Manufacture of experimental control rods by explosive powdercompaction

Andras Szalay[1], Istvan Zador dr[1], Jozsef Janik[2]

[1] S-Metalltech 98 Materials R&D Ltd, Budapest

[2]Hungarian Academy of Sciences Centre for Energy Research, Budapest

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- Basics and defining terms regarding the controlling rods
- Dynamic compactions
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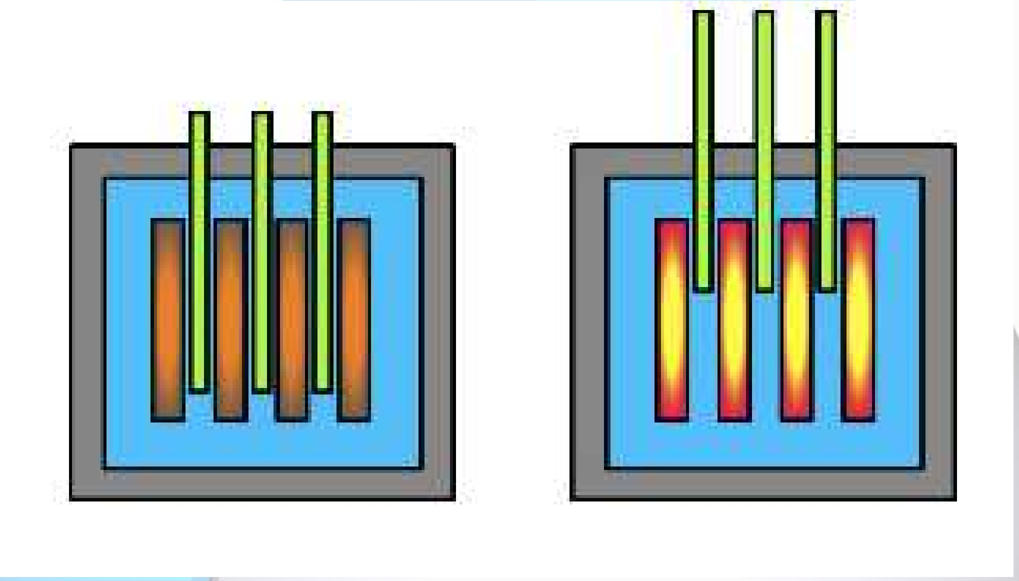
- Conclusions

Basics and defining terms

Control rods serve for maintaining the desired state of fission reactions within a nuclear reactor. They constitute a real-time control of the fission process, which is crucial for both keeping the fission chain reaction active and preventing it from accelerating beyond control.

Basics and defining terms

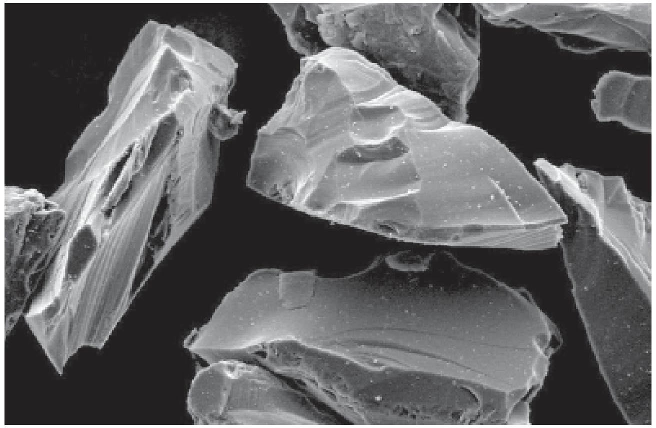


The control rods made of a material that absorbs neutrons are inserted into the uranium bundle using a mechanism that can raise or lower them.

Basics and defining terms

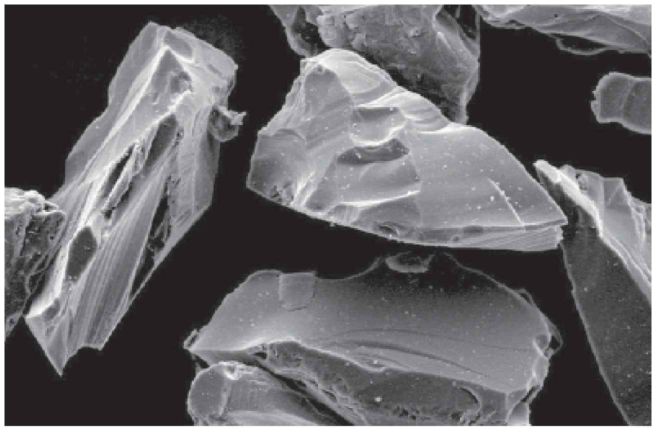
As the functionality of a control rod depends on its ability to absorb neutrons from the fission chain reaction, the choice of highly neutron-absorbing material is crucial.

