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COMPACT LOOP WITH ELECTROMAGNETIC PUMP WITH ROTATING PERMANENT MAGNETS FOR MATERIAL COOLING WITH MERCURY

MAZGABARĪTA KONTŪRS AR ELEKTROMAGNĒTISKU INDUKCIJAS SŪKNI AR ROTĒJOŠIEM PASTĀVĪGAJIEM MAGNĒTIEM MATERĀLU DZESĒŠANAI AR DZĪVSUDRABU

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Abstract: During material testing under radiation conditions they are bombarded with neutrons. A lot of heat is generated. It is necessary to cool the tested material. The most effective coolant is liquid metal flow because metals have both good heat conductivity and capacity. Loop for tested material cooling with liquid mercury was developed. To provide metal circulation in the loop electromagnetic pump with rotating permanent magnets was chosen. Pump has a simple construction and is safe in use.

In this case mercury as a cooling media was chosen because of its physical properties such as lowest melting temperature and simple construction of experimental loop. Other heavy metals have higher melting temperatures. In the case of mercury is not necessary to heat the metal to melting point and higher and no need to heat the loop for filling it with metal (temperature of the loop must be higher than the melting temperature of the metal under filling).

To create satisfactory mercury flow the electromagnetic pump with rotating permanent magnets was chosen. Both the pump and the loop were developed and manufactured in Institute of Physics of University of Latvia (IPUL) for Oakridge National Laboratory (USA) to do tests of material samples bombardment with neutrons. This is another prosperous example of the collaboration of different research teams.

The main pump parameters were chosen to reach necessary pressure and flow rate. After the analysis of restrictive parameters the choice of the construction of the mercury loop was done. Then the design and the production of the loop were performed. The technological task was following: to create the loop filled with mercury matching below listed parameters. Velocity of the flow in test section – 0.35 m/s, pressure below 1.4 bar. Active part of the loop should be 600 to 600 mm made from rectangular shape tube of following dimensions: 50 x 25 x 1.5. Total weight of the loop should be less than 450 kg. Dimensions of the loop – 1400 x 1100 x 780 mm. Loop must be enclosed in secondary container, which in the case of accident wouldn't let the mercury to split out. There should be windows in secondary container opposite the test section. All the system must be mobile with quickly connectable communications.

Principal scheme of the loop was developed. It can be seen on the figure 1. Briefly the operating principles of the loop are following. The mercury is filled in the loop 2 from the tank 22. Filling is performed by using pressure from the He vessel 20. Electromagnetic induction pump with rotating permanent magnets make the mercury to circulate in the loop. The test section with the tested material is bombarded with neutrons. Test section is being cooled by liquid mercury, flowing in the loop. Bubbler injects the little gas bubbles into the mercury to prevent hydraulic shock to the walls of the loop. Due to the neutron bombardment the temperature of the mercury locally sharply increases and the mercury sharply expands. Gas bubbles work as a shock absorbers due to the compressibility of the gas.

Electromagnetic induction pump with rotating permanent magnets was chosen because it has several advantages comparing with other kinds of pumps. The main advantage comparing with mechanical pumps is the fact that there is absolutely hermetic pumps channel [4]. So there are no gaskets and a leakage possibility is much lower. Construction of the pump is simpler. And it is possible to replace the pump with another without touching the pump's channel. Electromagnetic induction pump with rotating permanent magnets has more simple construction than electromagnetic induction and conduction pumps and they have higher efficiency coefficient [3]. That's because there is no need to waste energy to create magnetic field as it is in 3 – phase induction pumps. And there are no problems with wetting and corrosion of electrodes in case of conduction pumps [1].

There are no windings at all in these pumps so they are simpler and cheaper. While the pump is operating it can provide self - cooling as the rotation of the rotor causes the turbulent air flows around the pump [2].

Cross section of the active part of the channel is 10 to 82 mm. The active pert of the channel is 180°. NiFeB permanent magnets with inner induction 1.25 T and dimensions 15 x 20 x 50 were used. Schematic view of the pump is given in the figure 2.

On the outer side of the channel the laminated ferrous passive yoke is placed. Magnetic flux completes through this yoke. It increases the efficiency of the pump. Pump is driven by 3 – phase asynchronous motor of power 0.25 kW. Revolutions of the pump and wherewith pressure – flow rate are handled by frequency converter.

Cylindrical pump with 6 permanent magnets was chosen. Outer diameter of the rotor is 74 mm.

