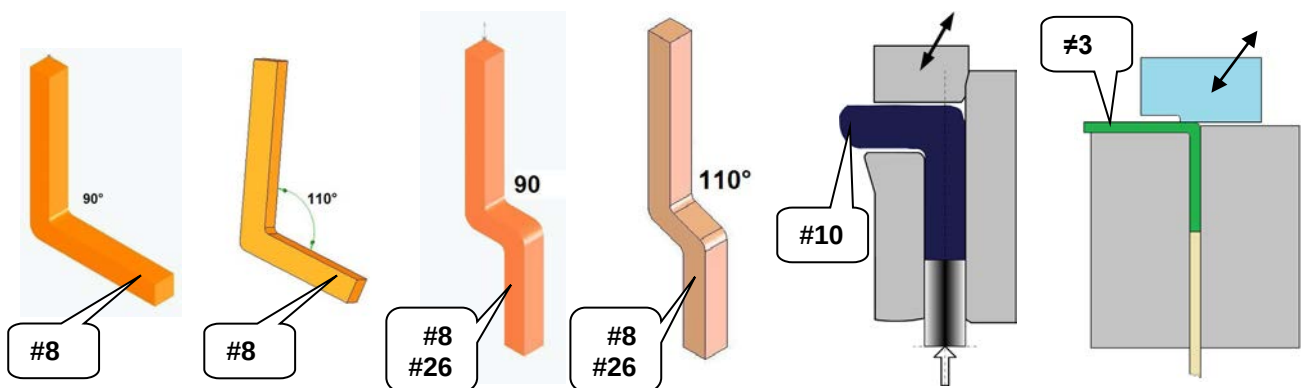
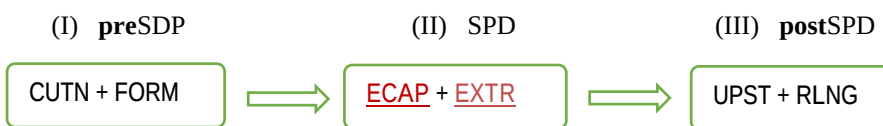


SPD facilities for grain refinement



EQUIPMENT in the **UFGTechLAB** workshop for hybrid SPD
(hbrdSPD = preSPD + SPD + postSPD)

Schematics of hybrid SPD developed for production of UFG sheets



CONTACT: dr hab. inż. Lech OLEJNIK, prof.PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

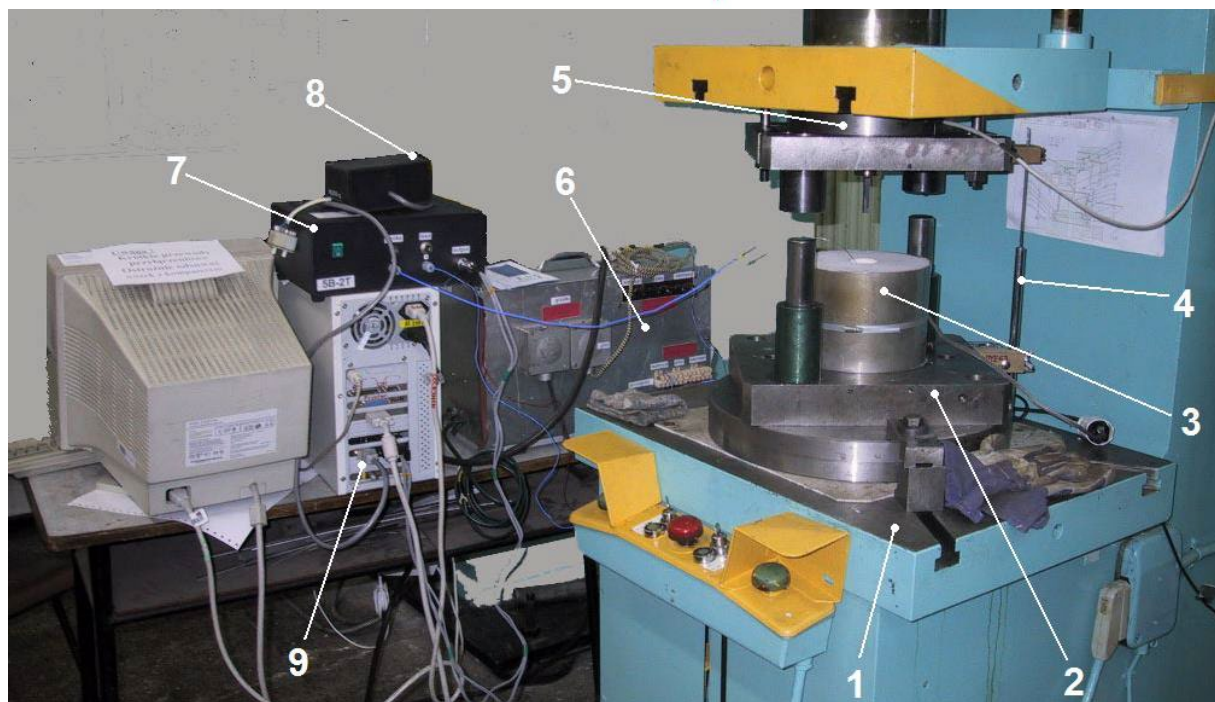
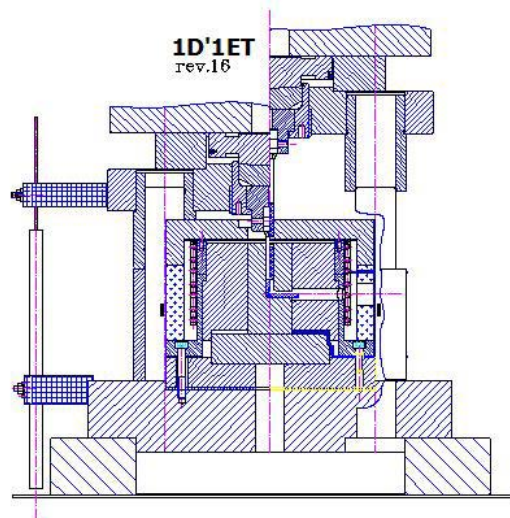
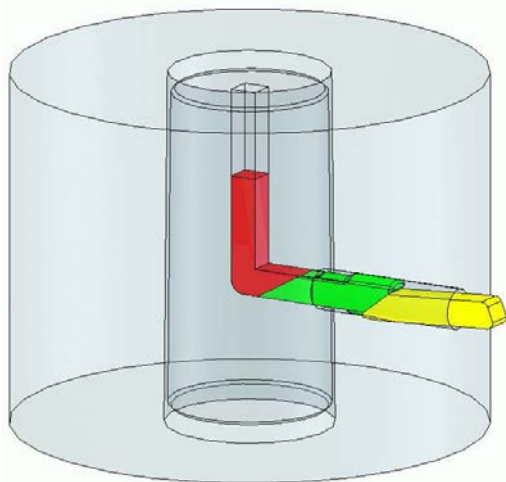
Narbutta 85, PL 02-524 Warszawa, Poland

Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Classical Equal Channel Angular Pressing for Grain Refinement

ECAP rig for 8 mm×8 mm billets (classical channel 1×90°, metal forming type: shearing):
1--600 kN hydraulic press PYE63, 2--die set plates with pin-bushing guiding system,
3--ECAP tool (1D'1et), 4--stroke transducer, 5--load cell, 6--temperature controller,
7-- temperature recorder, 8--force monitoring system, 9--DAQ computer system

CONTACT: prof. nzw. dr hab. inż. **Lech OLEJNIK**,

Email: lech.olejnik@pw.edu.pl

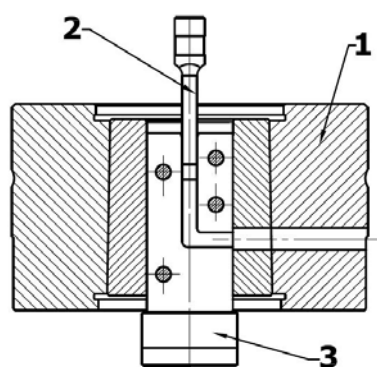
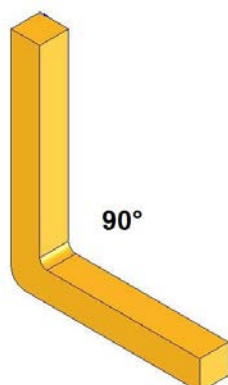
**DEPARTMENT of METAL FORMING and CASTING**

Narbutta 85, PL 02-524 Warszawa, Poland

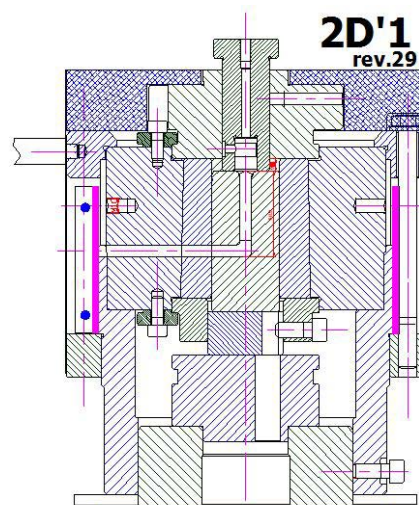
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>

**Faculty of Mechanical and Industrial Engineering**

Classical Equal Channel Angular Pressing for Grain Refinement

1-prestressed die
2-punch
3-base plate



ECAP rig for 8 mm×8 mm billets (classical channel 1×90°, metal forming type: shearing):
 1--ECAP tool (2D'1et), 2--400 kN hydraulic press, 3--DAQ computer system, 4--force measurement system, 5--stroke measurement system, 6--temperature controller

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl

**DEPARTMENT of METAL FORMING and CASTING**

Narbutta 85, PL 02-524 Warszawa, Poland

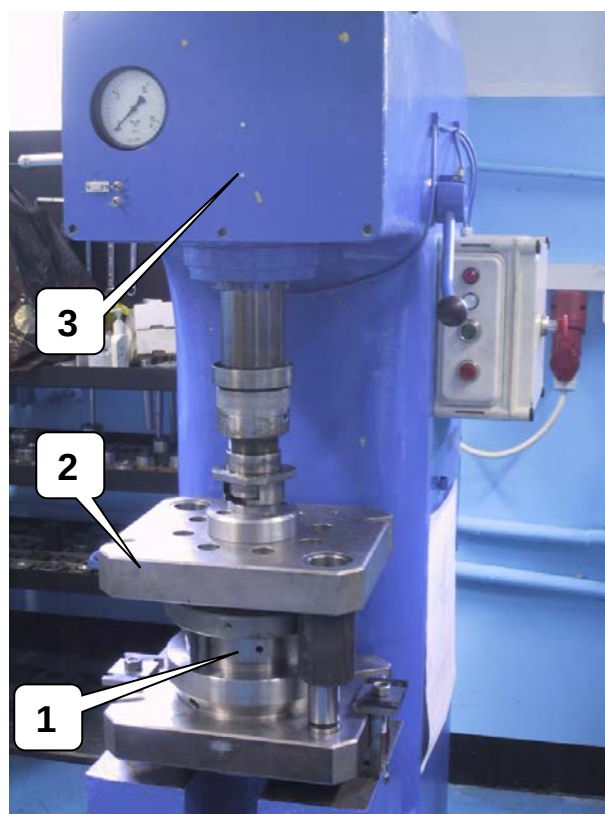
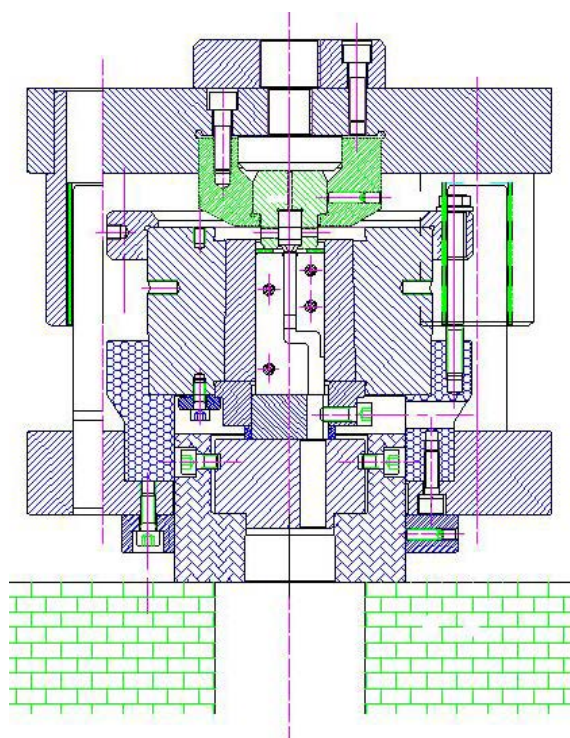
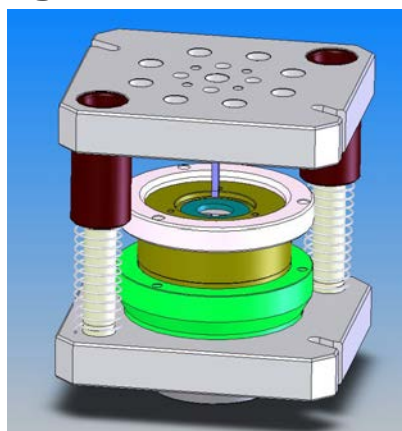
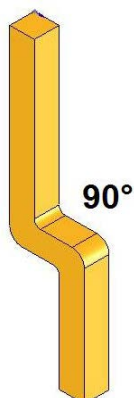
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Equal Channel Angular Pressing for Grain Refinement



