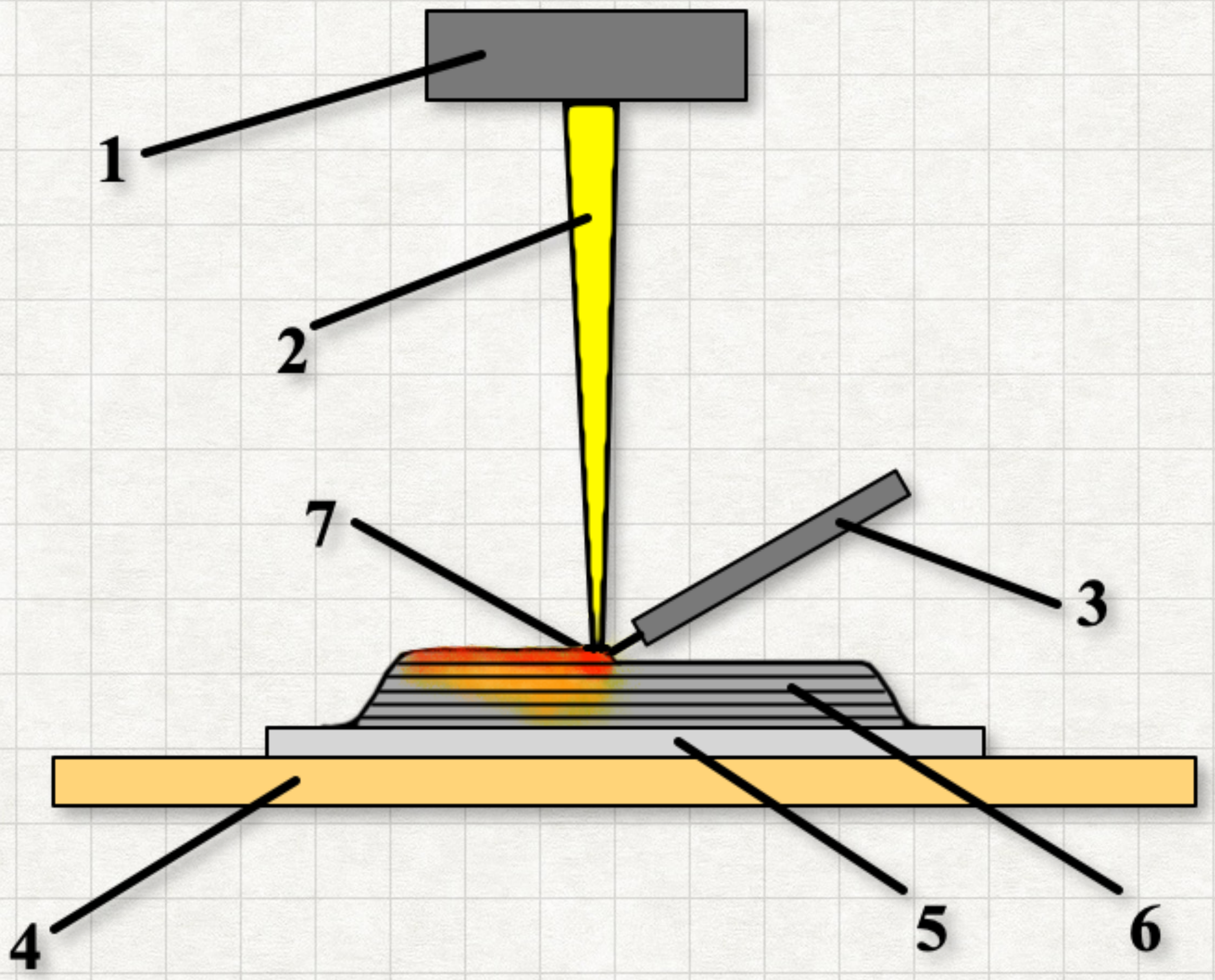
ISPMS SB RAS

THE INFLUENCE OF THE WIRE FEED GEOMETRY ON THE PROCESS OF THE ELECTRON-BEAM FREEFORM FABRICATION OF TI-6AL-4V COMPONENTS

Kalashnikov Kirill

TABLE OF CONTENTS

ELECTRON-BEAM FREEFORM FABRICATION (EBF^3)

