Ultrasonic Assessment of Permanent Joints of Powder Metallurgy Parts Obtained by Pulsed Electromagnetic Field

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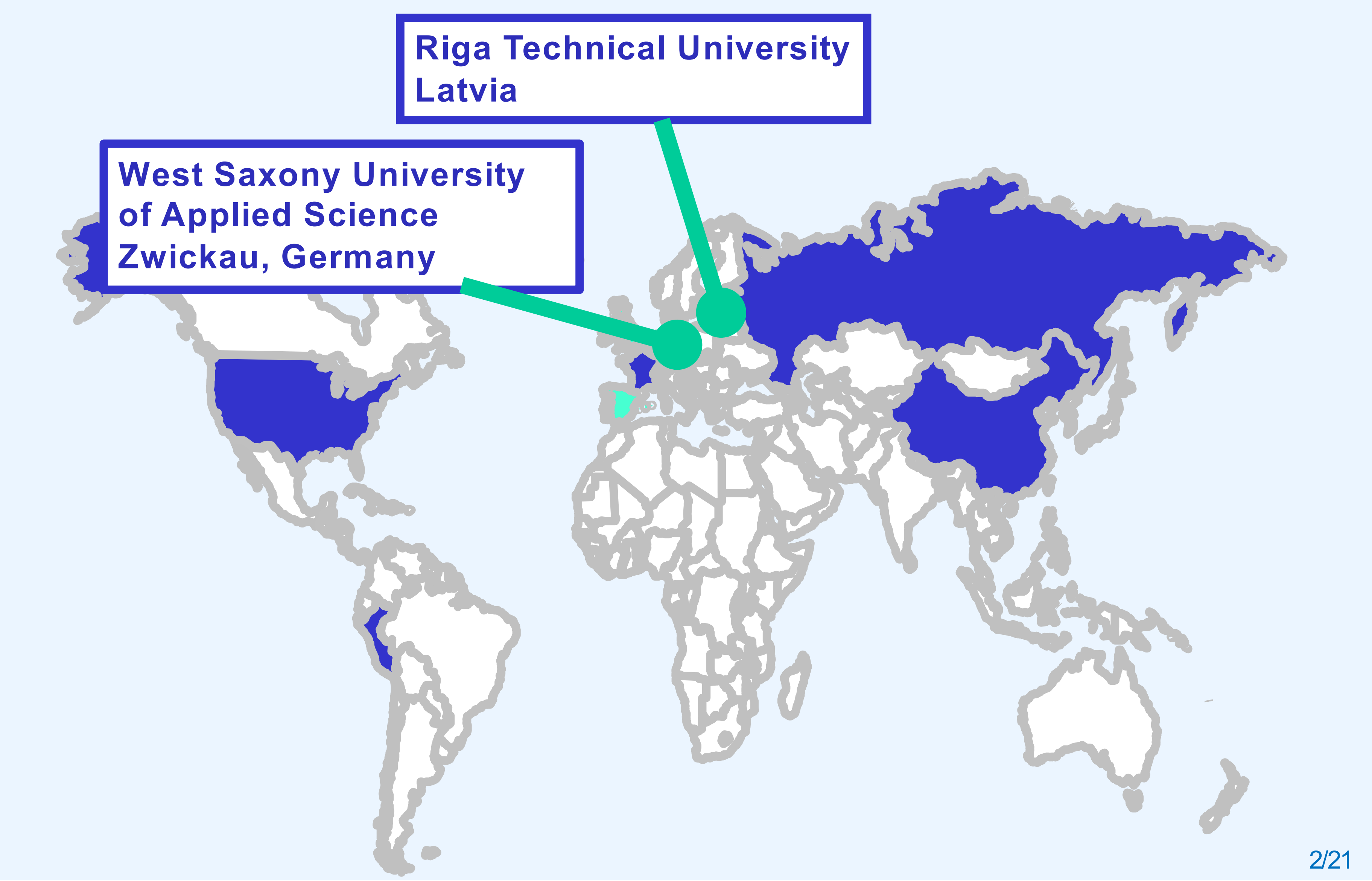
1. Introduction



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of Applied Science
Zwickau, Germany

1. Introduction

RIGA TECHNICAL UNIVERSITY (RTU)
Laboratory of Powder Materials

PROF. MIRONOV DR. TATARINOV

Main research areas

- Electromagnetic (EM) forming of metals
- Powder materials EM compacting and forming
- EM transport of powder materials
- EM Infiltration of powder materials
- Shielding EM