Boron is one of the best neutron absorbers. However, Boron's mechanical properties are less than desirable for building a control rod structure, as it is a brittle material.



Basics and defining terms

One of the methods to overcome this problem is filling mechanically suitable metallic tubes with B-10 or Boron Carbide (B_4C) powder



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Dynamic compaction

The manufacture of the metal sheathed controlling rods needs also a special technique. For the sake of preparing metal sheathed controlling rod of rigid boron carbide granulates we applied **dynamic compaction techniques**, where the compaction of the powders or granulates are carried out at a velocity higher than 10^2 m/s.

Dynamic compaction

Application of the dynamic compaction represents a new paradigm in the field of production of knowledge-based more components materials: the processing of the materials is carried out directly, by high speed, high energy shock waves, without using energy transforming equipment as hydraulic presses etc.

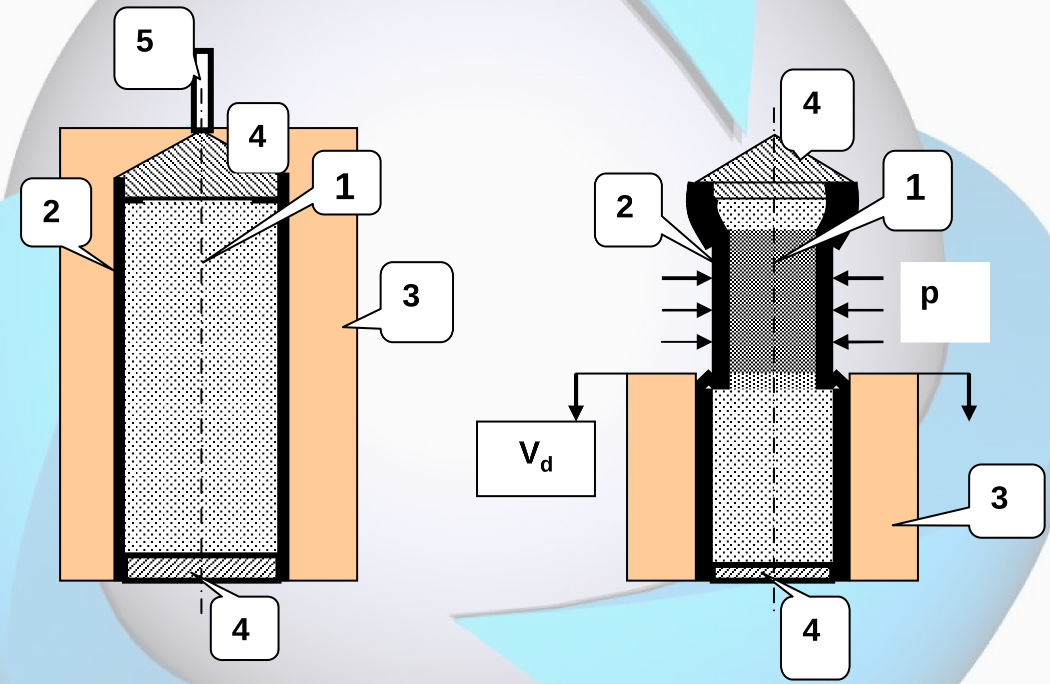
The energy sources of the dynamic compactions are either the electrical energy stored in capacitors –these techniques are the electrodynamic compactions – or chemical energy stored in the high explosives – these techniques are the explosive compactions.

Dynamic compactions

The high compaction pressures and velocities offer the possibility of preparation of bulk metal, ceramic and composite parts with high density.