ECAP rig for 8 mm × 8 mm billets (channel 2×90°, size: #8, metal forming type: shearing):
 1--ECAP tool (140'2) for intense shear straining at room temperature, 2--die set plates with pin-bushing guiding system, 3--120 kN hydraulic press PH12

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW, Email: lech.olejnik@pw.edu.pl



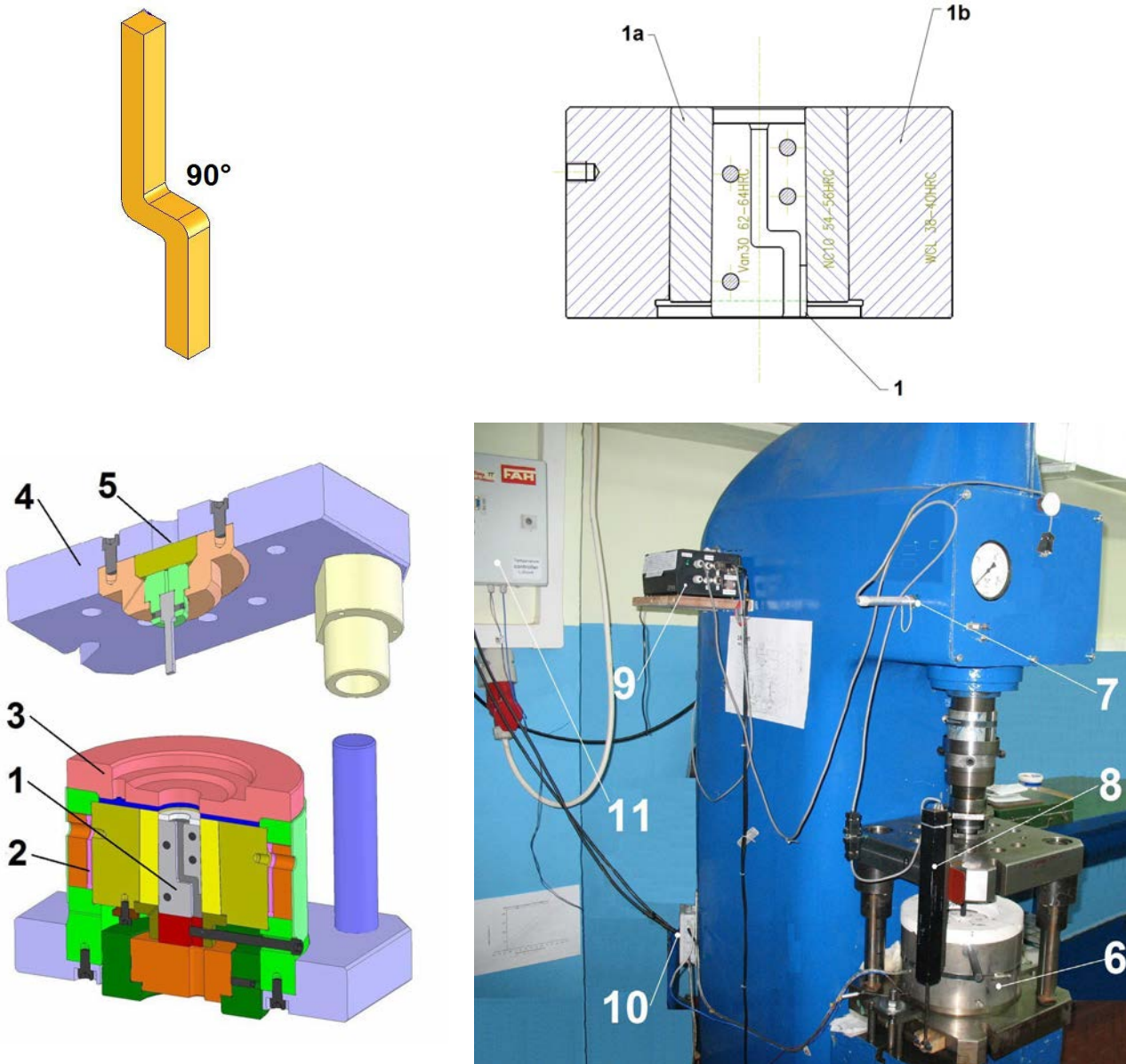
DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland
 Tel + 4822 849 9437, + 4822 849 9797 <https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Equal Channel Angular Pressing for Grain Refinement



ECAP rig for 8 mm × 8 mm billets (channel 2×90°, size #8, metal forming type: shearing):
 1-segmented die insert, 1a-innner prestressing ring, 1b-outer prestressing ring, 2-electrical heater, 3-ceramic plate, 4-die set plates with pin-bushing guiding system, 5-coupling shank, 6-ECAP tool (160°2et), 7-pressure (load) transducer, 8-stroke transducer, 9-load vs. stroke monitoring system, 10-termocouple connection point, 11-temperature controller

CONTACT:

dr hab. inż. **Lech OLEJNIK**, prof. PW,

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

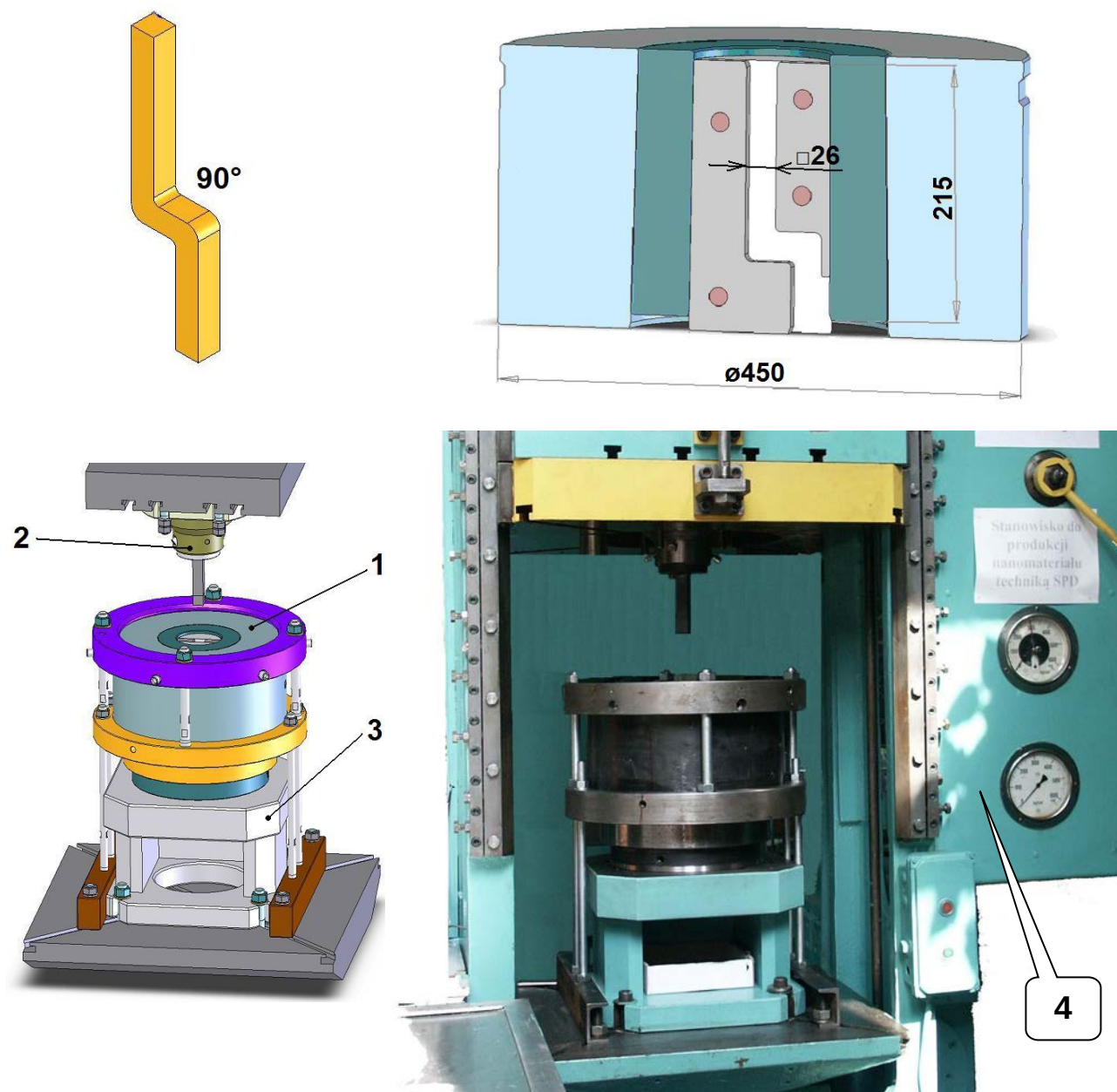
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Scale up Equal Channel Angular Pressing for Grain Refinement



ECAP rig for **26 mm × 26 mm** billets (channel 2×90°, size #26, metal forming method: cold shearing = pressing at the room temperature):

1--segmented die insert armored with two prestressing rings,
3--base block,

2--punch holder,

4--1000 kN hydraulic press MPH100

CONTACT: dr hab. inż. **Lech OLEJNIK**, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

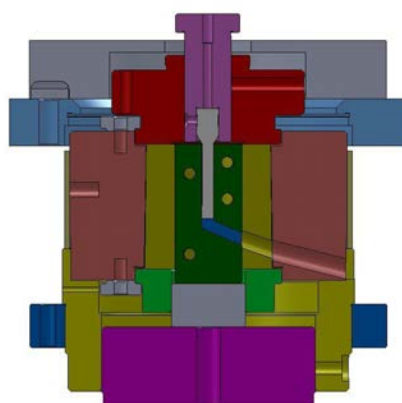
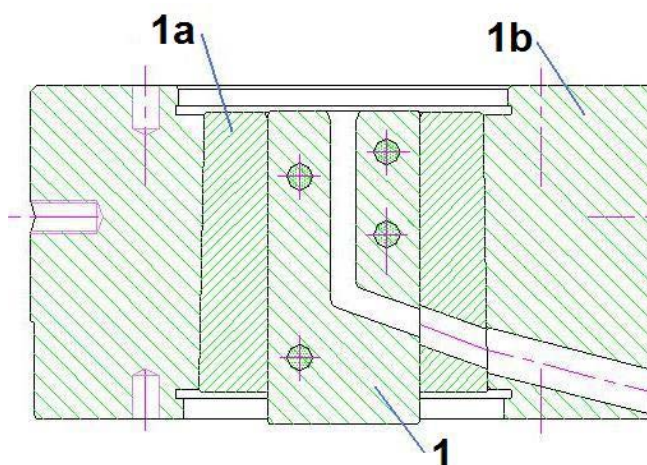
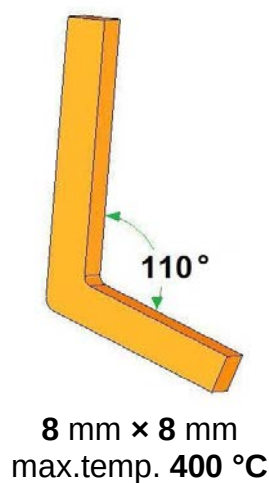
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Equal Channel Angular Pressing for Grain Refinement



ECAP rig for 8 mm × 8 mm billets (channel 1×110°, size #8, metal forming method: warm shearing = pressing at the elevated temperature):

1--segmented die insert, 1a--inner prestressing ring, 1b--outer prestressing ring,
2--table of the 400 kN hydraulic press ZD40