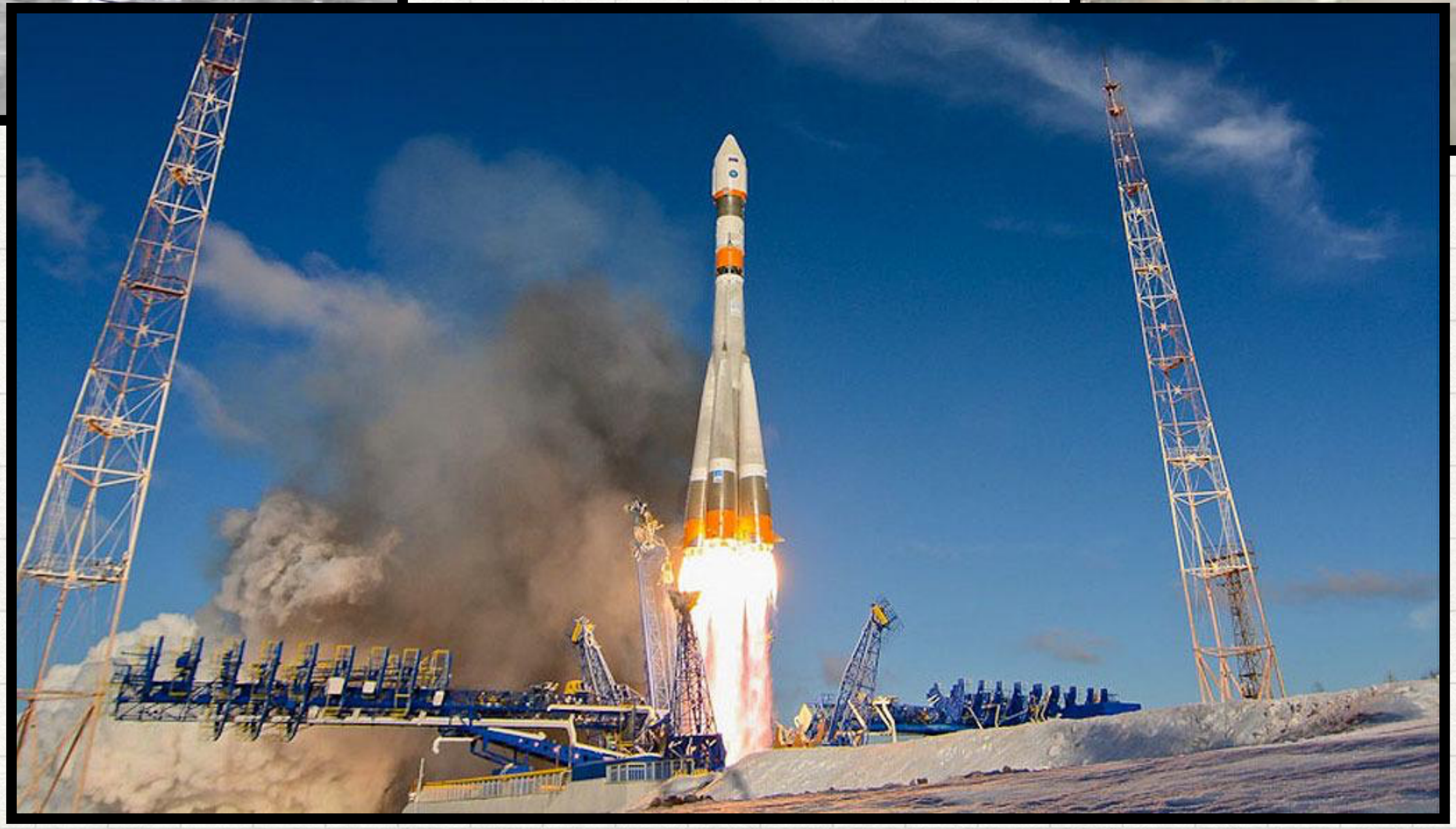


1 – Electron-beam gun, 2 – electron beam, 3 – wire feeder, 4 – cooled table, 5 – substrate, 6 – printed sample, 7 – molten bath

Electron-beam additive manufacturing (EBAM, EBF^3) is a technology based on wire feeding into a molten bath. The process occurs in a vacuum and the molten bath is formed by an electron beam.

Topicality: EBF³ Application

Aircraft



Aerospace

Automotive

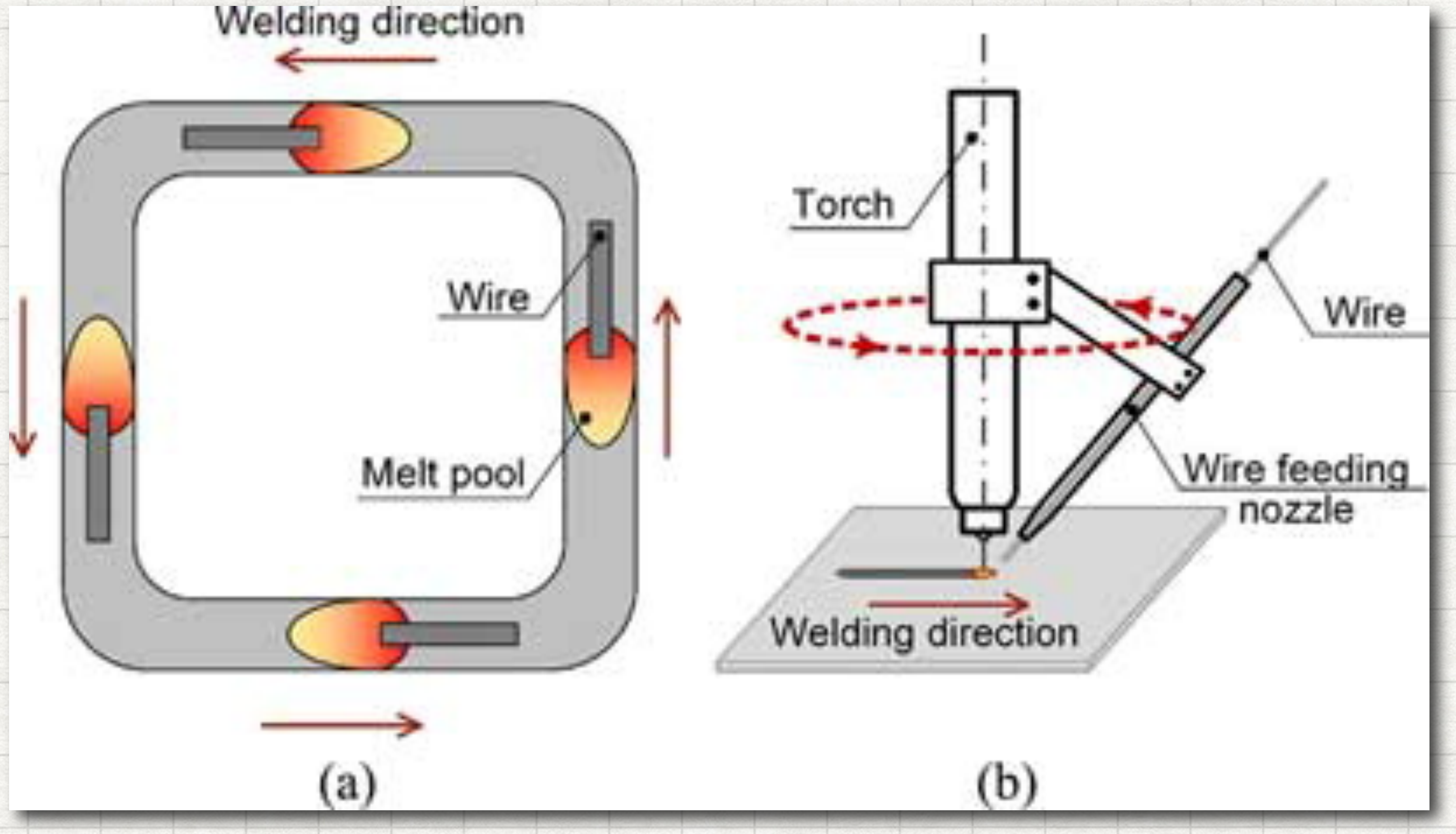
Foreign corporations:

- **Airbus**
- **Boeing**
- **Lockheed Martin**
- **NASA**

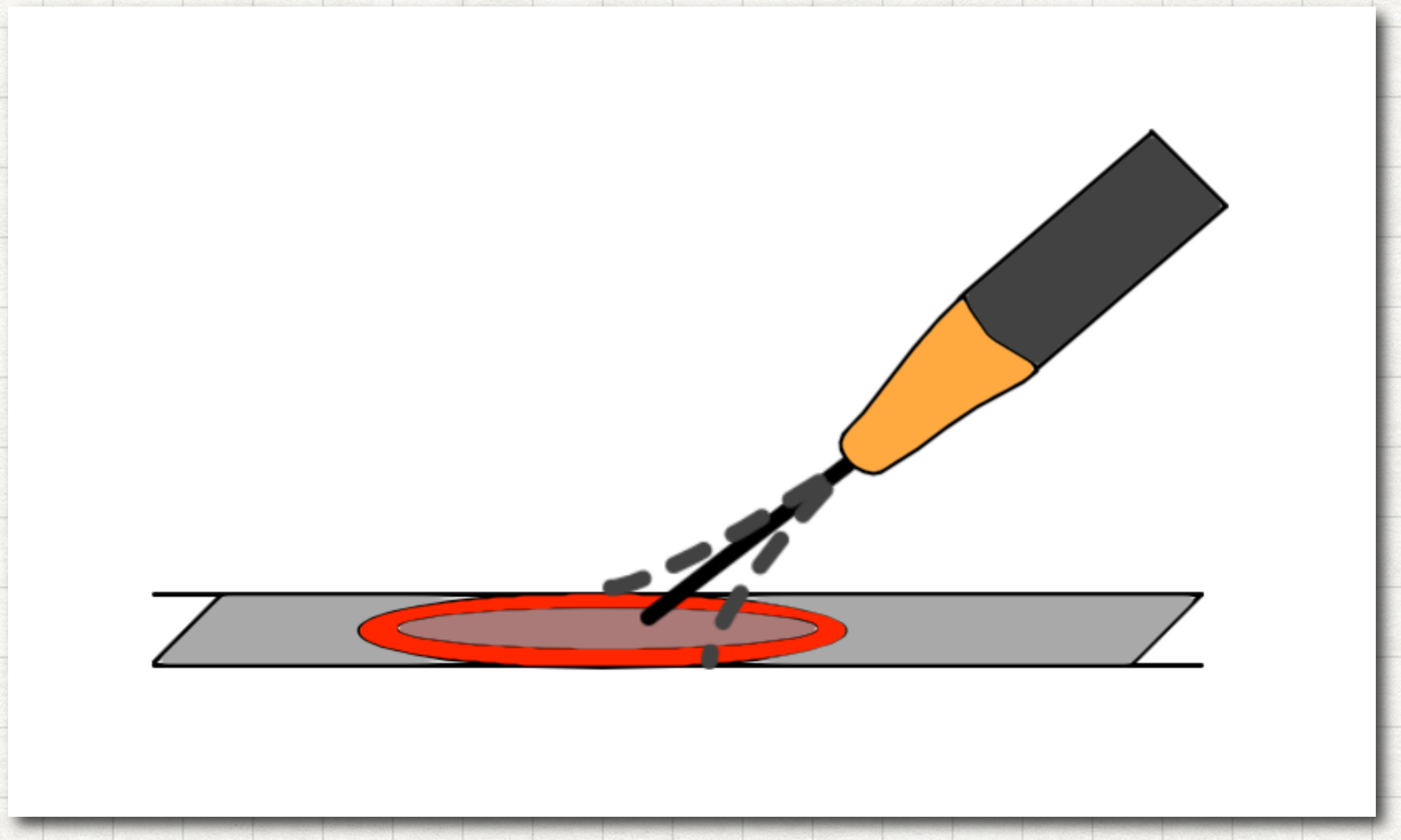
Russian corporations:

- **«SESPEL» Cheboksary Enterprise**
- **S.P. Korolev RSC «Energia»**

Topicality: Factors that influence product formation process at 3D printing



Scanning strategy. Printing geometry*

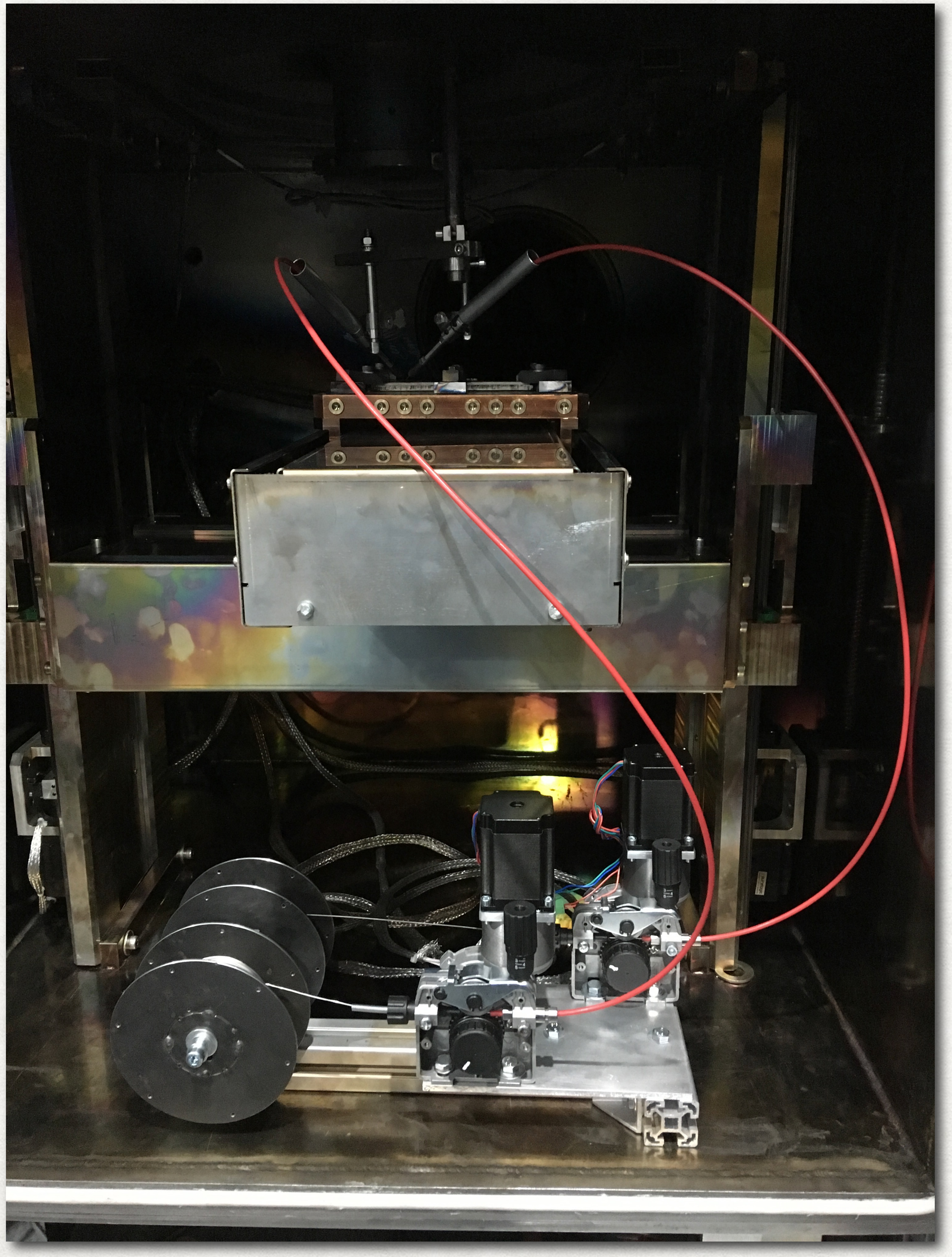


Wire feeding stability

The aim of this work is to study the printing geometry influence on the process of electron-beam additive manufacturing of titanium alloy Ti-6Al-4V

*Wu Q, Lu J, Liu C, Shi X, Ma Q, Tang S, Fan H, Ma S (2017) Obtaining uniform deposition with variable wire feeding direction during wire-feed additive manufacturing. Mater Manuf Process 32:1881–1886. https://doi.org/10.1080/10426914.2017.1364860