Explosive compaction: theoretical schema

After ignition of the detonator, the detonation proceeds along the metal tube wall at the velocity V_D, rapidly accelerates the container tube to a velocity depending the load, leading to a reducton of the tube diameter and compression of the powder



Before ignition **After ignition**

1 – powder 2 – metal tube (powdercontainer) 3 – high explosive 4 – end plug 5 - detonator

Explosive compaction

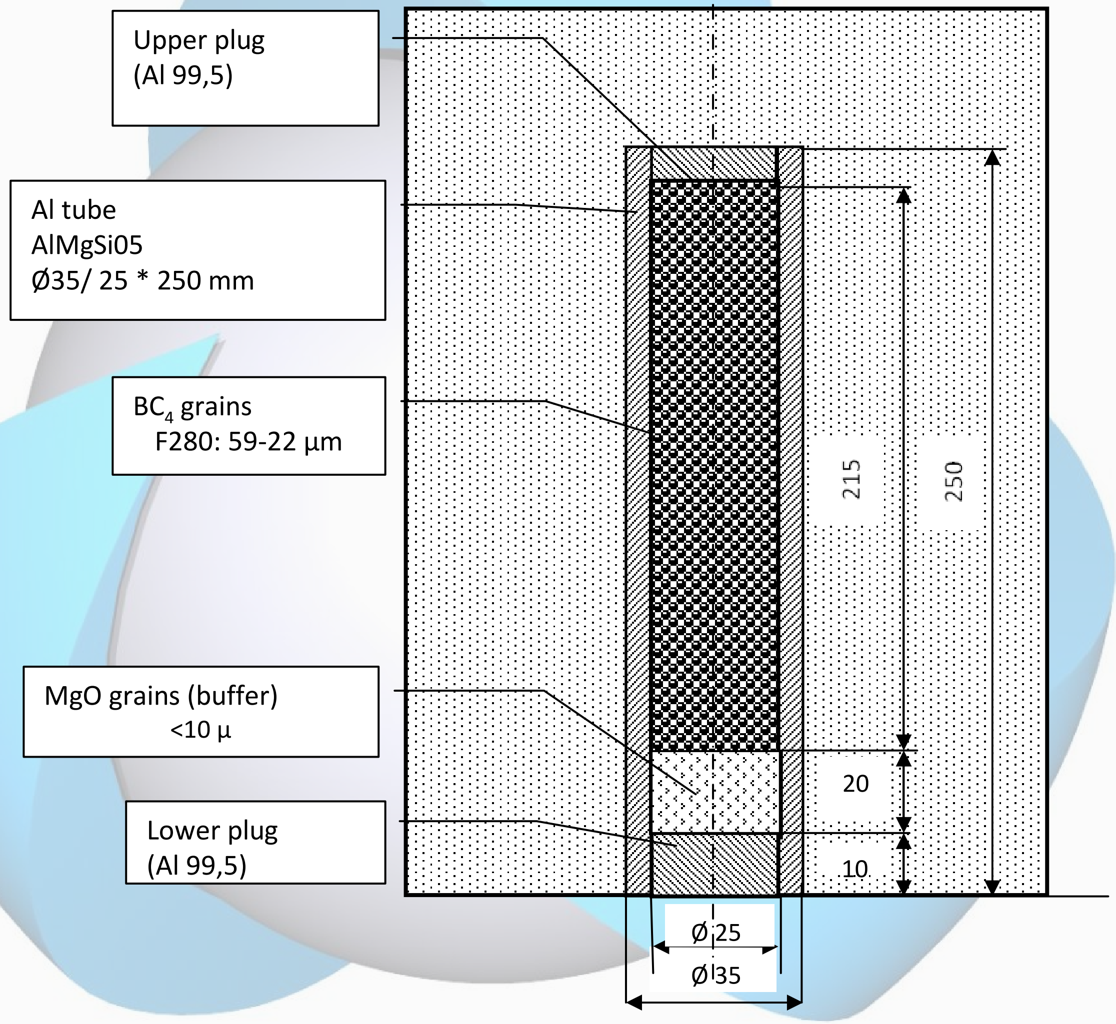
The main technological parameters of the explosive powdercompaction are **the mass ratio**: the ratio of the mass of the high explosive to the mass of the powder to be compacted, furthermore **the detonation velocity**, V_D.

Numerical simulation is a useful tool to study their effect and to predict the shape and density distribution inside the final ceramic components.
Explicit Finite Element models of the PIT compaction process are developed using LS-DYNA.