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

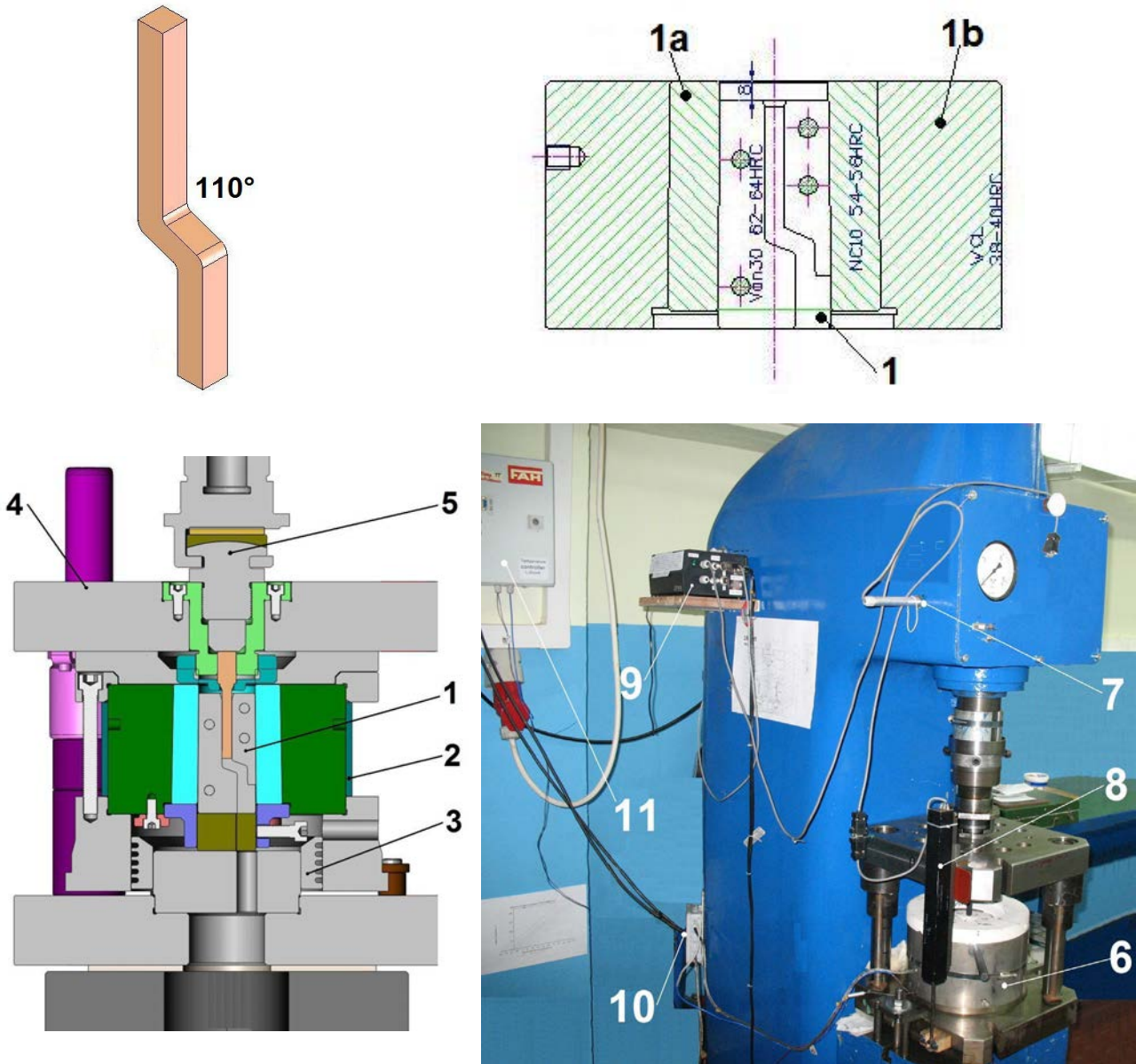
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Equal Channel Angular Pressing for Grain Refinement



ECAP rig for **8 mm × 8 mm** billets (channel 2×110°, size: #8, metal forming type: shearing):
 1-segmented die insert, 1a-innner prestressing ring, 1b-outer prestressing ring, 2-electrical heater, 3-water cooling ring, 4-die set plates with pin-bushing guiding system, 5-coupling shank, 6-ECAP tool (11zet), 7-pressure (load) transducer, 8-stroke transducer, 9-load vs.stroke monitoring system, 10-termocouple connection point, 11-temperature controller

CONTACT:

dr hab. inż. **Lech OLEJNIK**, prof. PW,

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

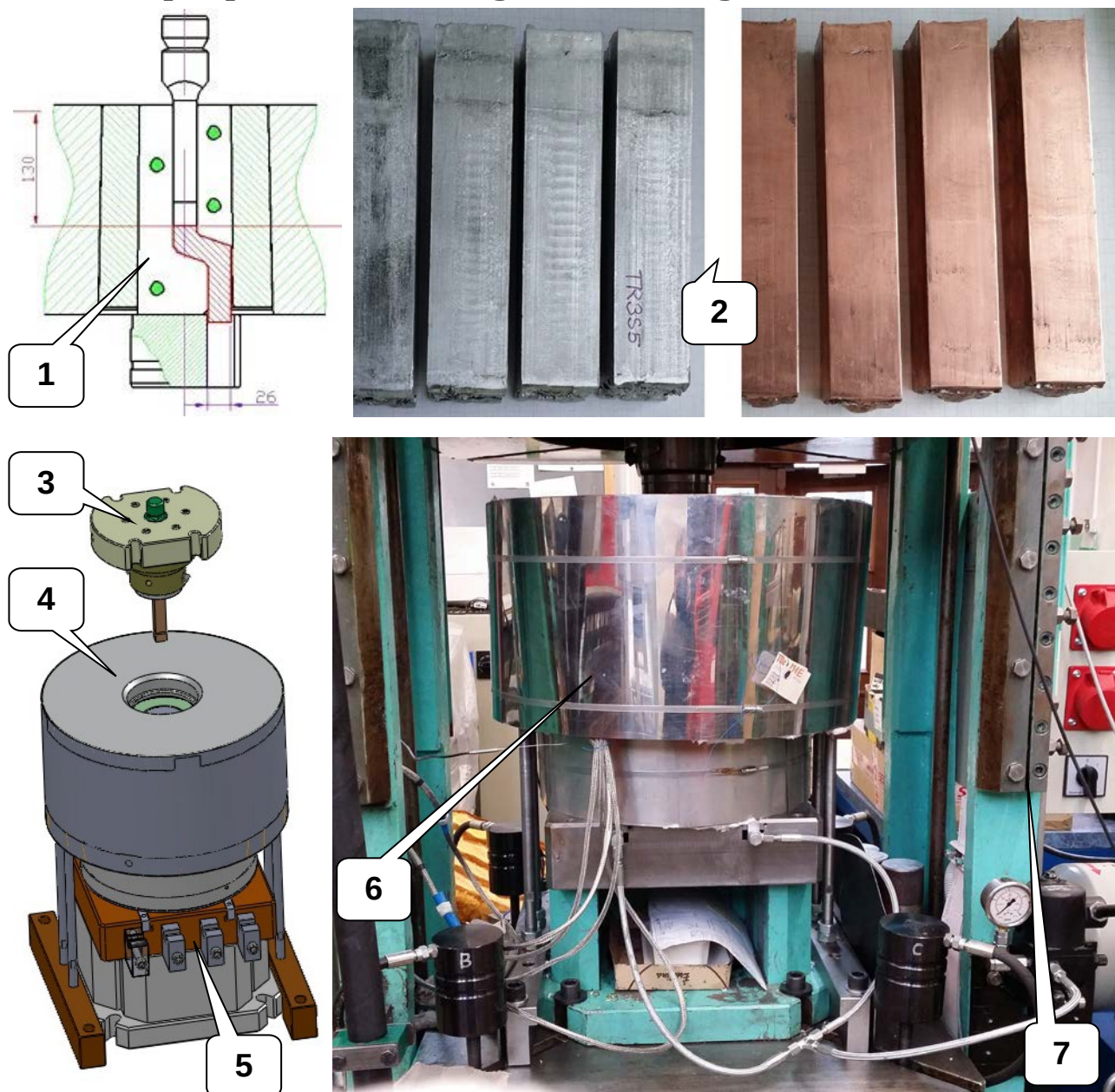
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Scaled up Equal Channel Angular Pressing for Grain Refinement



ECAP rig for **26 mm × 26 mm** billets (channel $2 \times 110^\circ$, size #26, metal forming method: warm shearing = pressing at the elevated temperature): 1—segmented die insert armored with prestressing rings, 2—collection of Al & Cu slugs, 3—punch holder, 4—die set, 5—bolster, 6—tooling for warm ECAP, 7—frame of the 1000 kN hydraulic press MPH100

CONTACT:

dr hab. inż. Lech OLEJNIK, prof. PW

 Email: lech.olejnik@pw.edu.pl

DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

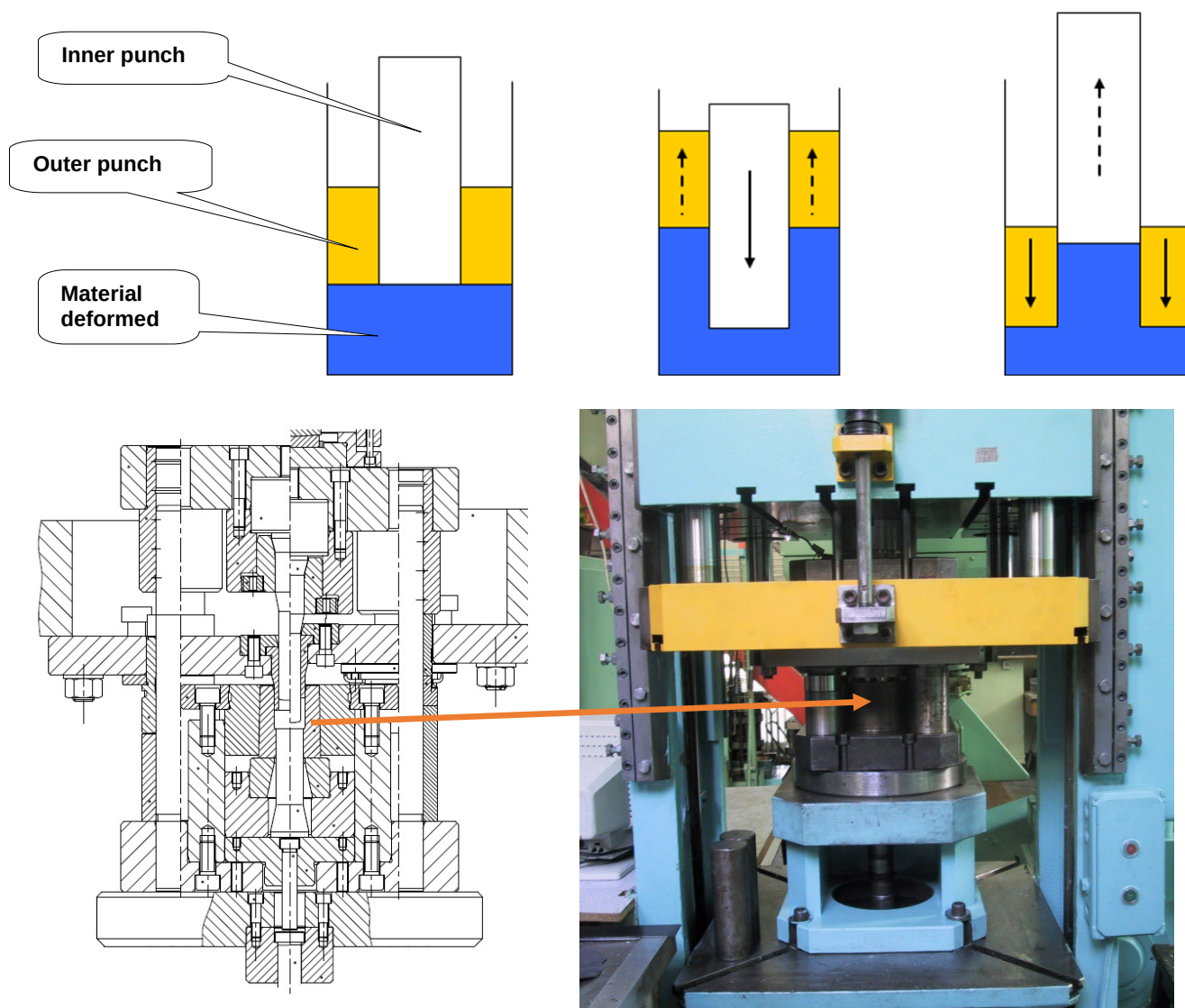
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>

Faculty of Mechanical and Industrial Engineering

Nanostructuring bulk metals by SPD

Cyclic Backward Extrusion (CBE)



ECAP-like rig for cups or short tubes (dimension of a cup: $\varnothing 33/\varnothing 23 \times 33$ [mm]); metal forming method: cold shearing during a cup backward extrusion (processing at the 1000 kN double acting hydraulic press MPH100)

CONTACT:

dr hab. inż. **Lech OLEJNIK**, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

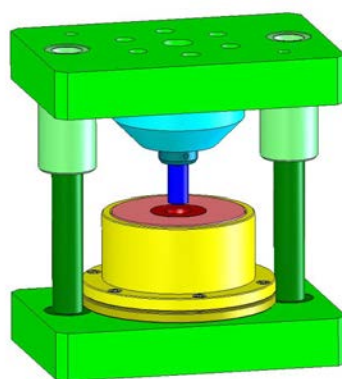
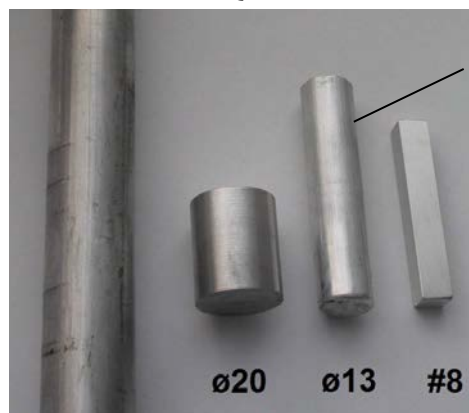
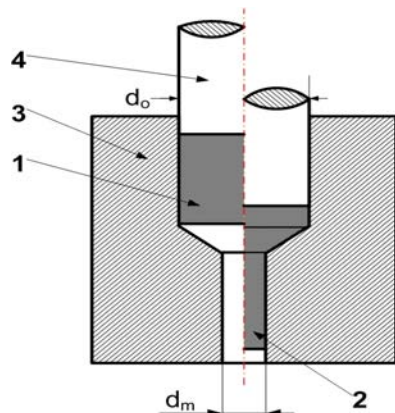
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>