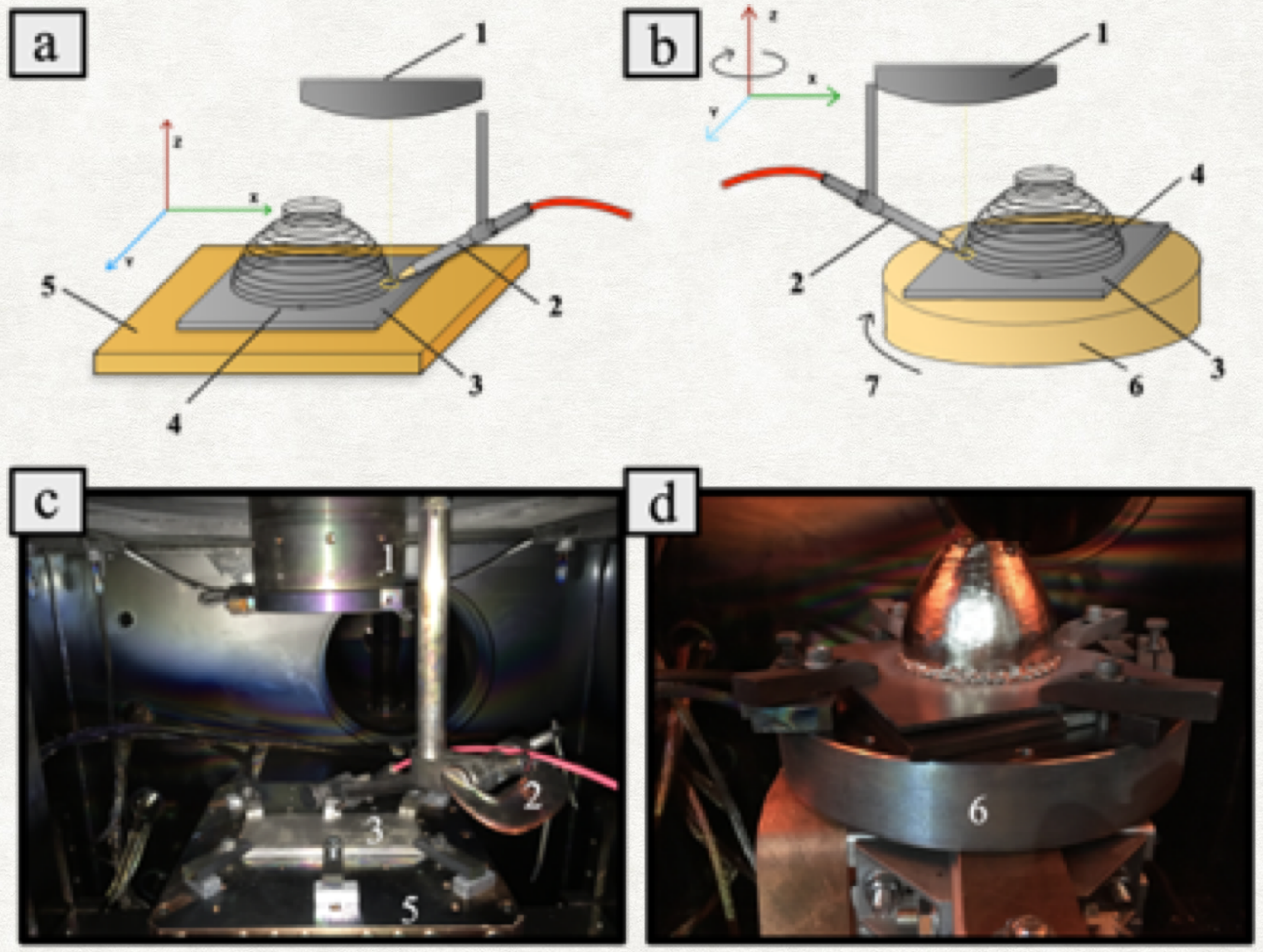
MATERIALS AND METHODS



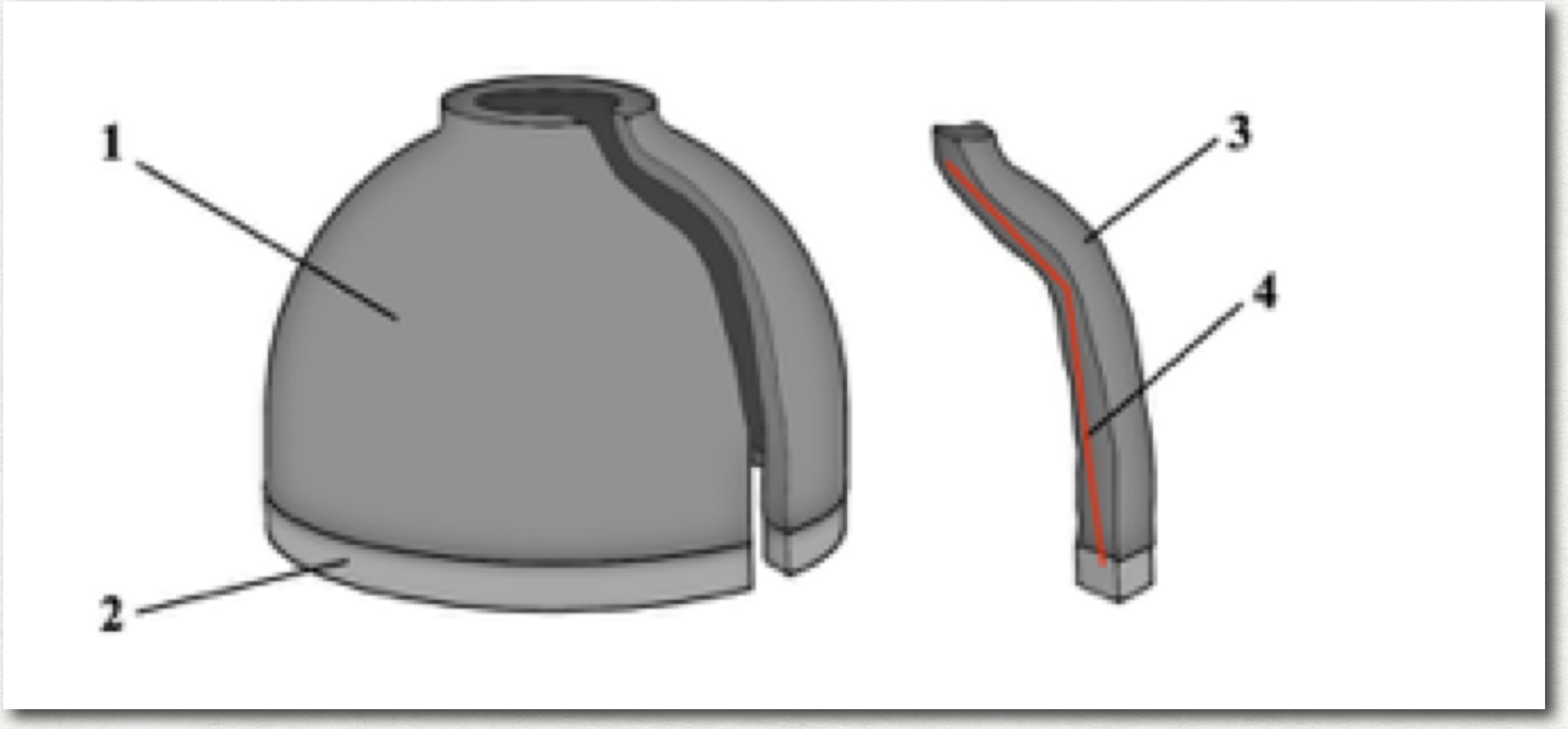
- The samples were printed from titanium alloy Ti-6Al-4V wire with diameter of 1 mm;
- A cooled three-axis table and a four-axis table without cooling were used for printing;
- Specimens for metallographic studies, microhardness measurements, and X-ray structure analysis were cut with the use of an electrical discharge machine;
- Metallographic studies were carried out on the Altami MET 1S optical microscope and the OLYMPUS LEXT OS4100 confocal microscope;
- Microhardness was measured on Duramin 5 microhardness meter;
- X-ray analysis was carried out on Drone 7.