Test compaction using powderform high explosives

V_D = 2800 m/s

- Design -



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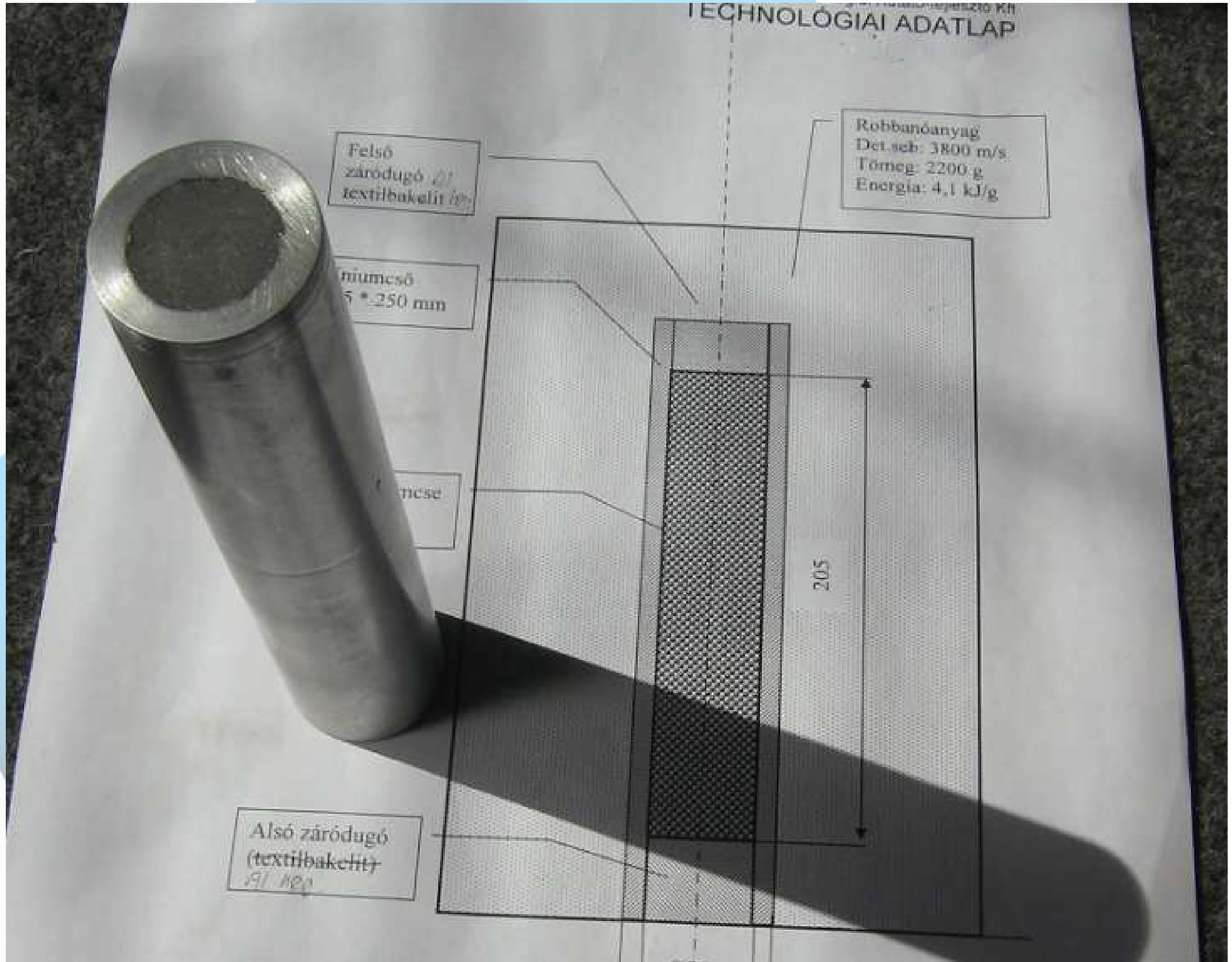
Realization of the design