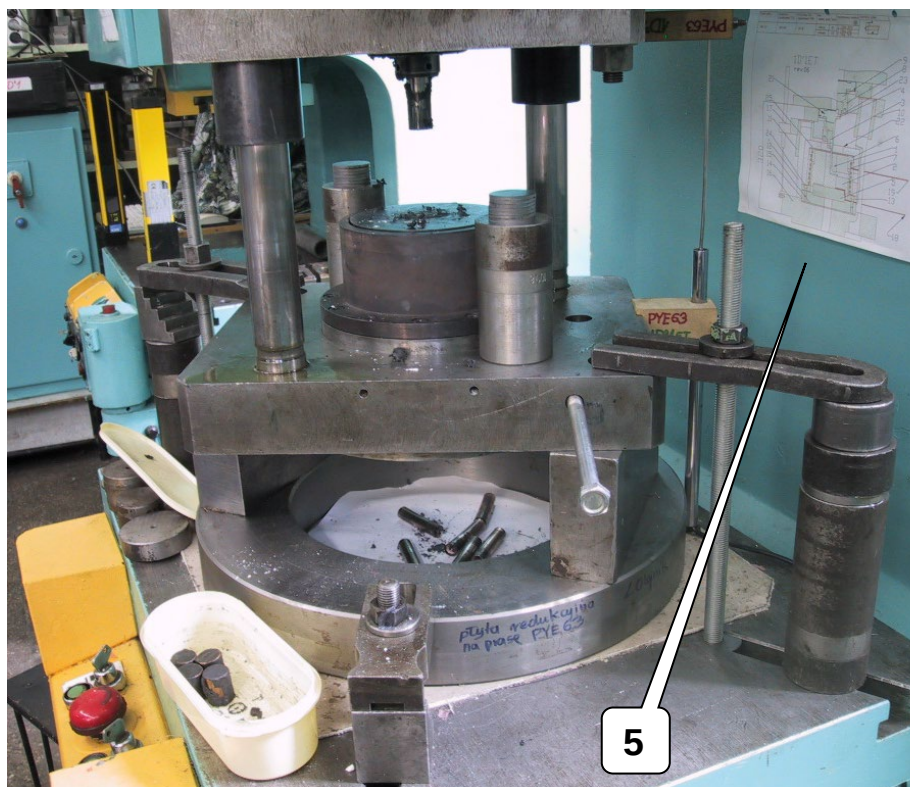


Faculty of Mechanical and Industrial Engineering

Initial Strain Hardening before ECAP (for billet size #8)



ø20 → ø13



FORM rig for initial strain hardening the billets before ECAP (reduction: ø20 mm → ø13 mm for ECAP billet size #8, metal forming method: cold forward extrusion):
 1—ø20 mm billet for cold extrusion, 2—extruded ø13 mm work-piece for milling the 8 mm × 8 mm ECAP billet (size #8), 3—insert of a prestressed die, 4—punch, 5—600 kN hydraulic press PYE63

CONTACT:

prof. nzw. dr hab. inż. **Lech OLEJNIK**

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

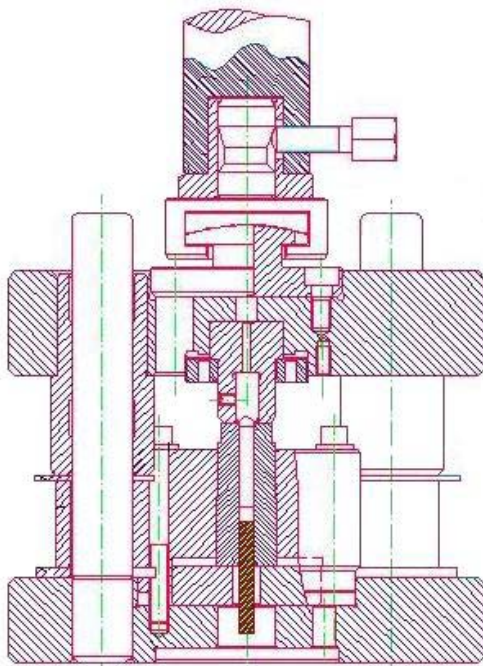
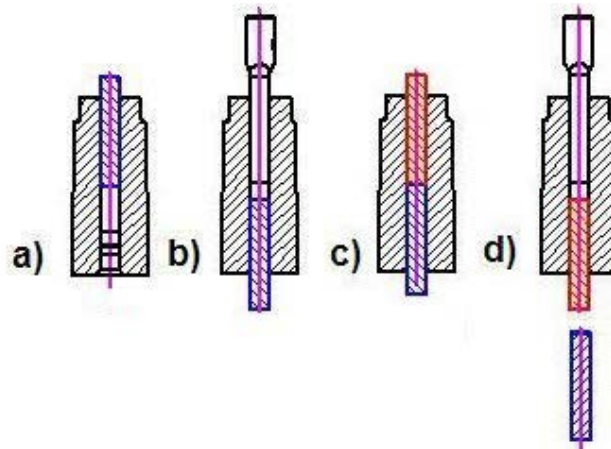
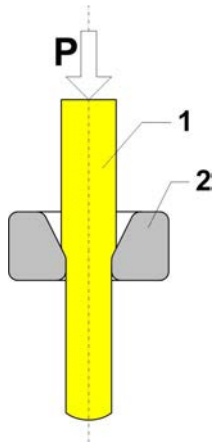
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>

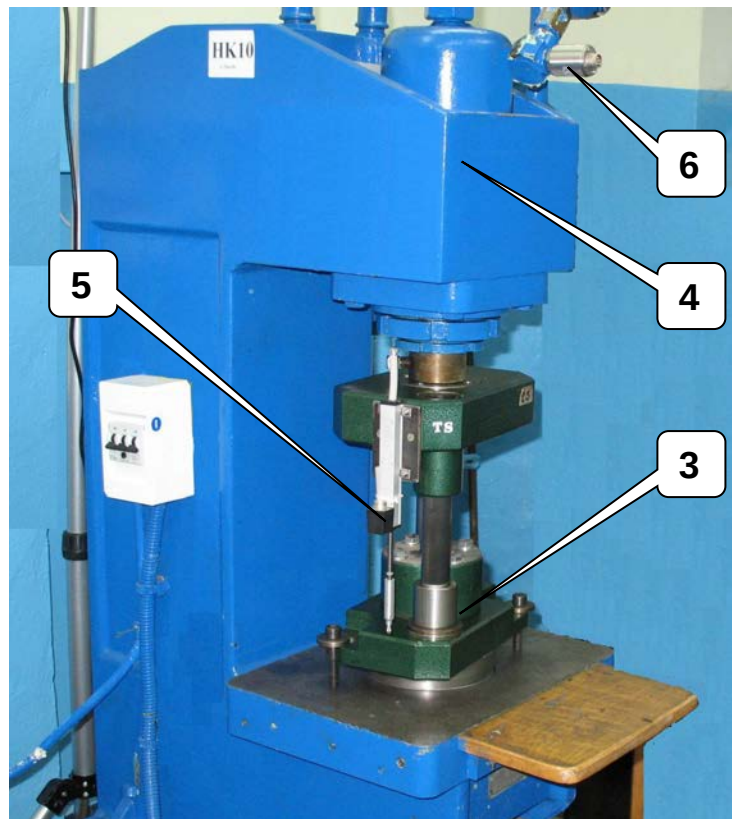


Faculty of Mechanical and Industrial Engineering

Reduction of Billet's Cross-Section Area before ECAP



Design of tooling



EXTR rig for reducing the ECAP billets (size #8, metal forming method: cold open die extrusion): 1—8 mm×8 mm billet after ECAP, 2—segmented die insert, 3—tooling TS (die set plates with pin-bushing guiding system), 4—100 kN hydraulic press HK10, 5—stroke transducer, 6—pressure transducer

CONTACT: dr hab. inż. **Lech OLEJNIK**, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

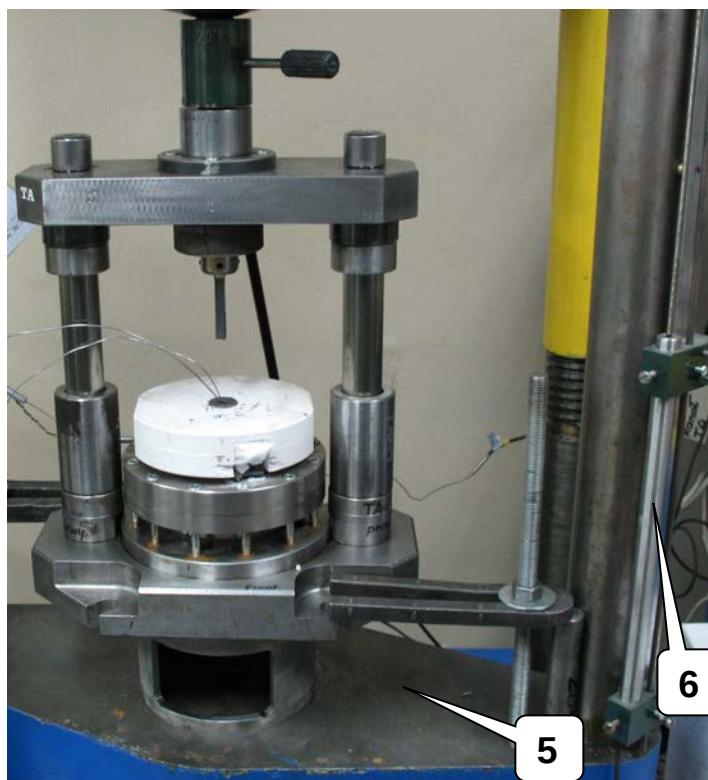
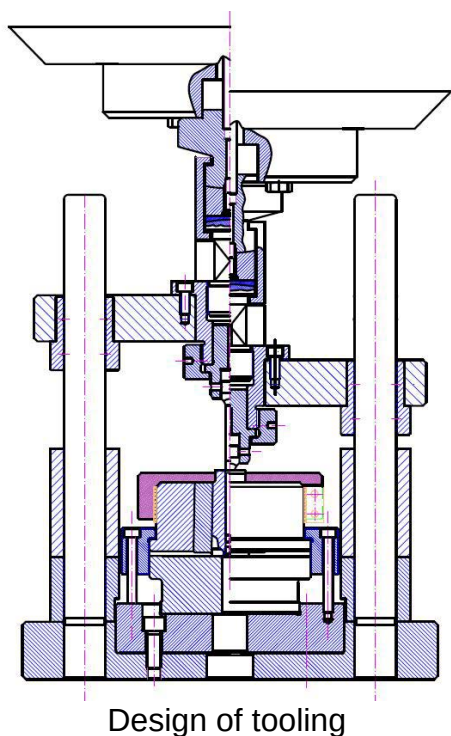
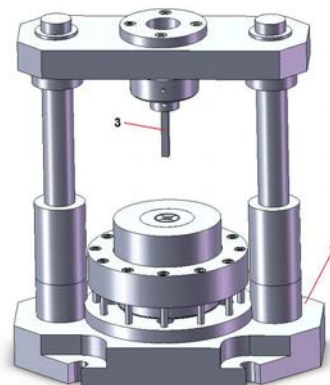
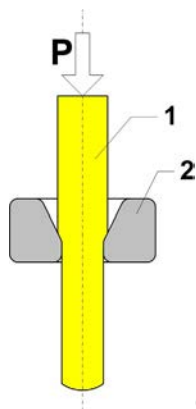
Narbutta 85, PL 02-524 Warszawa, Poland

Tel + 4822 849 9437, + 4822 849 9797 <https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Reduction of Billet's Cross-Section Area before ECAP



EXTR rig for reducing the ECAP billets (size #8, metal forming method: warm open die extrusion): 1--8 mm × 8 mm billet after ECAP, 2--segmented die insert, 3--punch, 4--die set plates with pin-bushing guiding system, 5--crosshead of the 400 kN hydraulic press ZD40, 6--stroke transducer

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

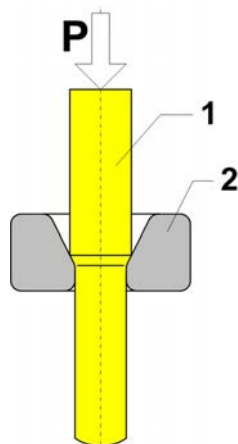
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>