1. Introduction

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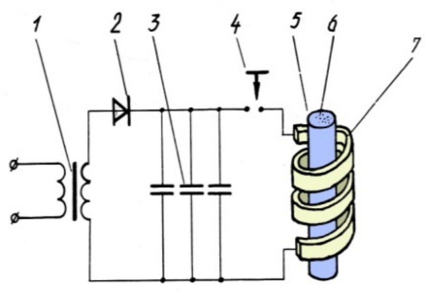
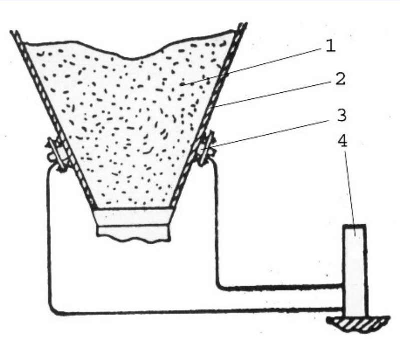
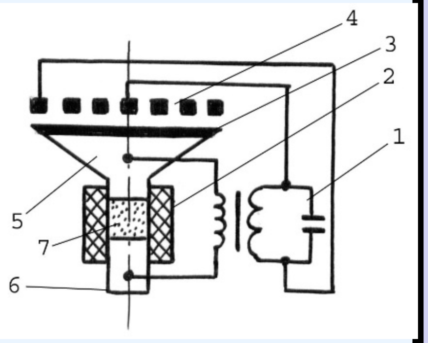
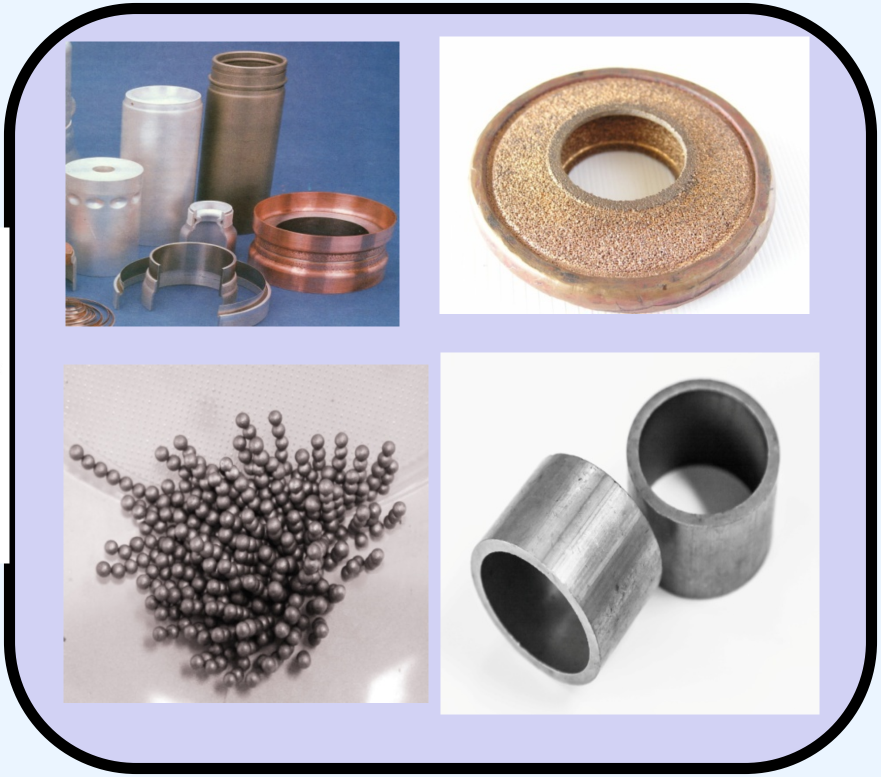
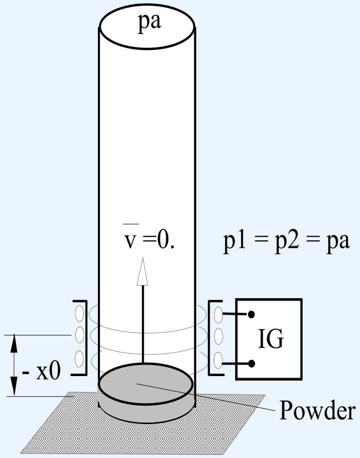


APPLICATIONS OF PULSED ELECTROMAGNETIC FIELD (PEMF)









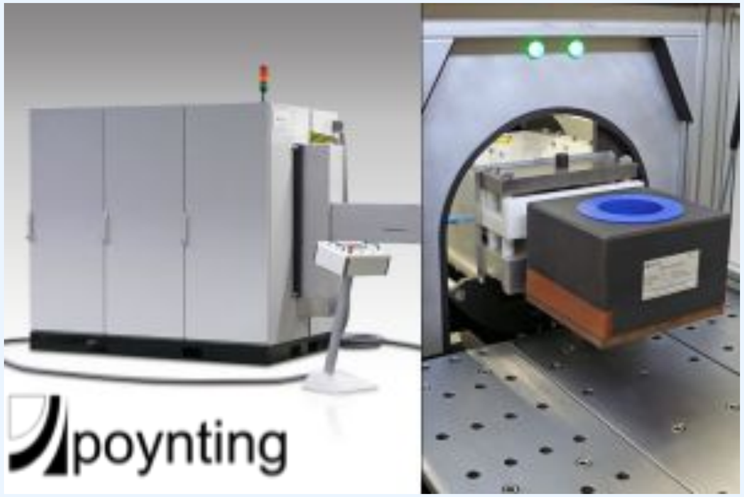
1. Introduction

WHZ ZWICKAU - MAIN RESEARCH AREAS

- Radial compression of tubular parts
- Magnetic pulsed compaction process of pure titanium powder