The result



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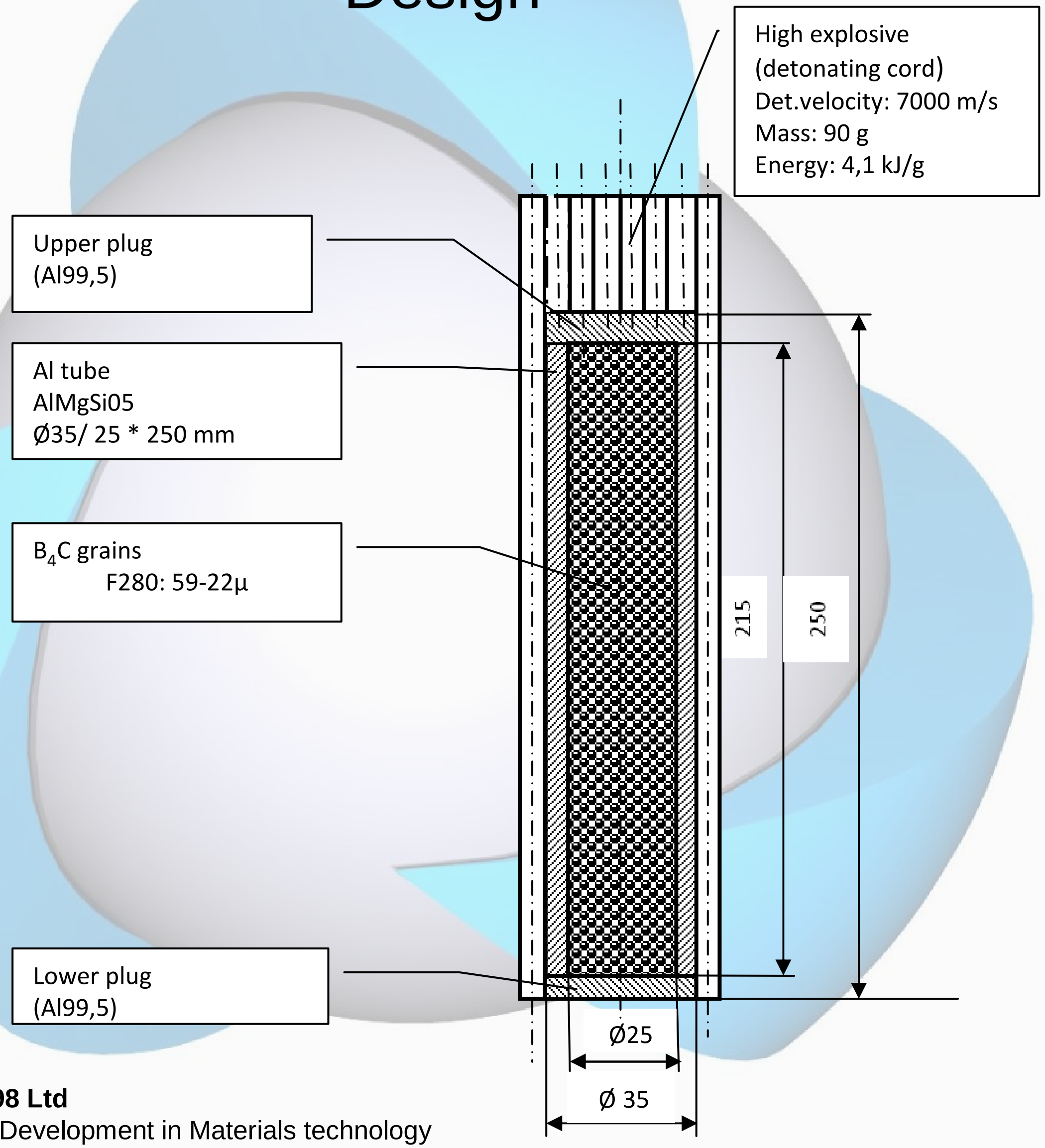
Test compaction using detonating cord
V_D = 7000 m/s
- Design -