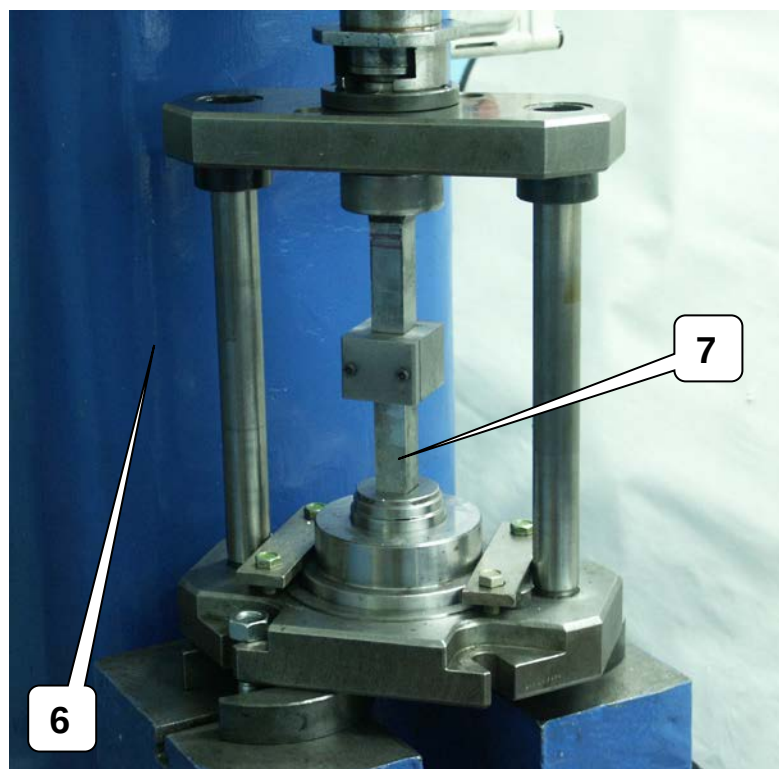
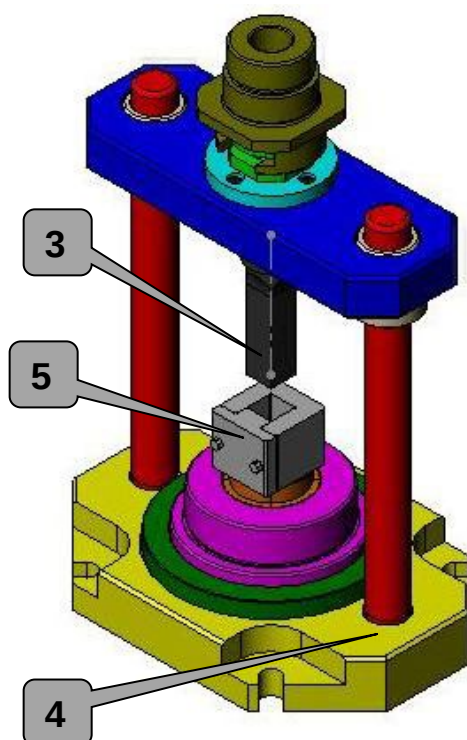
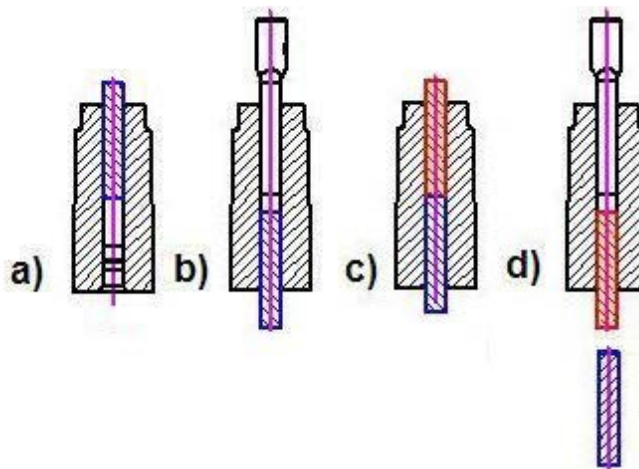


Faculty of Mechanical and Industrial Engineering

(Scaled up) Reduction of Billet's Cross-Section Area before ECAP



@ RT



EXTR rig for reducing the ECAP billets (size #26, metal forming method: cold open die extrusion): 1—26×26 [mm] billet after ECAP, 2—segmented die insert, 3—punch, 4—die set plates with pin-bushing guiding system, 5—clamping device for the uneven bit of the ECAP billet, 6—120 kN hydraulic press PH12, 7—26mm×26mm ECAP billet

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

Tel + 4822 849 9437, + 4822 849 9797

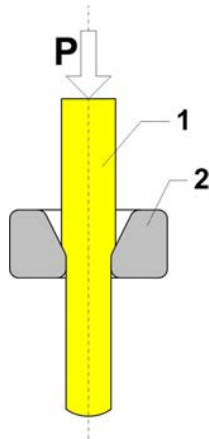
<https://www.mt.pw.edu.pl>



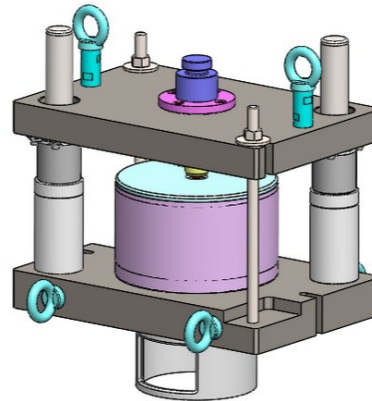
Faculty of Mechanical and Industrial Engineering

Reduction of Billet's Cross-Section Area before ECAP

Assembled die set (shown in closed position)

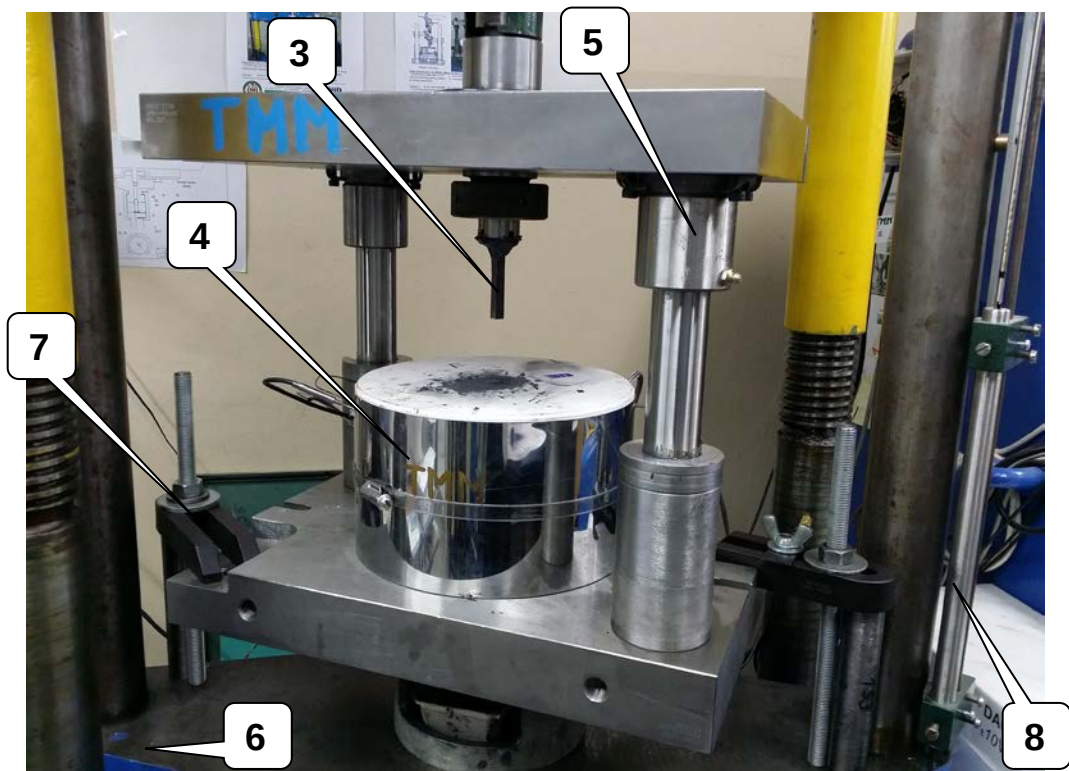


@ ET



← prepared for transportation

Assembled
die set
(shown in
open
position)
→



EXTR rig for reducing the ECAP billets (size #8, metal forming method: warm open die extrusion): 1—8 mm × 8 mm billet after ECAP, 2—segmented die insert, 3—punch, 4—armoured die equipped with heating and insulating elements, 5—die set plates with pin-bushing guiding system, 6—crosshead of the 400 kN hydraulic press ZD40, 7—clamping, 8—stroke transducer

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW, Email: lech.olejnik@pw.edu.pl



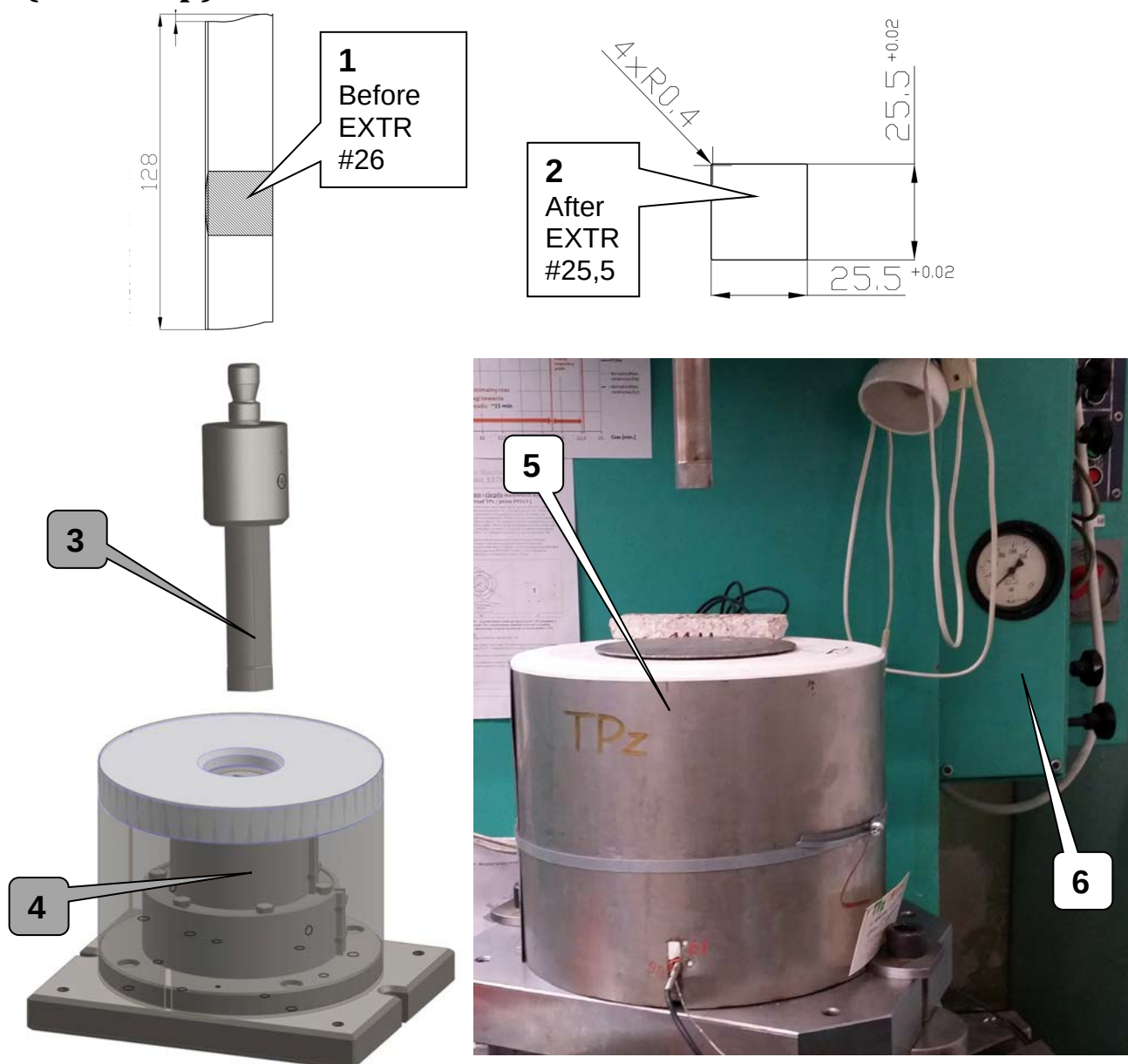
DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland
Tel + 4822 849 9437, + 4822 849 9797 <https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

(Scaled up) Reduction of Billet's Cross-Section Area before ECAP



EXTR rig for reducing the square ECAP billets (size #26, metal forming method: warm open die extrusion): 1—26 mm × 26 mm billet after ECAP, 2—reduced billet's cross section, 3—punch, 4—die set design, 5—die set view, 6—630 kN hydraulic press PYE63

CONTACT: dr hab. inż. **Lech OLEJNIK**, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