- Explosive welding

WHZ ZWICKAU - EQUIPMENT FOR PULSE FORMING

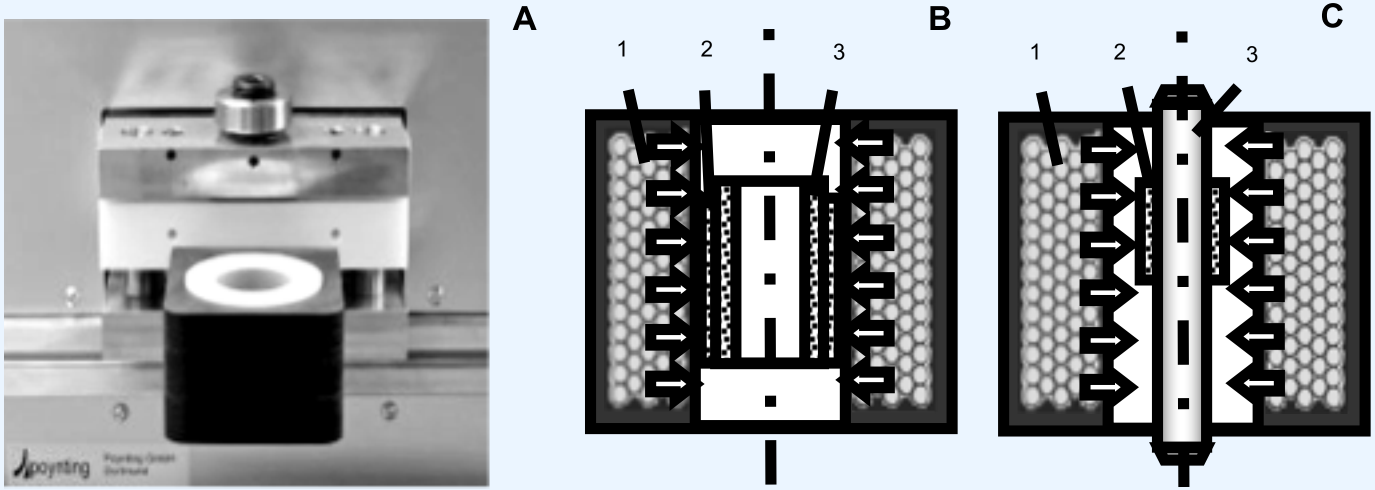


Experimental tools and devices for:

- Pulse electromagnetic forming, Poynting SSG-3020
- Under water shockwave generation
- Explosive welding with basic equipment (plane, tubular)

2. Basics of Investigation

it is possible to obtain rigid permanent joints of powder metal parts, such as bush-on-bush and bush-on-rod



method for joining of powder metal parts:

A – inductor coil of pulse generator equipment (Beerwald, Poynting GmbH Dortmund)

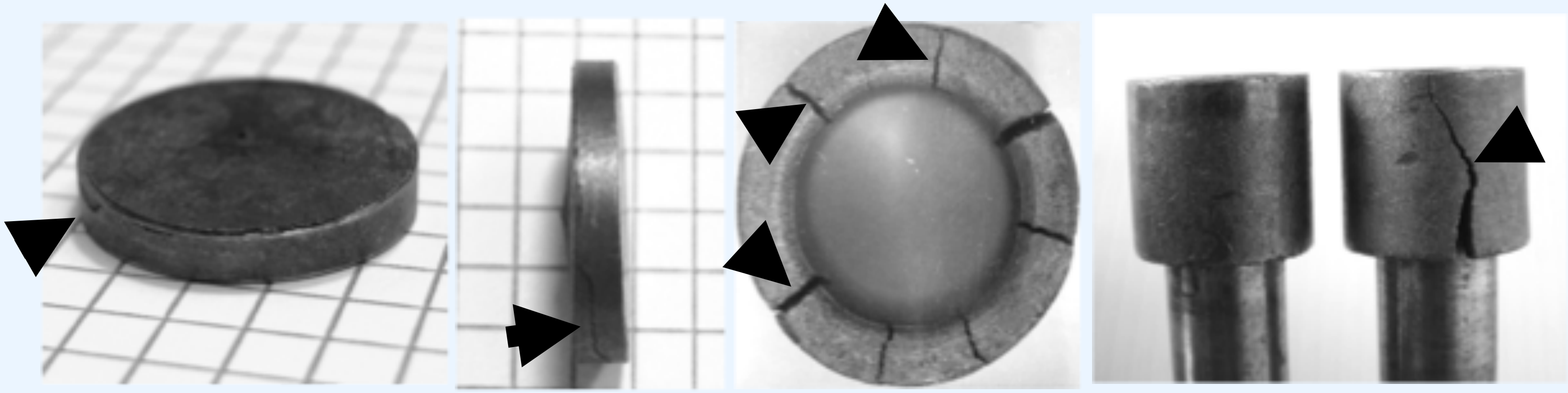
B, C – joining of powder metal parts – bush-bush and bush-rod,

1 – inductor coil, 2 – outer deformable part, 3 – inner basic part.

Arrows shows direction of applied pulsed elektromagnetic field (PEMF)

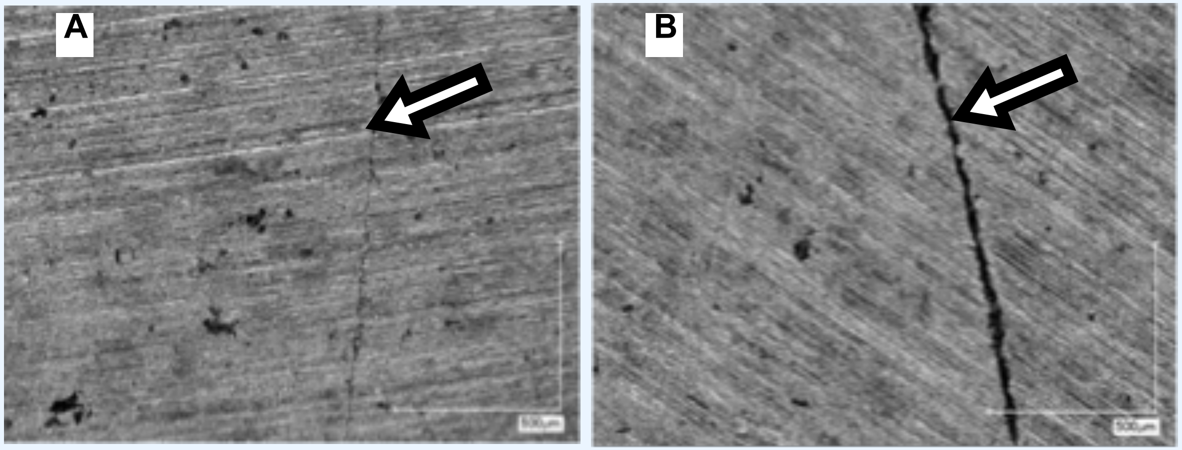
2. Basics of Investigation

- **Powder pressed parts** are characterized by increased **brittleness** and have residual **porosity**
- it is important to ensure the **correct value of compressive forces**;
- surface of the substrate should **not** have **scoring or unevenness**;
- **gap** between the joint parts and intensity of applied PEMF should be chosen optimal
- **cracks** appears as the result of **excessive or asymmetric** PEMF