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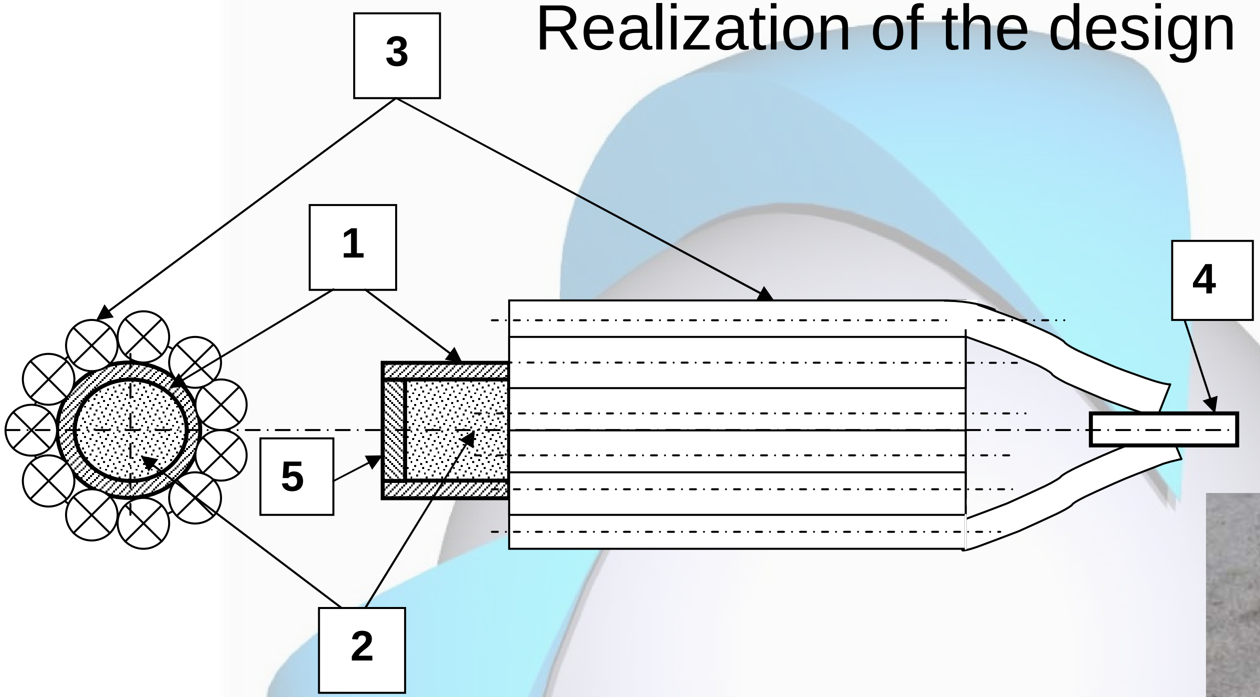
Realization of the design