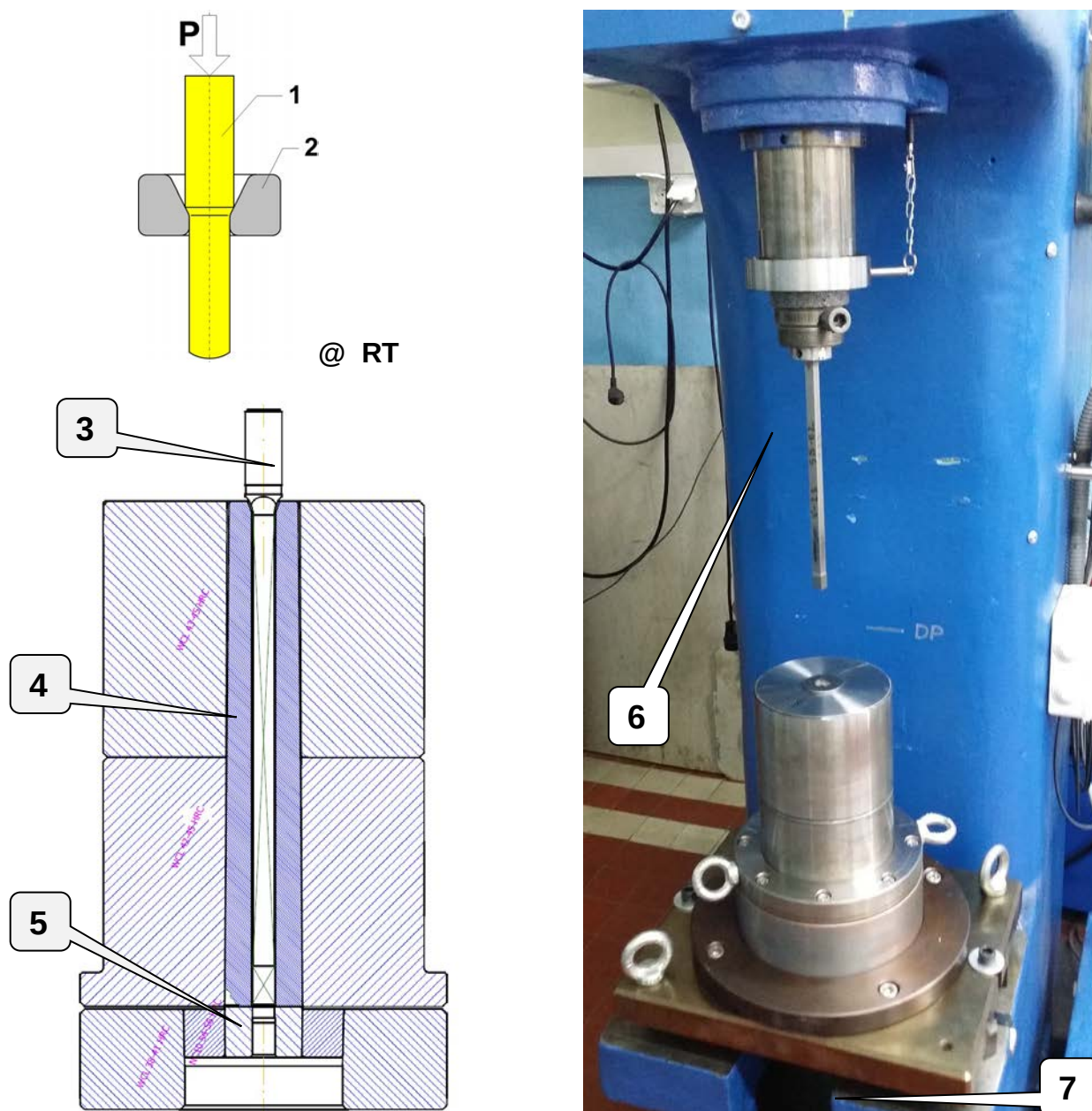
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Reduction of Billet's Cross-Section Area before I-ECAP



EXTR rig for reducing the long I-ECAP billets (size #10, metal forming method: cold open die extrusion): 1—#10 [mm²] billet after ECAP, 2—reducing die, 3—punch, 4—prestressed die container, 5—prestressed die insert, 6—frame of the 120 kN hydraulic press PH12, 7—press table

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW,

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

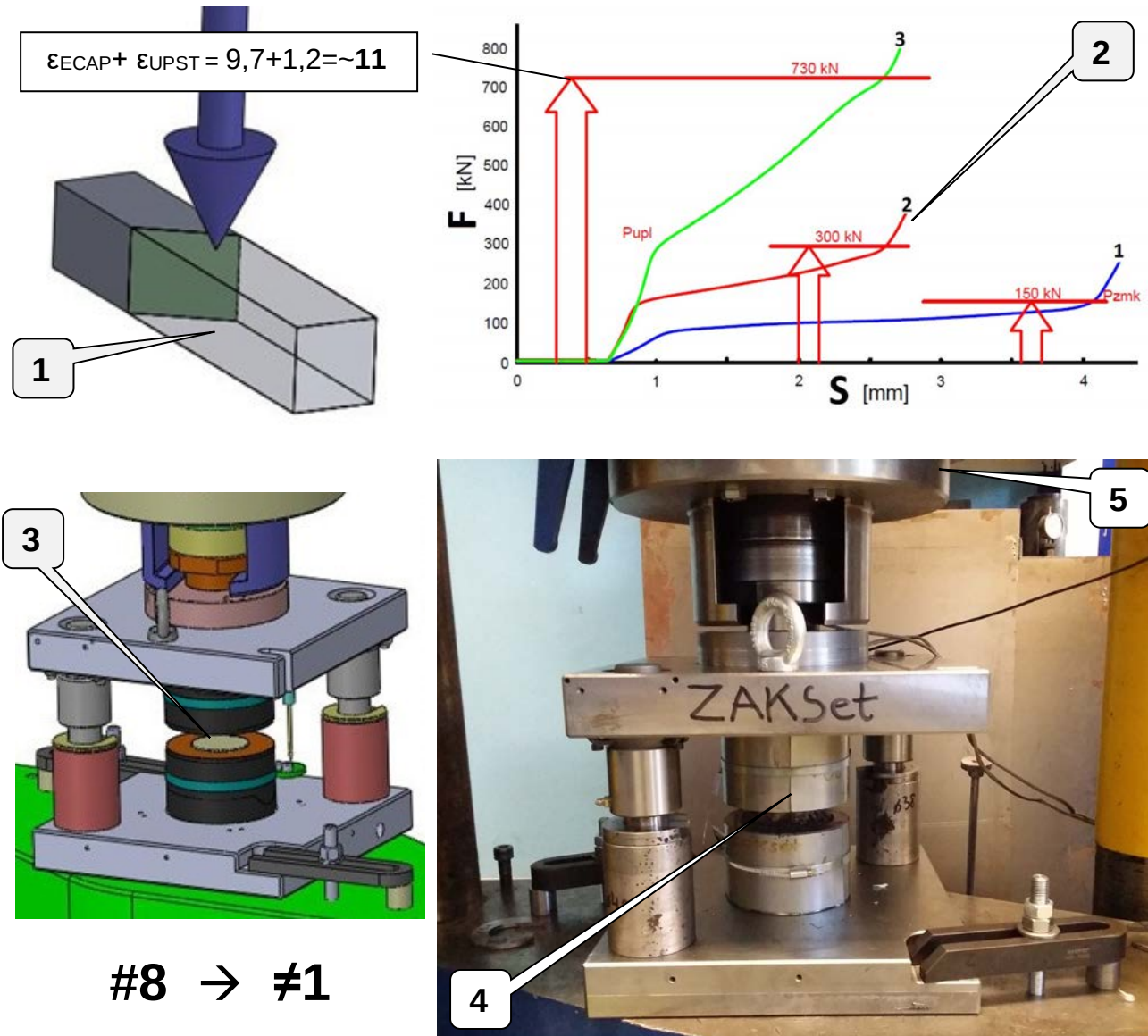
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

3 stage upsetting of ECAP billets (size #8) for 1mm UFG plates



UPST rig (#8 → #1 mm) for postprocessing the ECAP billets (size #8, metal forming method: flat-die upsetting at elevated temperature): 1—ECAP billet (size #8) before upsetting, 2—Force vs. stroke diagram during 3-stroke upsetting, 3—model of tooling ZAKSet, 4—view of ZAKSet for upset forging @ET, 5—800kN hydraulic press ZD100

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

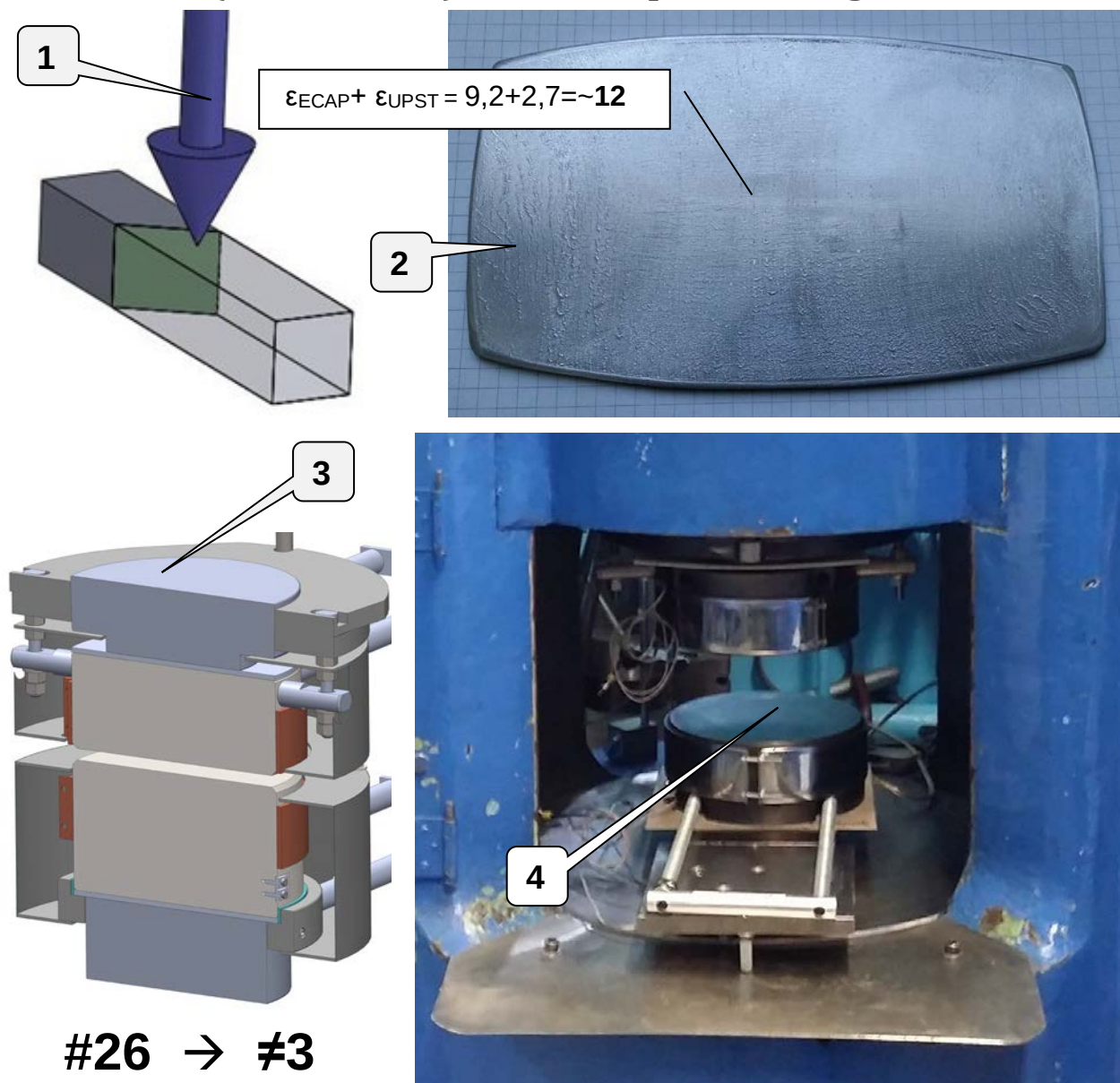
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Multi-stroke flat-die upsetting #26 bars after ECAP to obtain flat rods (thickness #3) for subsequent rolling UFG sheets



UPST rig (#26 → #3 mm) for postprocessing the ECAP billets (size #26, metal forming method: flat-die upsetting at room or elevated temperature): 1—recommended upsetting direction, 2—3 mm flat billet upset from UFG bar processed by ECAP (size #26), 3—tool design for upset forging @ET, 5—upsetting tool DGN in 10000 kN hydraulic press PYXP1000