2. Basics of Investigation

- insufficient or **asymmetric** PEMF creates a **poor connection** with **gaps**.
- **differences in joining grade** were confirmed by microscopic observation the bonded zones in the cross sections



Microscopic images of tight (A) and weak (B) bonded zones in bush-bush joint (magnification x200)

Arrows denote the bonded zone between bushes.
Black dots correspond to pores in powder bronze graphite

2. Basics of Investigation

Objectivs of the Investigation:

- adequeate **non-destructive** testing method needed

- investigation the **sensitivity of ultrasonic methods** to identify tight and weak connections of powder metal parts of **various sizes**

- the specific structure and porosity of powder metal parts, like **bronze graphite**, **strong attenuation** of high-frequency ultrasonic waves

3. Materials and Methods

- Testing objects were joints of powder metal parts two types: **bush-on-bush** and **bush-on-rod**
- bushes intended for antifriction operation
- **bronze graphite** obtained by sintering powders: copper 88%, tin 9% and graphite 3%
- residual **porosity** reached 12-15%.

A – bush-on-bush; B – bush-on-rod
wall thickness 3mm and 2,5 mm
outer diameter 32mm and 16 mm

Basic Principles of ultrasonic non-destroying testing

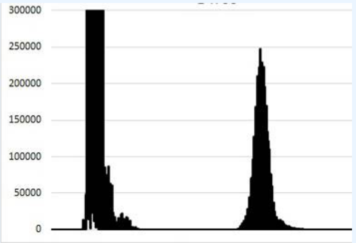
- An ultrasonic pulse **passes through the parts** at the characteristic sound velocity,
- In the course of this an **interaction with the part structures** takes place,
- The corresponding evaluation of the **signals received** (amplitude, time of flight) allows conclusions to be drawn as to the **internal quality of the object** without destroying it
- In the **pulse echo method** the **sound portions reflected back** to the probe are evaluated
- In the **time-of-flight method**, the probe contains two transducers placed at a certain distance, the transmitter and the receiver, and the propagation signal between them is evaluated in the time scale

3. Materials and Methods

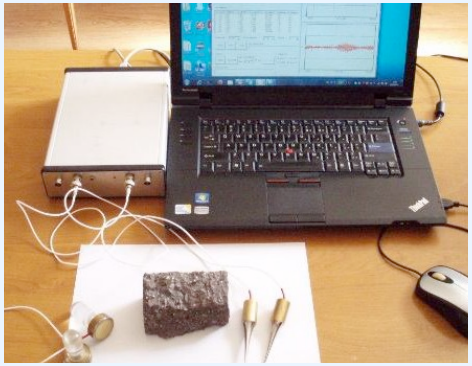
Two methods of ultrasonic non-destroying testing were compared:

1) **pulse-echo** using a commercial flaw meter;

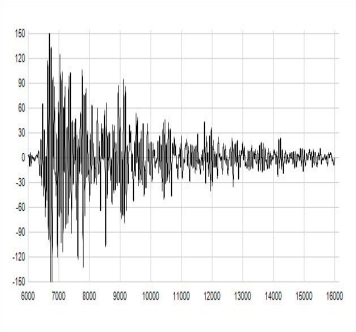
A-mode:
time of echo ~ depth



2) **time-of-flight (TOF)** method implemented in a custom made system



Analysis of entire **signal on time scale**



3. Materials and Methods

1) **pulse-echo** using a commercial flaw meter

ultrasonic flaw detector USM-25 (Krautkramer GmbH)

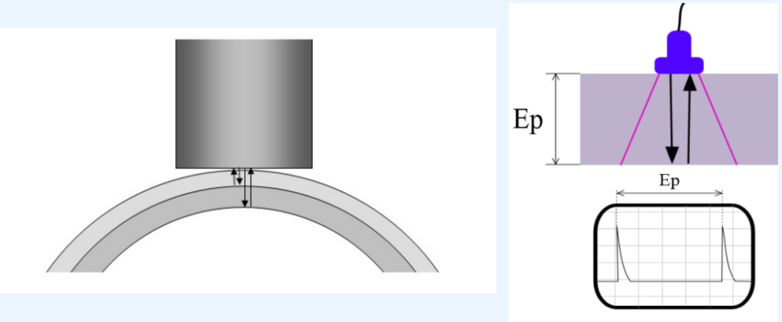
adjusted for bronze graphite
dual-element transducer Olympus 01JJ4L

frequency 3 MHz

Diameter of the transducter: 20 mm

Medium for connecting: oil

Strong echo response



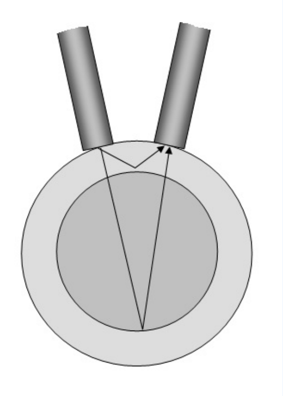
2) **time-of-flight (TOF)** method implemented in a custom made system