TESTED SAMPLES

ROTATION BODIES



The schemes of obtaining the samples and photos of vacuum chamber with a standard 3-axis water-cooled table (a, c) and rotating uncooled table (b, d). 1 – Electron beam gun, 2 – Wire feeder, 3 – Substrate, 4 – Spiral trajectory of the sample formation, 5 – Three-axis water-cooled table, 6 – Uncooled rotating table, 7 – Direction of rotation.



The scheme of cutting the templates and measuring microhardness.

1 – Sample,

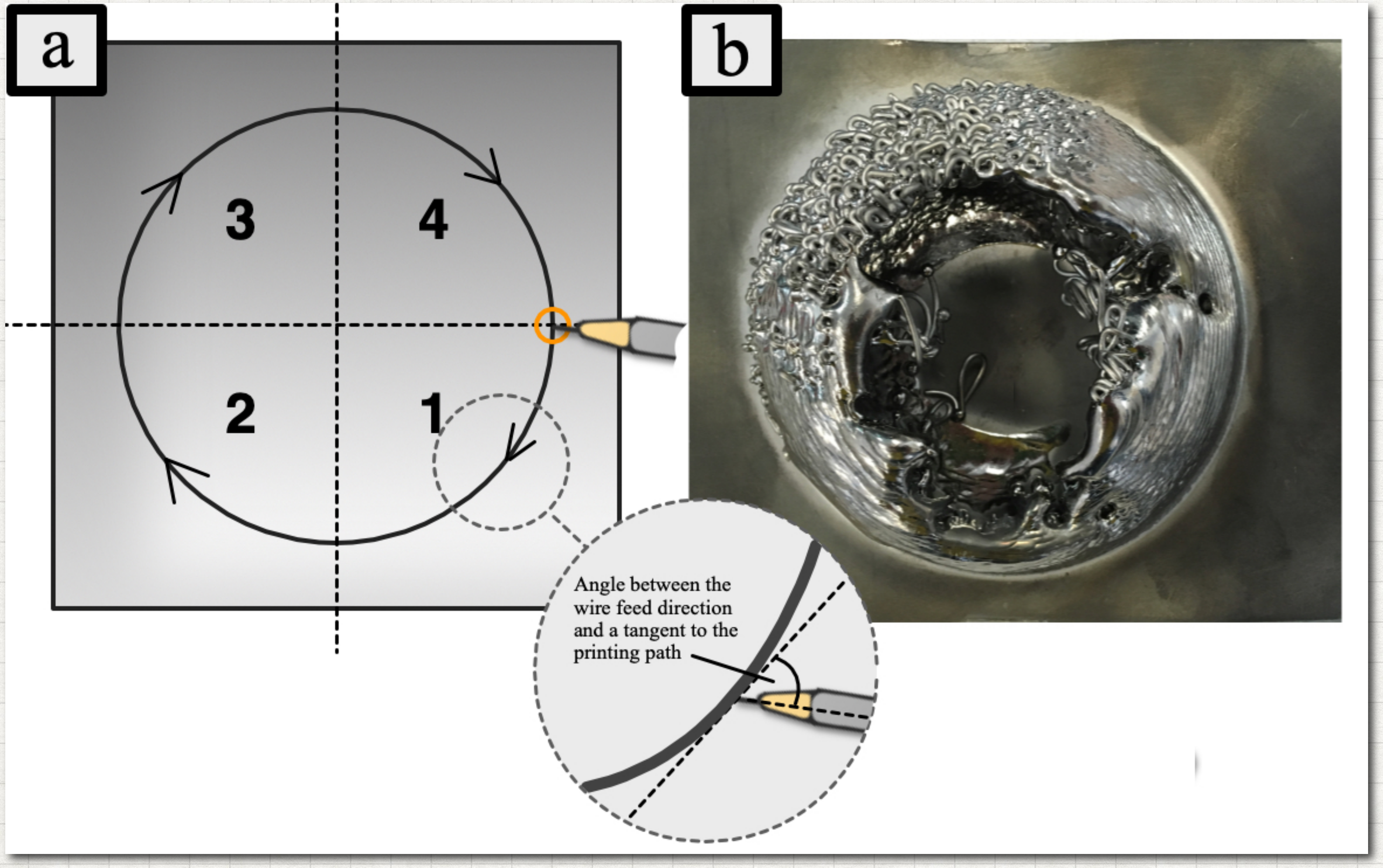
2 – Substrate,

3 – Template,

4 – Line of microhardness measurements

RESULTS AND DISCUSSION

SAMPLE MANUFACTURED BY METHOD 1



The geometry affected zones on samples manufactured with the use of the standard 3-axis table:
a – the scheme,
b – the sample.