CONTACT:

dr hab. inż. Lech OLEJNIK, prof. PW

 Email: lech.olejnik@pw.edu.pl

DEPARTMENT of METAL FORMING and CASTING

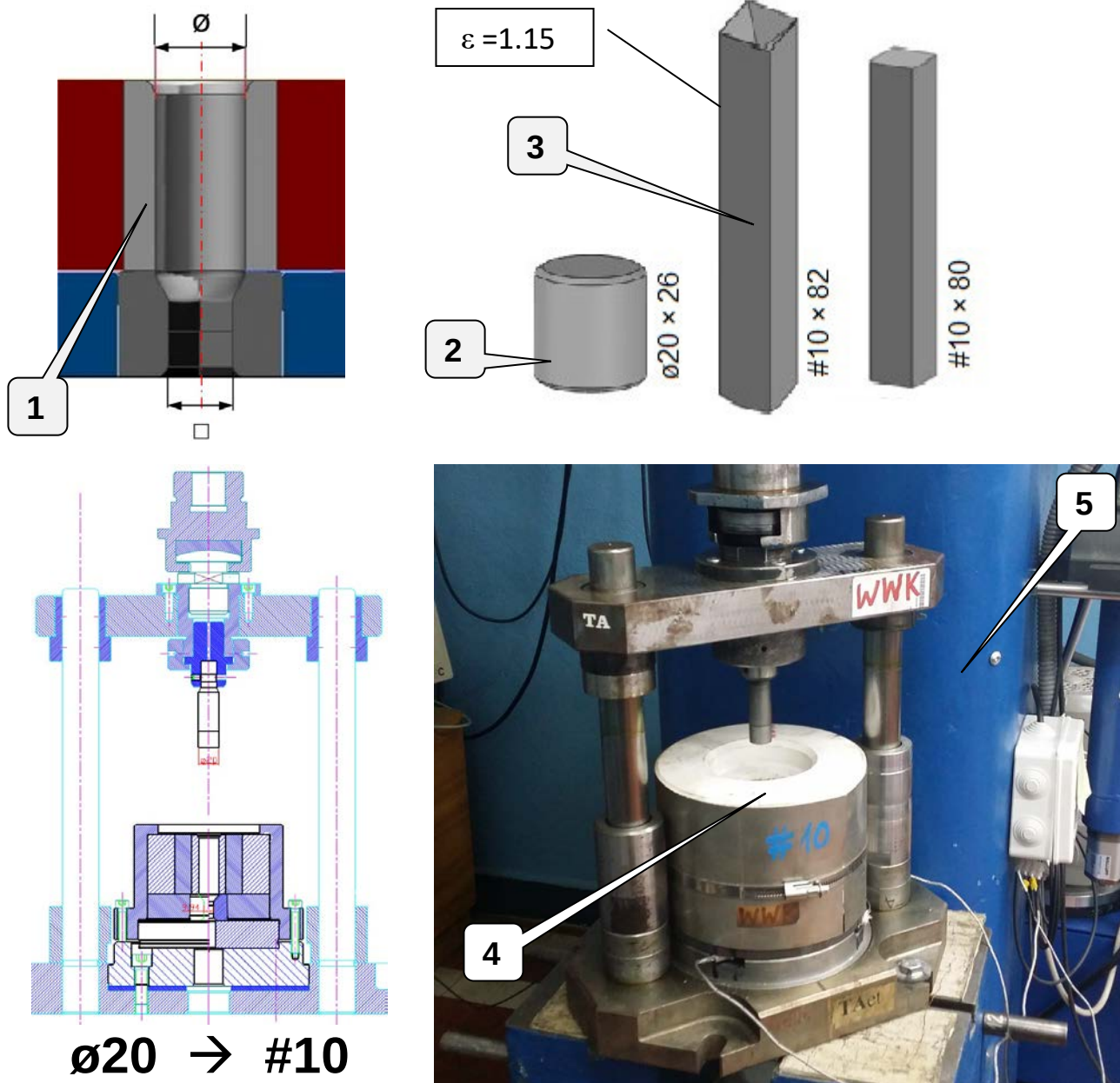
Narbutta 85, PL 02-524 Warszawa, Poland

Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>

Faculty of Mechanical and Industrial Engineering

Square billets (size #10) for ECAP with initial strain hardening



FORM rig ($\varnothing 20 \rightarrow \#10$ mm) for shaping the ECAP billets (size #10, metal forming method: forward extrusion at elevated temperature): 1—prestressed die for extrusion, 2— $\varnothing 20$ mm billet for extrusion, 3—extruded #10 [mm²] work-piece for ECAP billet (size #10), 4—extrusion tooling WWK, 5—120 kN hydraulic press PH12

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

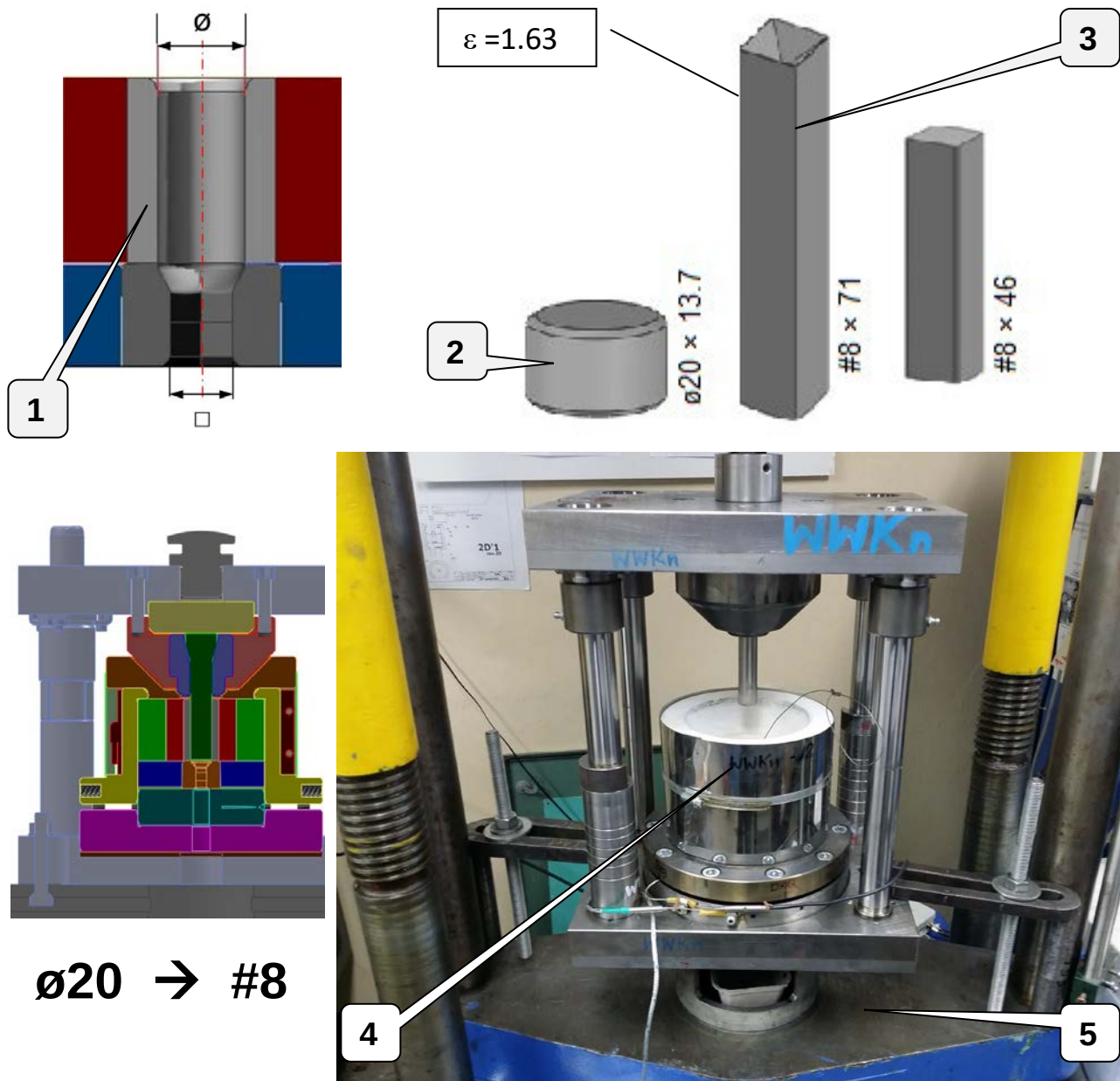
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Square billets (size #8) for ECAP with initial strain hardening



FORM rig ($\varnothing 20 \rightarrow \#8$ [mm]) for shaping the ECAP billets (size #8, metal forming method: forward extrusion at elevated temperature): 1—prestressed die for extrusion, 2— $\varnothing 20$ mm billet for extrusion, 3—extruded #8 [mm²] work-piece for ECAP billet (size #8), 4—extrusion tooling WWKn, 5—400 kN hydraulic press ZD40

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

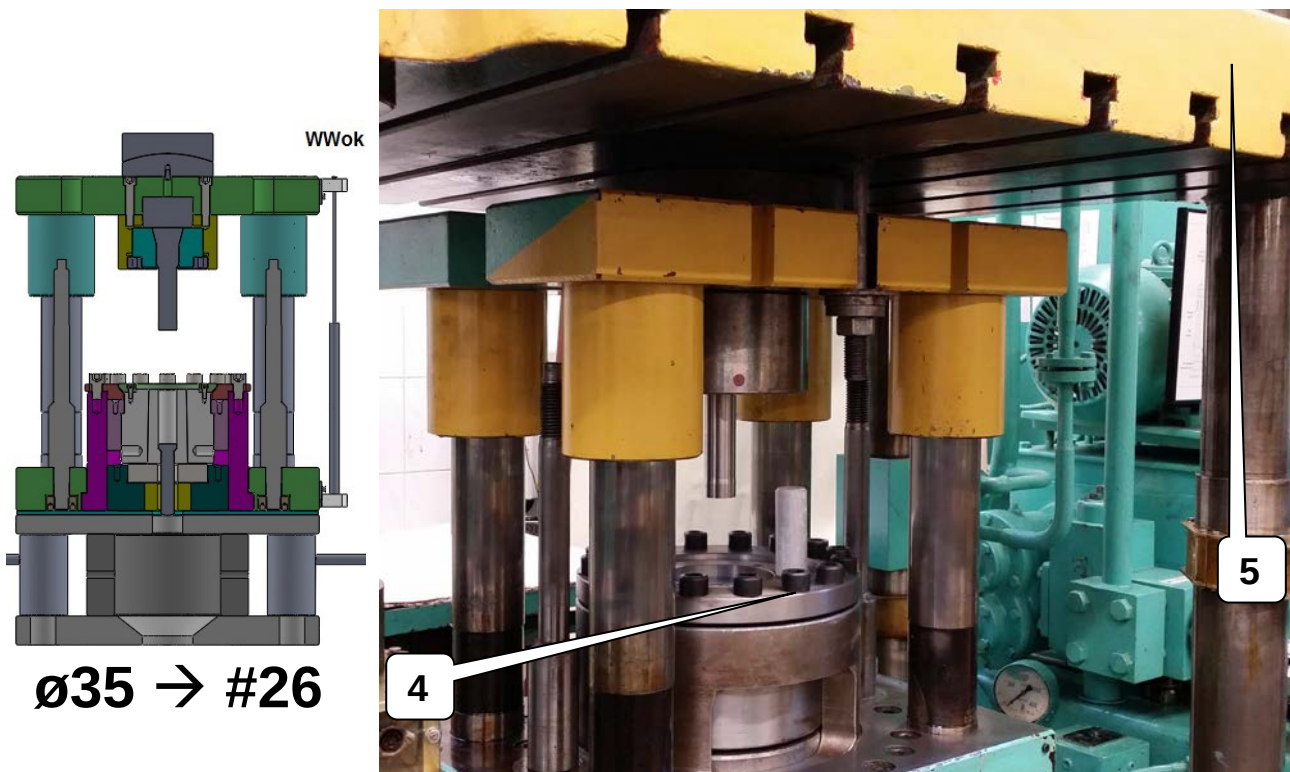
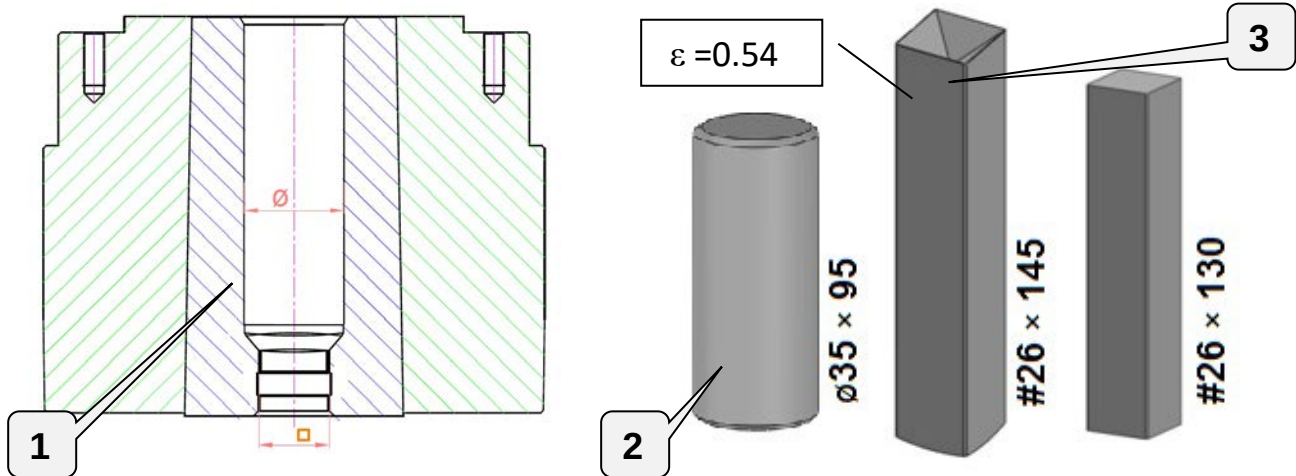
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Strain hardened billets for ECAP (square bars, size #26)



FORM rig ($\varnothing 35 \rightarrow \#26$ mm) for shaping the ECAP billets (size #26, metal forming method: forward extrusion at room or elevated temperature): 1—prestressed die for extrusion, 2— $\varnothing 35$ mm billet for extrusion, 3—extruded #26 [mm²] work-piece for ECAP billet (size #26), 4—extrusion tooling WWok, 5—2500 kN hydraulic press PYS250