a pair of custom quasi-point transducers frequency 2 MHz

Contact area of the transducter: 1x4 mm

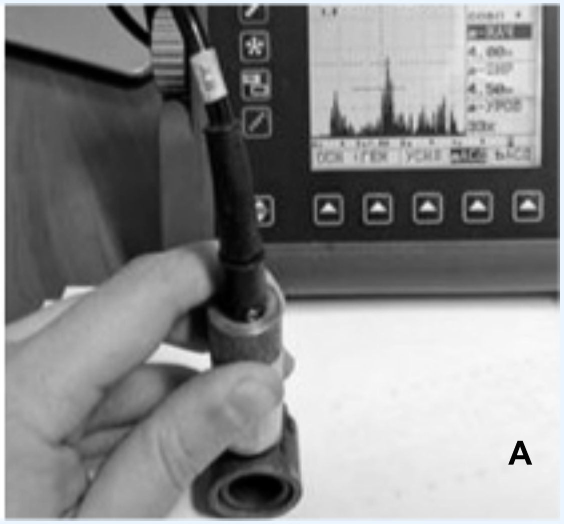
Medium for connecting: oil

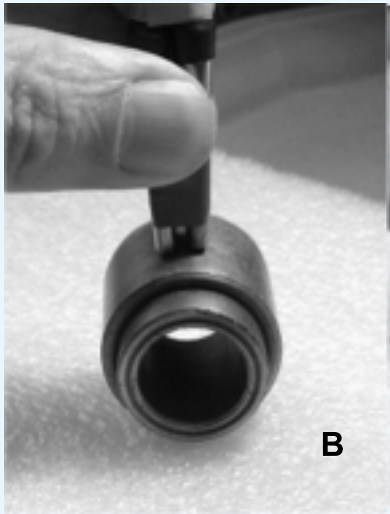
Multiple propagation paths



Ultrasonic examination in the lab of bush-on-bush joints by pulse-echo method (A) and bush-bush and bush-rod joints by TOF method (B,C)

outer diameter of the powder bush 32mm (A, B) and 16 mm (C)





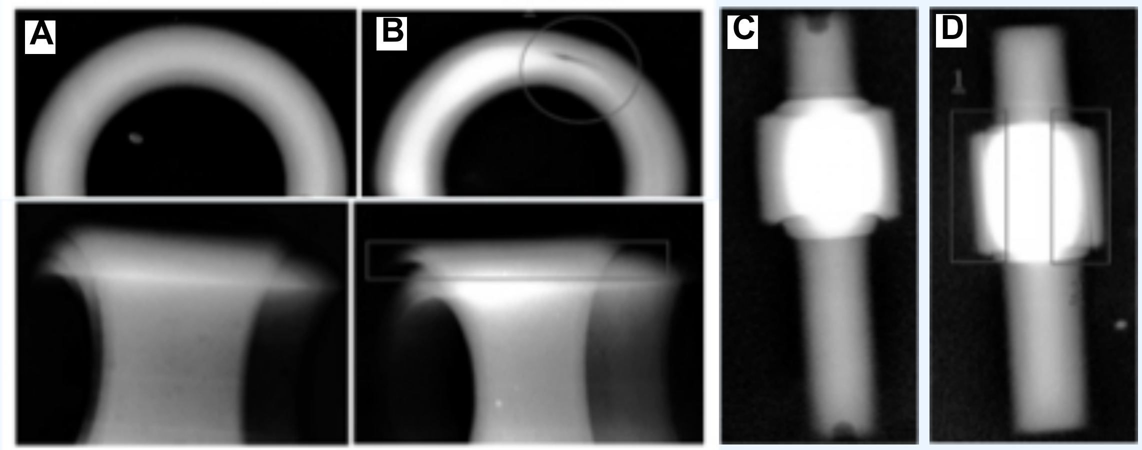
3. Materials and Methods

X-ray-examinations in addition:
Radiographic testing of bush-on-bush (A,B) and bush-on-rod (C, D) joints, but:

x-ray images didn't provide a quantitative assessment of the mechanical toughness of the joints

A,C tight joining; B,C weak joining

A,B top line: X-ray circumferetial view; bottom line: axial view



+ gaps between outer and inner parts in these joints were visualized in both views
- providing images with emphasized gaps is difficult

- time and labor for multiple attempts are required
- X-ray images didn't provide any quantification of mechanical toughness of joints.