1-aluminum tube 2-B_4C powder 3-high explosive

4-ignitor 5-end plug

The result

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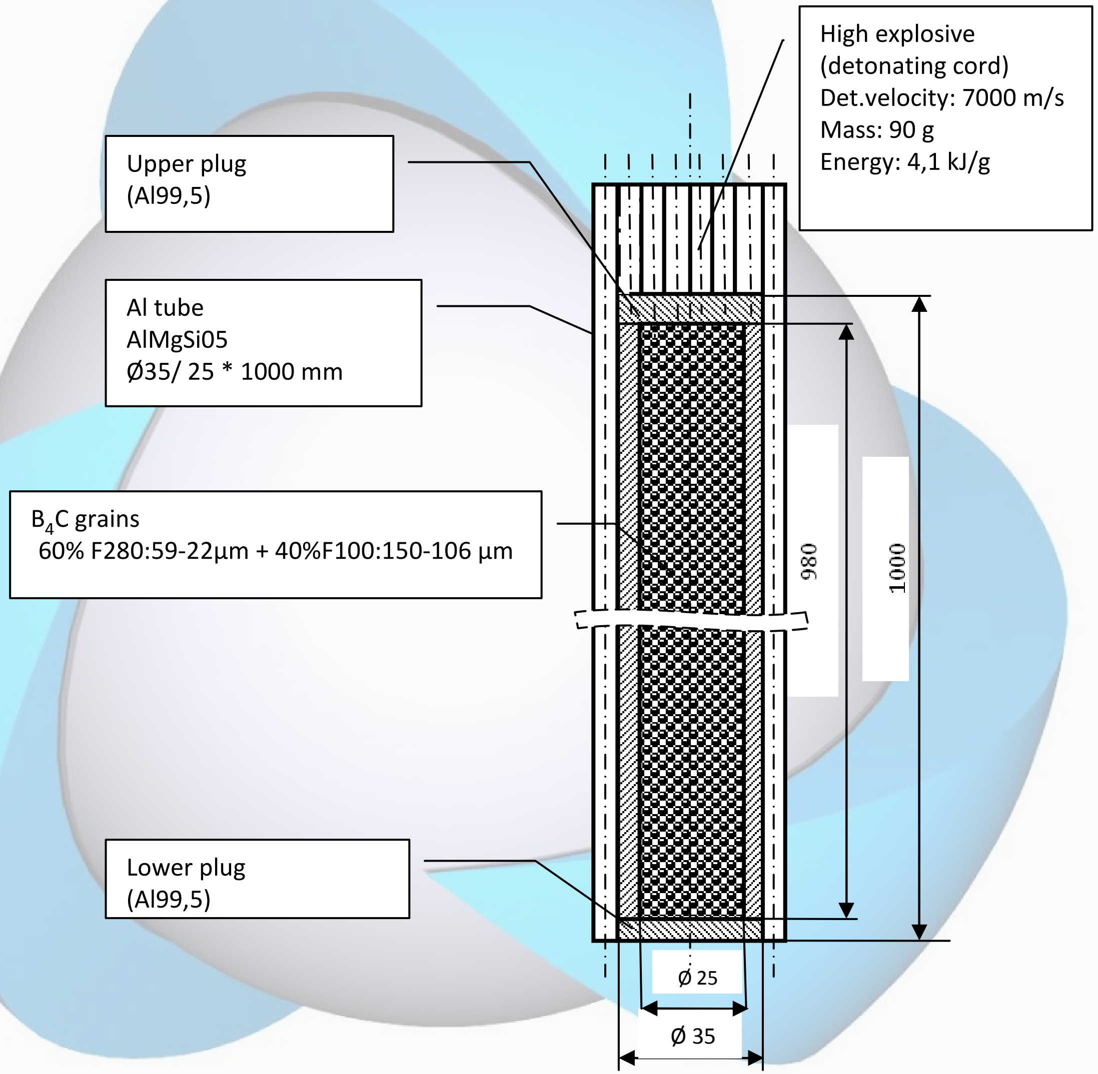
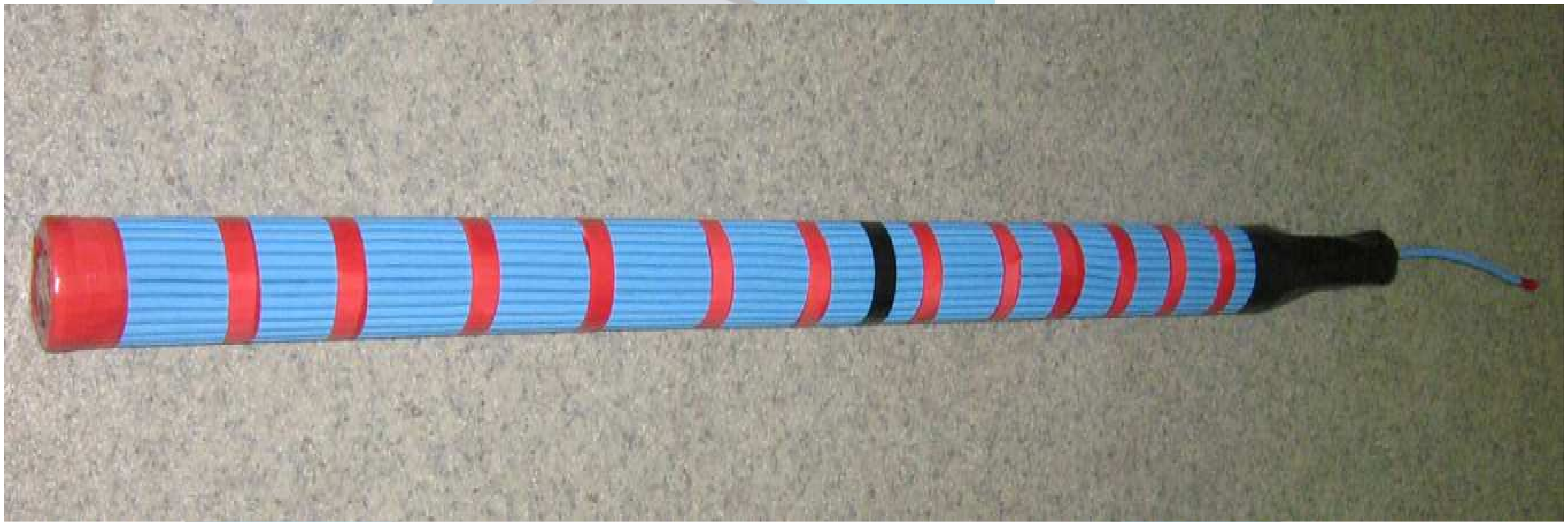
Manufacture of test piece