Rectangular tube with dimensions 50 x 25 x 1.5 made from stainless steel 316L was required because of its corrosion resistance against mercury and its mechanical and technological features. Also other tubes for pressure, vacuum and mercury filling tubes in the loop are made from the same material. They are connected with Swagelok connectors and supplied with same producer's valves.

Every tube in the loop is at least in 3° angle against horizontal to ensure that all the mercury can be drained out of the loop.

Mercury tank is also made from stainless steel 316L. Its volume is 8 liters. There is 5 liters of mercury in the tank.

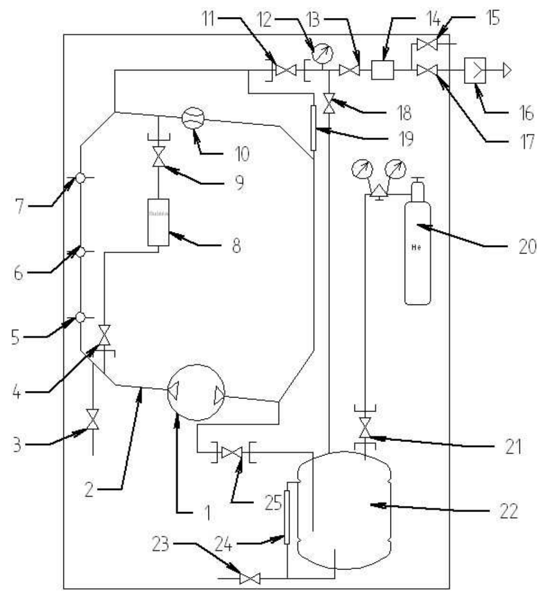

Fig. 1. Principal scheme of the test loop: 1 – Electromagnetic induction pump with rotating permanent magnets; 2 – active part of the loop; 3, 4, 9, 11, 13, 15, 17, 18, 21, 23, 25 – valves; 5, 7 – hydrophones; 6 – material test section; 8 – bubbler; 10 – electromagnetic flow meter; 12 – pressure – vacuum gauge; 14 - Hg filter; 16 – vacuum pump; 19 – level meter; 20 – He vessel; 22 – Hg tank; 24 – level indicator

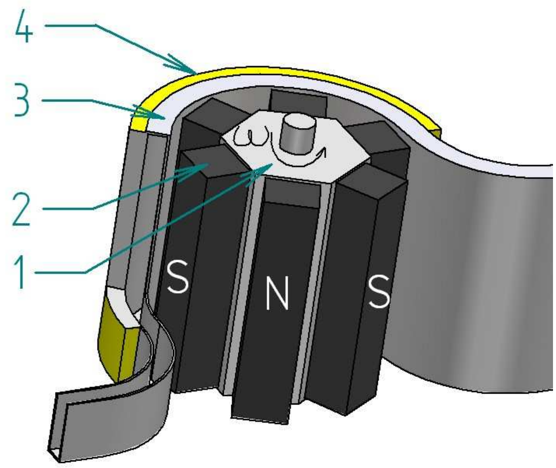

Fig. 2. Principal scheme of the cylindrical induction pump with rotating permanent magnets: 1 – rotor; 2 – permanent magnets; 3 – pump channel; 4 – laminated ferrous passive yoke

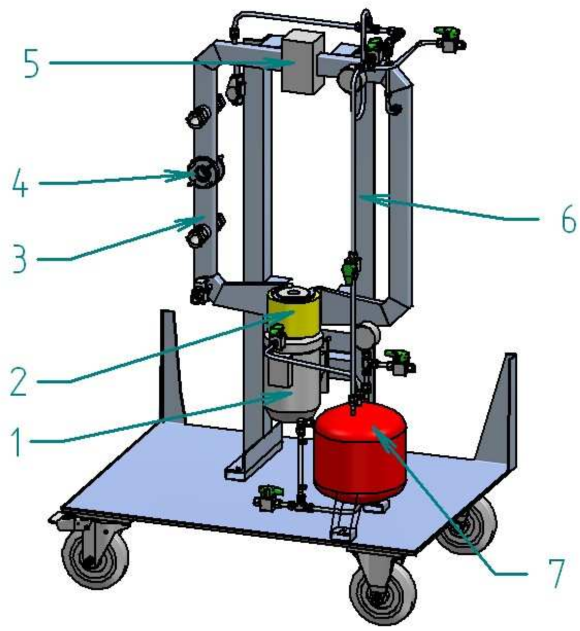

Fig. 3. Experimental loop for material testing under radiation conditions without the upper part of the second container and with cutouts (for a better view) in the lower part of the secondary container;: 1 – three – phase asynchronous electric motor; 2 – electromagnetic induction pump with rotating permanent magnets; 3- loop; 4 – test section; 5 – electromagnetic flow meter; 6 – frame of the stand; 7 – mercury tank