4. Results of Investigation

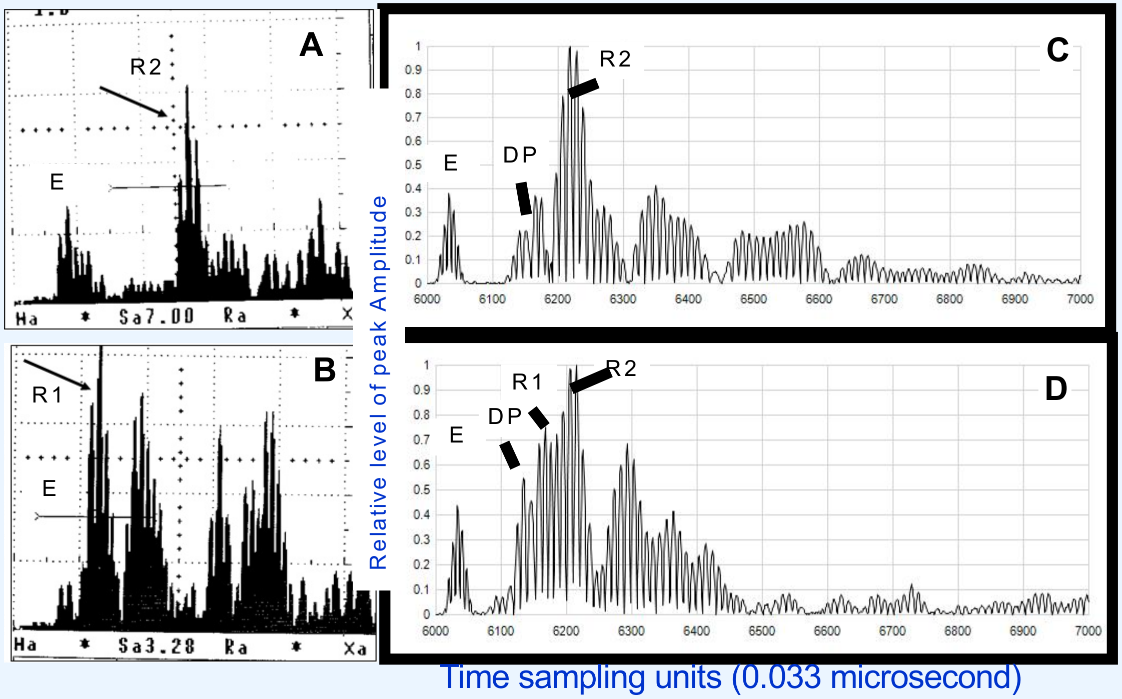
Pulse-echo **TOF**

Tight

LR2 = 7.00 mm

Weak

LR1 = 3.28 mm



TOF

No signal R1

R1/R2 → 0

TOF

R1/R2 ≈ 0.7

Ultrasonic signals obtained in bush-bush joints in comparison

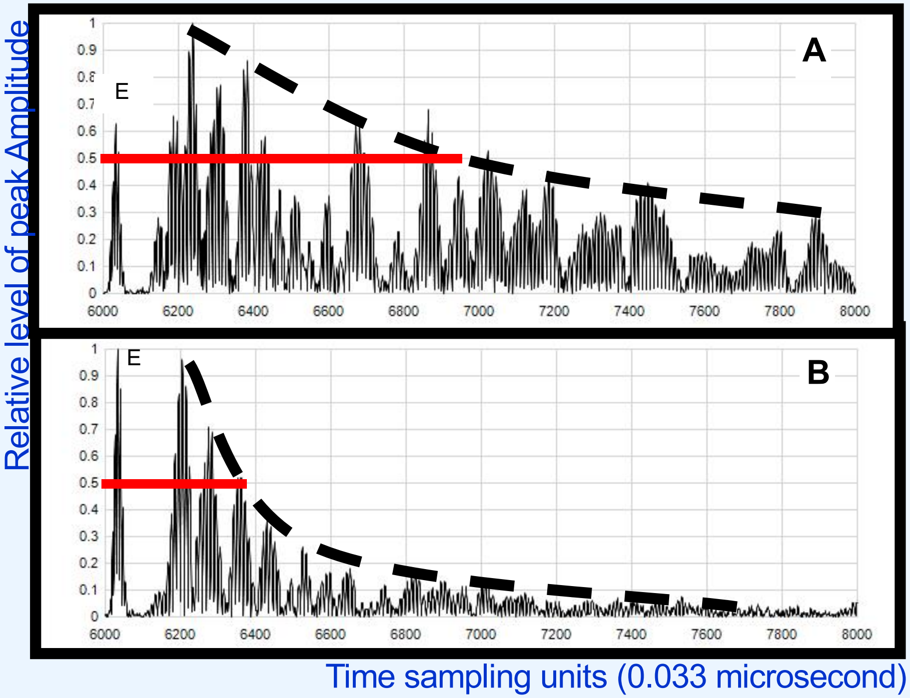
pulse-echo (A,B) and TOF (C,D) methods,
where A and C – tight clamping; C and D – weak clamping;

signs on graphs:
E – trace of excitation; DP – direct propagation;
R1 – reflection from interface between bushes;
R2 – reflection from inner surface of inner bush
L – depht of echo

4. Results of Investigation

Tight

Weak



Multiple propagation paths in bush-rod complex

Tr0.5 ≈ 28 µs

Signal attenuates in bush's wall

Tr0.5 ≈ 10 µs

Ultrasonic signals obtained by TOF method in bush-rod joint:

curved lines approximate signals damping

A – tight joining; B – weak joining;
E denotes excitation trace; (30MHz: 1 unit= 0,033 µs)

4. Results of Investigation

NDT method	Advantages	Limitations	Applicability for rapid diagnostics of joints
Industrial radiography	Imaging, visual presentation of gaps	Needs labor consuming adjustment, not specific to toughness	Not rapid, not enough specific to joint quality
Ultrasonic testing: pulse-echo	Clear interpretation of contact toughness based on echo signals	Limited by surface curvature and sizes of parts	Applicable for relatively flat surfaces
Ultrasonic testing: TOF with point contact transducers	Access to small parts and curved surfaces	Angle sensitive, complex wave pattern, pre-studies required	Applicable for wide range of shapes after pre-studies

Comparison of applicability of different NDT methods to testing of joints quality

5. CONCLUSIONS

- This presentation outlines scientific and engineering developments in applications of **p**ulsed **e**lectro**m**agnetic **f**ield (PEMF), developed in Riga Technical University (Latvia), and supported by Westsaxony University of Applied Science in Zwickau (Germany).
- The current study showed **sensitivity of ultrasonic pulse-echo and TOF methods** to mechanical integrity **of powder metal part joints** by pulsed electromagnetic compaction.
- Obtaining quantitative dependences between ultrasonic parameters and the mechanical strength of joints for industrial quality assurance can be **a subject of further research investigation**

Thank you!