Design of the full lenght controlling rod



Manufacture of test piece

Realization of the design



Manufacture of test piece

The result

Al tube outer diameter 31,2-32,0 mm

B_4C diameter: 20,3 mm

B_4C density: 1,75 g/ cm^3

~ 69% of the theoretical density

Manufacture of test piece

The processed final product

The first test results

X-Ray analysis of the experimental controlling rod

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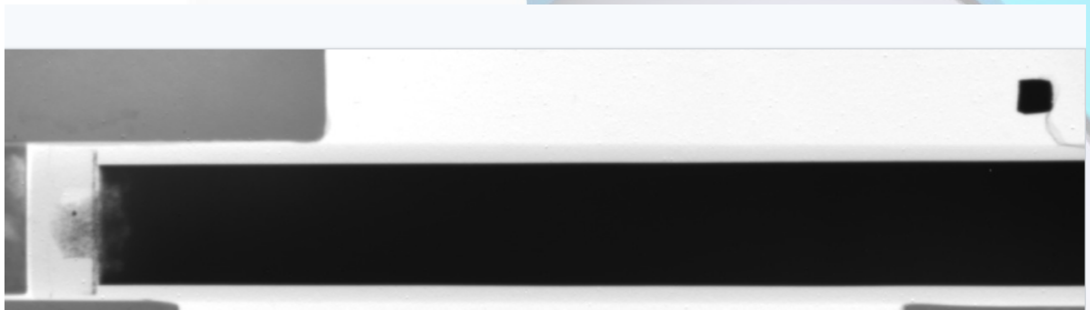
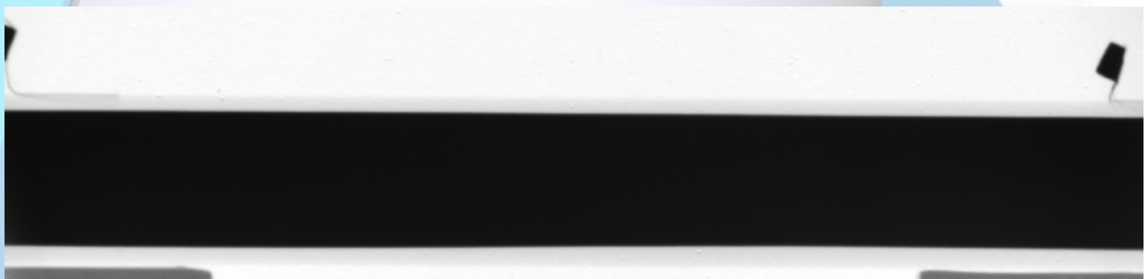
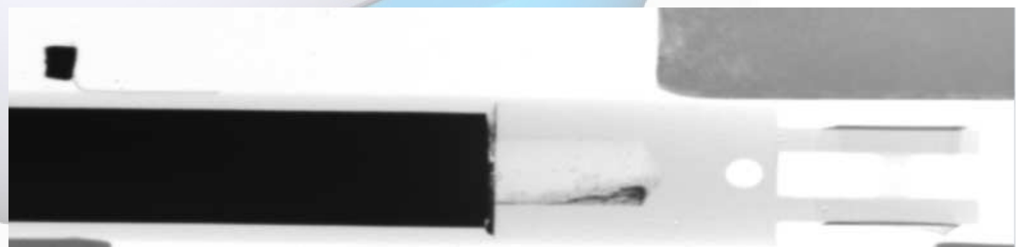
The first test results

Neutron analysis of the controlling rod







Conclusions

- By applying the properly calculated and directed shock waves on powders and granulates special tasks can be realised as manufacture of aluminum sheathed boron carbide rods for fabrication of control rods for nuclear reactors

- The applied compaction energy should be recalculated and matched to the task, because the diameter of the boron carbide compact is smaller than the optimal geometry, furthermore the thickness of the aluminum tube is inhomogenous

-The explosive powdercompaction technologies can be carried out in industrial environment, using explosive chambers

Explosive chamber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Thank you for the attention!

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