RESULTS AND DISCUSSION

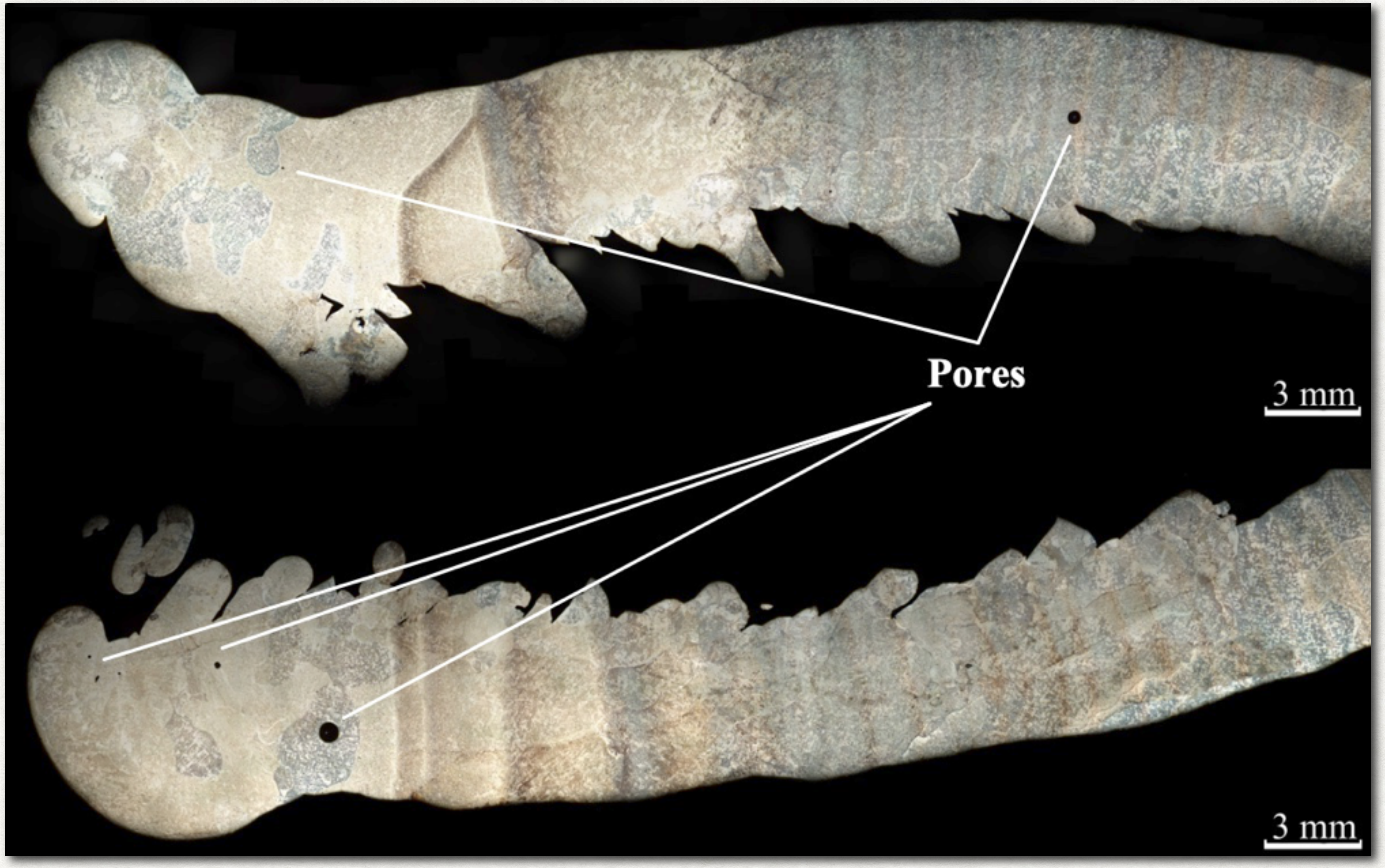
SAMPLE MANUFACTURED BY METHOD 1

Macrostructure of the sample in areas affected by the wire feed geometry

RESULTS AND DISCUSSION

SAMPLE MANUFACTURED BY METHOD 2

No geometry affected zones



Macrostructure of the sample at different wall sections

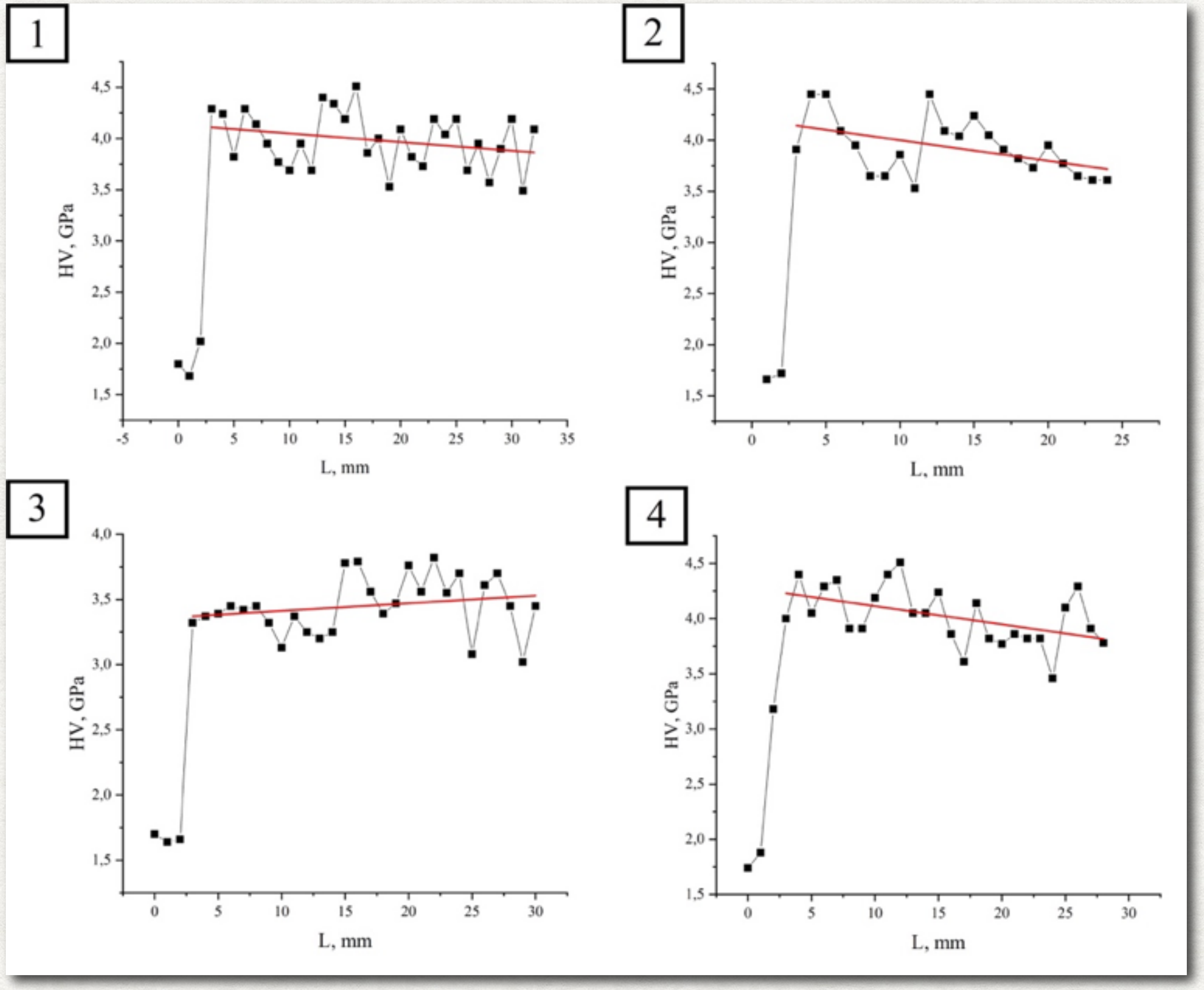
RESULTS AND DISCUSSION

X-RAY ANALYSIS

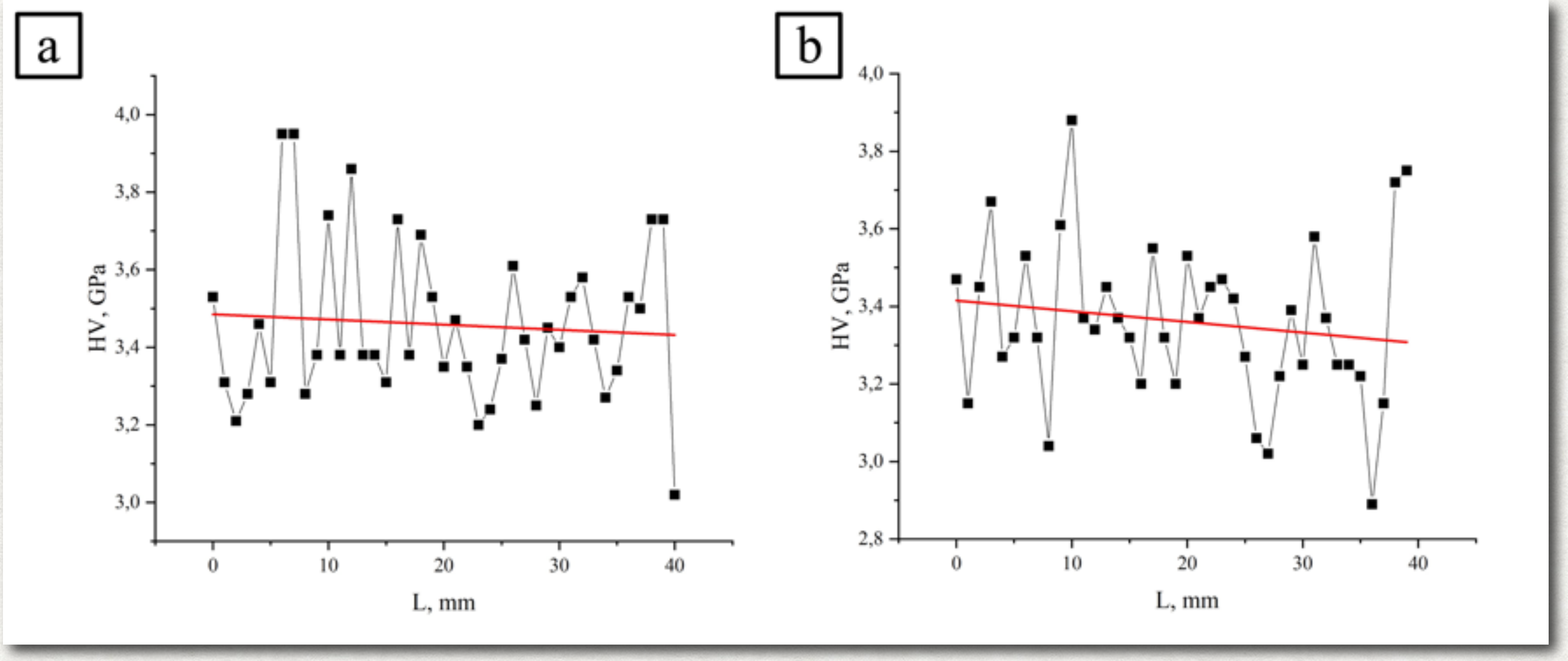
Method 1				Method 2			
Top (α)		Bottom (α′)		Top (α′)		Bottom (α + α′ + β)	
α	**β**	**α′**	**β**	**α′**	**β**	**α**	**β**
a = 2,92744		a = 2,92614		a = 2,92625		a = 2,96184	
c = 4,67744	–	c = 4,62904	–	c = 4,6660	–	c = 4,50815	a = 3,29311
V = 34.715		V = 34.325		V = 34.606		V = 34.249	V = 35.712
c/a = 1.59779		c/a = 1.581961		c/a = 1.59473		c/a = 1.52207	

RESULTS AND DISCUSSION

MICROHARDNESS MEASUREMENTS



Microhardness of the sample, manufactured on the 3-axis table (mode ***I***) in geometry affected zones



Microhardness of the sample, manufactured on the 4-axis table (mode ***II***) in different sections

CONCLUSIONS

- It was found that during printing on the standard 3-axis table the four characteristic quadrant zones, called geometry affected zones, were identified on the sample. The presence of such a zone makes it impossible to use the part obtained in this way. At the same time, due to high cooling rates, the resulting structural-phase state of such samples provides high values of microhardness of the product.
- The use of a rotary table allows to get rid of geometry affected zones in the printing plane. It allows achieving the highest accuracy of product formation and surface quality. At the same time, defects such as pores were detected, and the resulting structure does not provide the mechanical characteristics that are achieved at high cooling rates.
- Optimization of the part manufacturing parameters will allow improving the thermal modes of the process and get rid of such defects.

THANK YOU FOR YOUR ATTENTION!