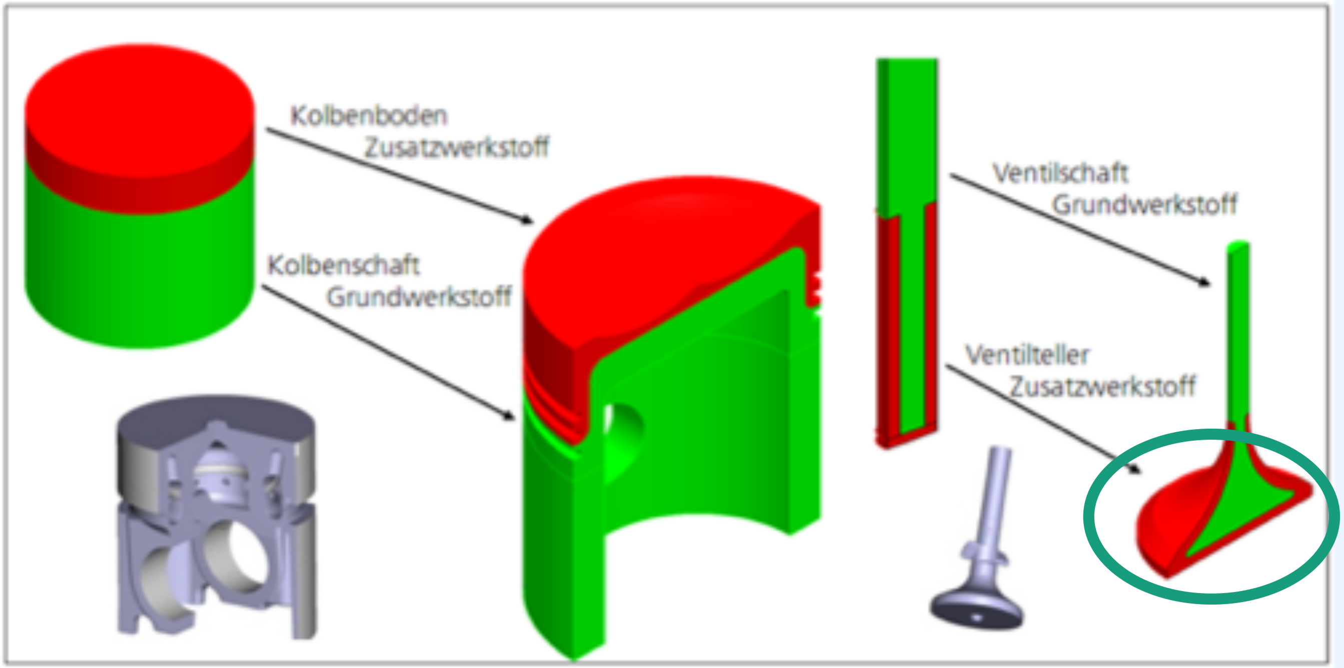
RTU

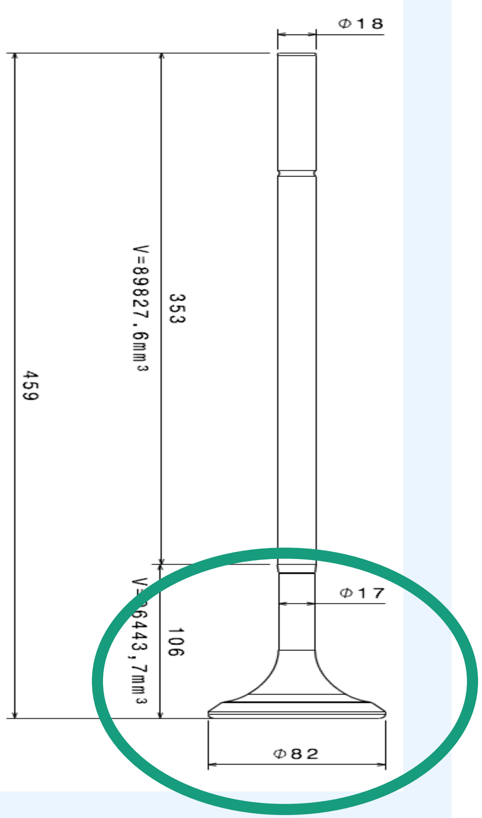
Westsächsische Hochschule Zwickau
University of Applied Sciences

Now in addition a special information about explosive welding

Remember to the 7th International Conference on High Speed Forming , Dortmund

Additional information: Hybride material composite – Explosive welding of valve shafts:



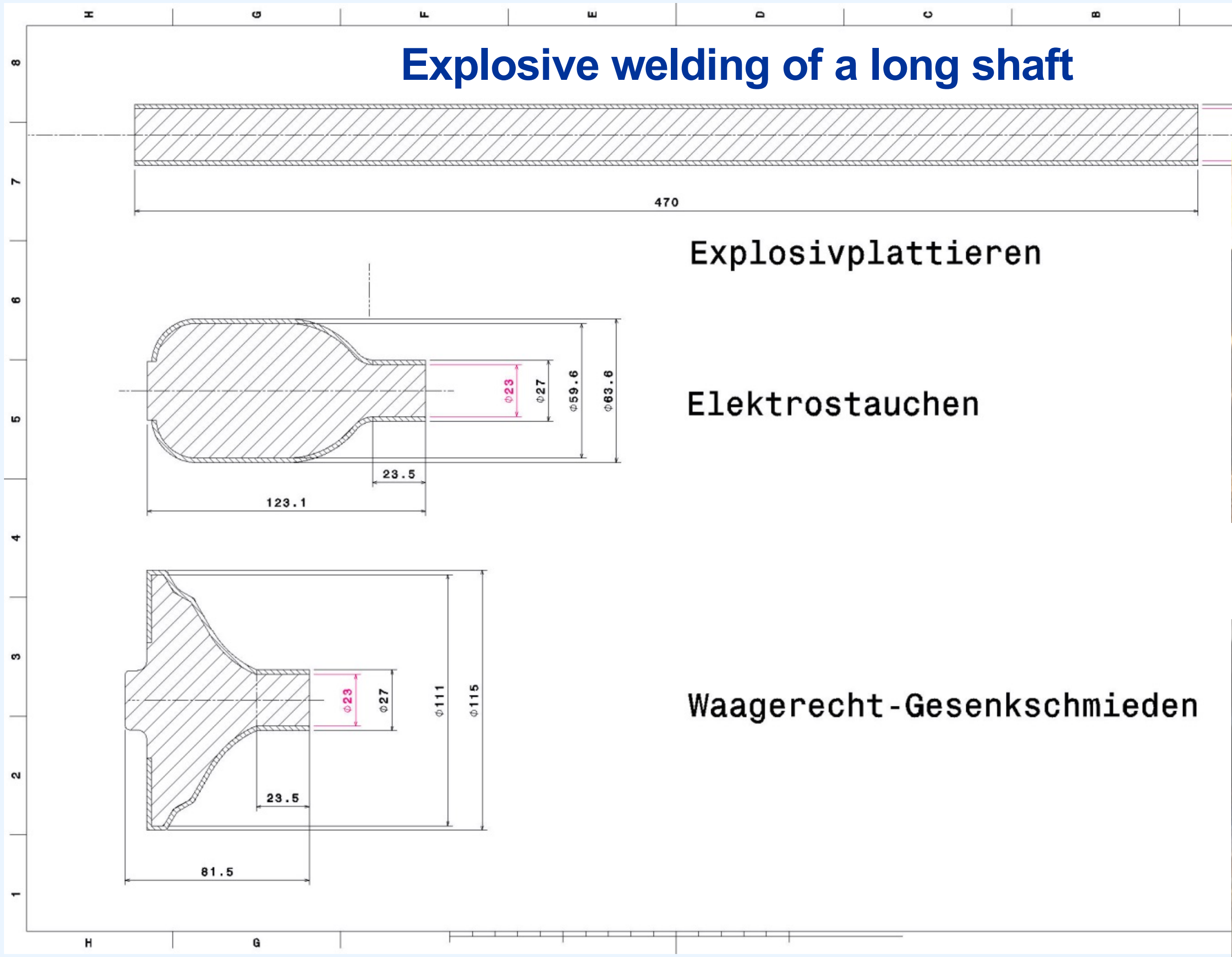


Hybride material composite – Explosive welding of piston bodys and valve shafts

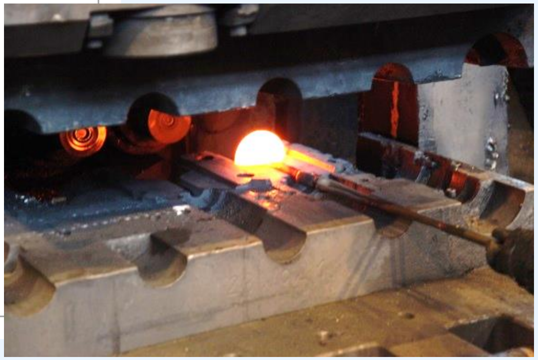
Development of the technique to join shafts (42CrMo4) with heat restistant material of the tube (NI, Alloy60)

Hybride material composite – Explosive welding of valve shafts: investigation route

Explosive welding of a long shaft

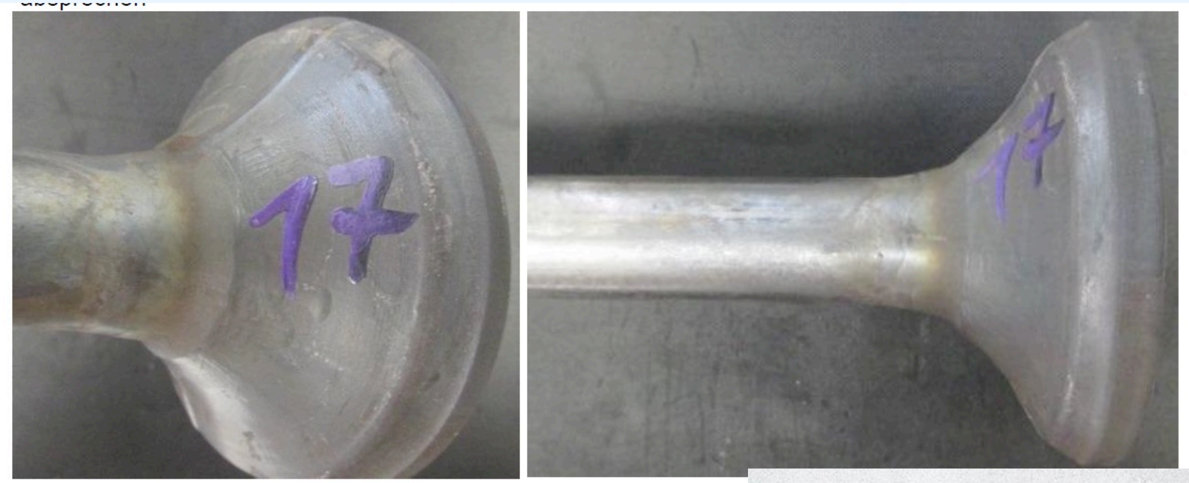


Upsetting the shaft



Horizontal Forging the valve

Explosive welding of parts for ship-engines



forged valve

Cross section showes the welded zone

completely coated by explosive welding,

(NI, Alloy60)

ready for machining process

Thank you for attention once again!