Loop grounds on the frame made from the L – shape profiles. Material is the same – stainless steel 316L. Loop is elastically fixed on the frame to avoid stresses during thermal expanding of the loop. Frame and tank grounds on the lower part of secondary container and can be easily dismantled. It is done because of the remaining radioactivity of the loop after the tests. All the system is dismantled and put into nuclear waste depositary. Secondary container consists of three parts. Lower part is made from stainless steel 316L plate and welded. On its bottom the wheels are mounted. Two upper parts are made from Plexiglas and L – shape profiles from stainless steel 316L. There are two sliding doors on the sides of the middle part of secondary container and one in the back side. Side doors are made for neutron bombardment and back doors are for engineering communications.

Secondary container is made in way to ensure that no mercury can be spitted out in environment in the case of accident.

Two upper parts of the secondary container can be dismounted for the service needs. Secondary container has wheels to relocate it. Loop without two upper parts and with cutouts (for a better view) can be seen on figure three but the outer container is showed on figure 4.

This experimental loop for material testing under radiation conditions was successfully tested without neutron bombardment in IPUL. It passed all necessary tests on vacuum and pressure and operating tests in real conditions with mercury but without proton beam. After that it was sent to Oakridge National Laboratory (USA) where tests of the facility were carried out successfully.

This example shows that electromagnetic induction pumps with rotating permanent magnets can work with different working fluids under different conditions and this kind of pumps has lot of application possibilities and development potential.

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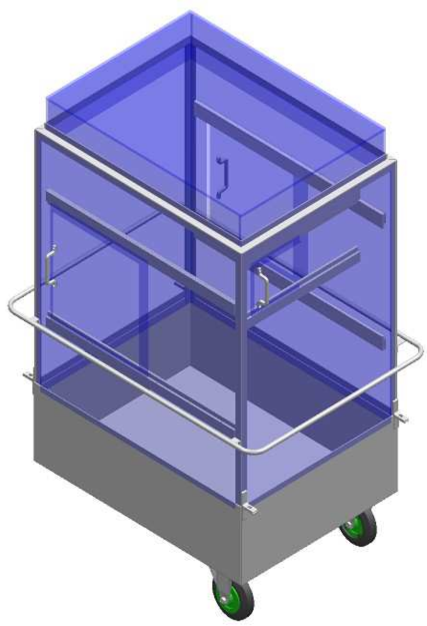

Fig. 4. Secondary container of the loop

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I. Bucenieks, G. Bunga, K. Kravalis. Mazgabarīta kontūrs ar elektromagnētisku indukcijas sūkni ar rotējošiem pastāvīgaliem magnētiem materiālu dzesēšanai ar dzīvsudrabu.
Pārbaudot materiālus radiācijas apstākļos tos bieži mēdz apšaudīt ar neitroniem. Izdalās liels siltuma daudzums. Tādēļ ir nepieciešams dzesēt pārbaudāmo materiālu. Visefektīvākie dzesēsanas šķidrumi ir šķidri metāli, jo metāliem ir laba siltumvadītspēja un siltumietilpība. Tika izstrādāts kontūrs pārbaudāmā materiāla dzesēšanai ar šķidru dzīvsudrabu. Lai nodrošinātu metāla cirkulāciju kontūrā tika izvēlēts elektromagnētisks sūknis ar rotējosiem pastāvīgiem magnētiem. Sūknim ir vienkārša konstrukcija un tas ir drošs lietošanā.

И. Буцениекс, Г. Бунга, К.Кравалис.Малогабаритный kонтур с электромагнитным насом с постояннимы вращающимся магнитами для охлаждения материалов ртутъю.
В тестирования материалов при воздействии излучения в условиях бомбардировки нейтронами образуется большое количество тепла. Исследуемый материал необходимо охлаждать. Наиболее эффективным теплоносителем является жидкий металл, поскольку поток металла обладает и хорошей теплопроводностью и теплоемкостью. Был разработан цикл для испытания обрацов ртутью. Для обеспечения циркуляции металла в петле исползуется электромагнитный насос с вращающимися постоянными магнитами. Насос имеет простую конструкцию и безопасен в использовании.