It was discovered that the addition of NbC nanopowder in process of plasma-arc spraying of coatings from flux-cored wires with WC fillers, inhibits the decarbidization process of tungsten carbides, and leads to an increase of hardness up to 700 MPa. Addition of 0,5 wt. % of $ZrO_2$ nanopowder to flux-cored wires with fillers: $B_4C$, $B_4C$ + $(Cr, Fe)_7C_3$, $B_4C$ + $(Cr, Fe)\ _7C_3$ + Al promotes refinement of the structure and to formation of dispersed borides participates $Fe_2B$, $Fe_3B$.

The performance and stability of the process are largely determined by the conditions of heat exchange between the anode wire and the heat sources acting on it. The introduction of nanoscale additives into the powder filler is a promising method of influence at the properties of the resulting powders. To date, it has been established that materials with nanoscale components can be used in tribology, electrochemistry, electronics, semiconductors, superconductors, photonics, detectors, biomaterials, biosensors, medicine, and other areas.