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

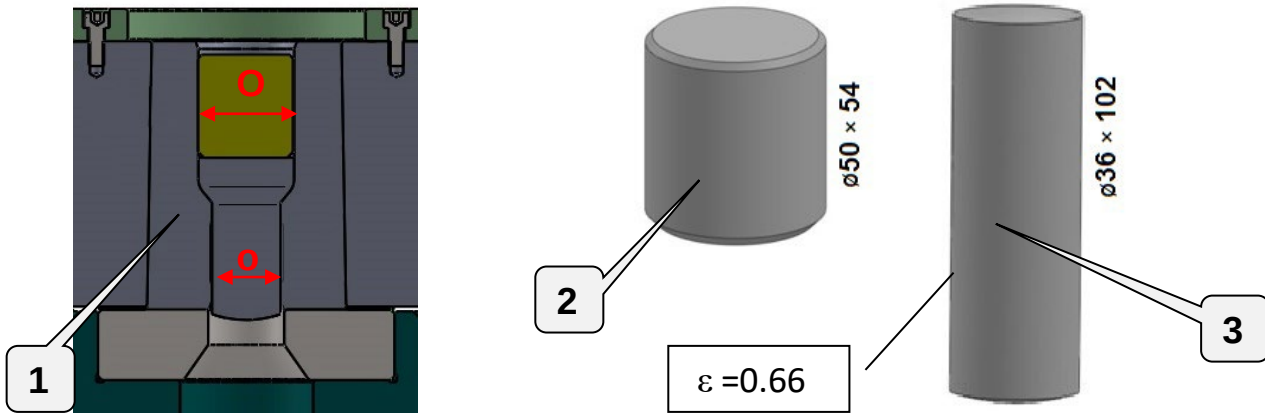
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>

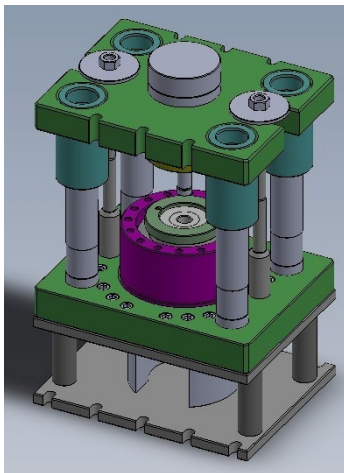


Faculty of Mechanical and Industrial Engineering

Reduction of billet size with initial strain hardening



WWoo



$\varnothing 50 \rightarrow \varnothing 36$



FORM rig ($\varnothing 50 \rightarrow \varnothing 36$ mm) for pre-shaping the ECAP billets (size #26, metal forming method: cold forward extrusion): 1—prestressed die for extrusion, 2— $\varnothing 50$ mm billet for extrusion, 3—extruded $\varnothing 36$ mm work-piece for further extrusion, 4—extrusion tooling WWoo, 5—2500 kN hydraulic press PYS250

CONTACT:

dr hab. inż. **Lech OLEJNIK**, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

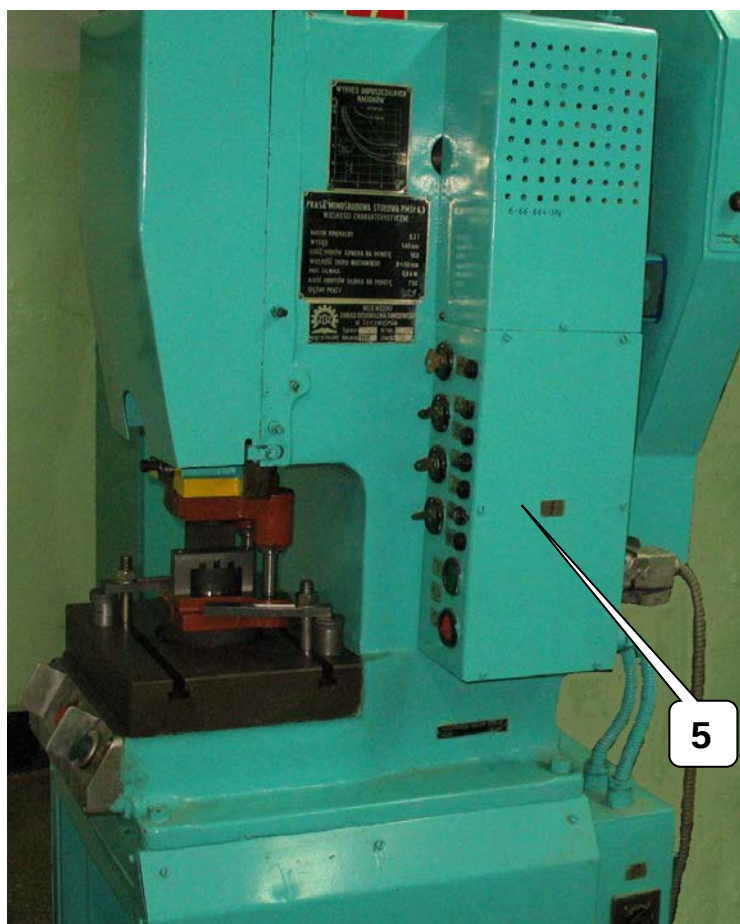
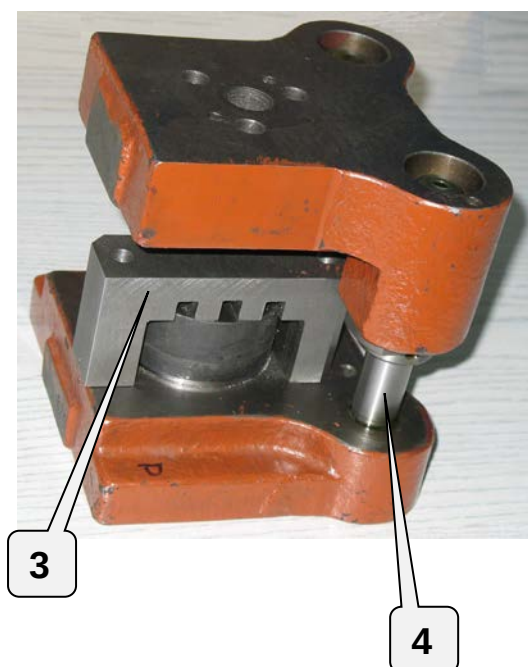
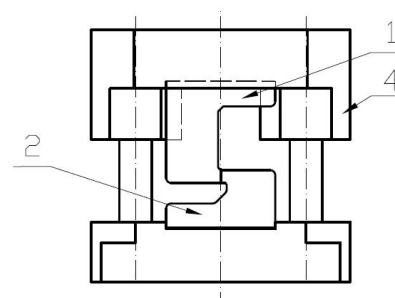
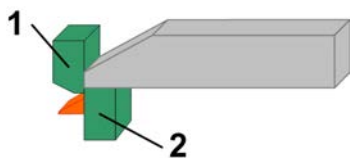
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Cropping of Billet's Sharp Ends after ECAP



CUTN rig for cutting the ECAP billets (size #8, metal forming method: cold cropping):

1-- cropping punch, 2--cropping die, 3--three bay billet jig, 4--die set plates with pin-bushing guiding system, 5--63 kN eccentric press PMSt6,3

CONTACT:

dr hab. inż. **Lech OLEJNIK**, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

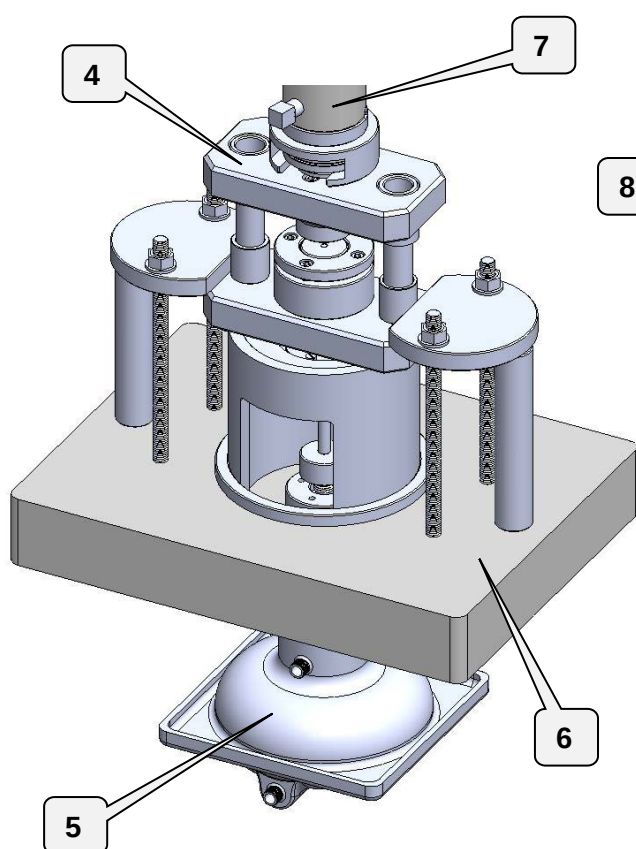
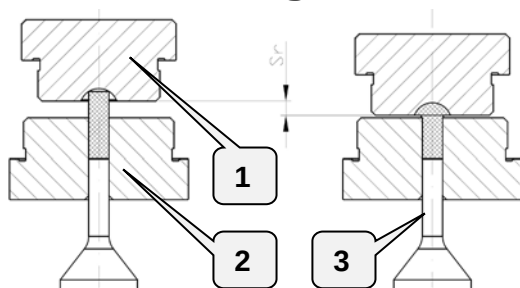
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Forming of round head rivets from UFG metals



UPST rig for heading rivets ($\varnothing 5 \times 10$, size is according to DIN 124 standardised):

1—heading punch, 2—upsetting die, 3—ejecting pin, 4—die set plates with pin-bushing guiding system, 5—pneumatic ejector, 6—press table, 7—press ram, 8—80 kN hydraulic press HK10, 9—control panel of the pneumatic drive

CONTACT:

dr hab. inż. **Lech OLEJNIK**, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



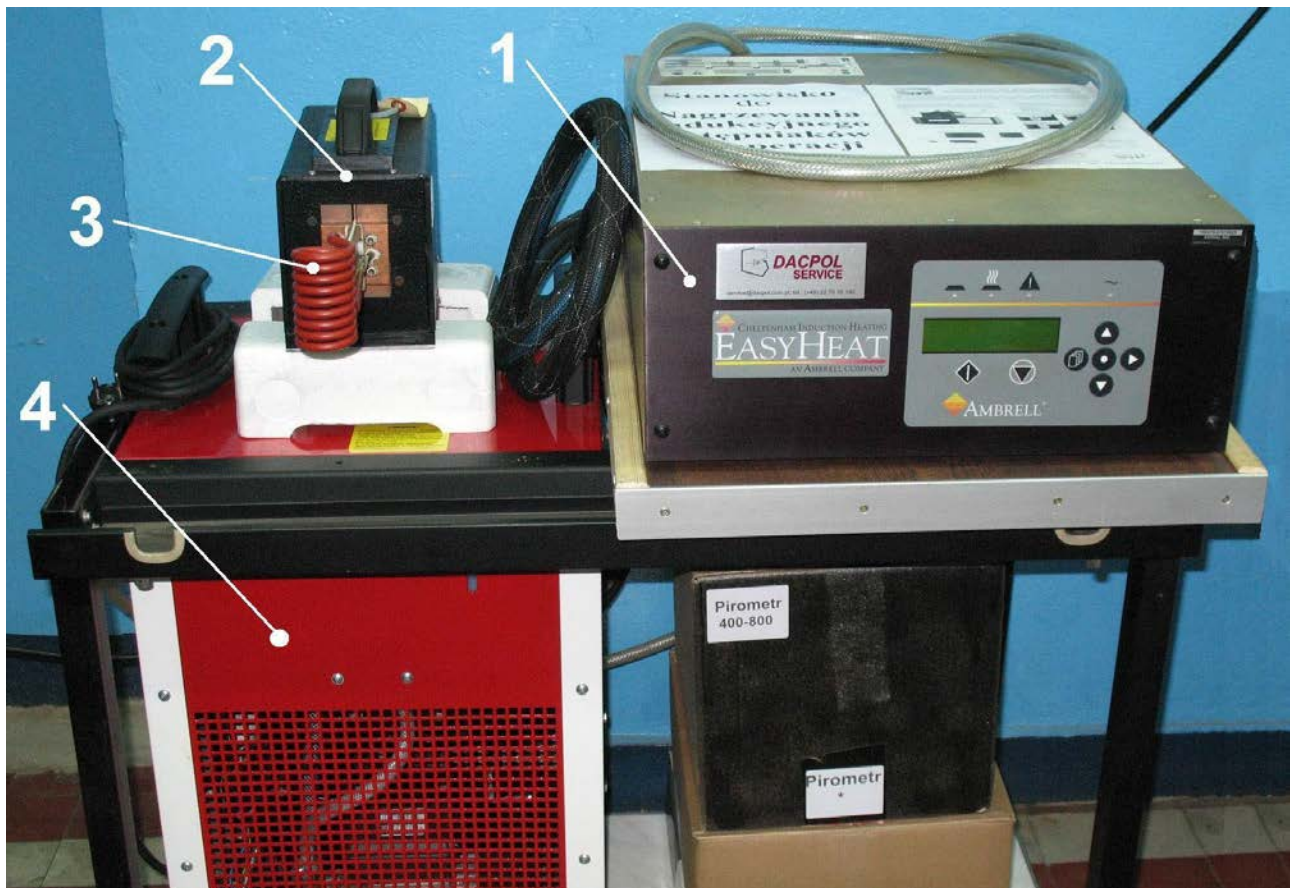
Faculty of Mechanical and Industrial Engineering

Precision Induction Heating Equipment for ECAP billets



Surface of the ECAP billet
(Al-Mg alloy covered with calcium aluminate coating and soaked with soap for lubrication)
← before heating

after heating →



Induction heating rig for 8mm×8mm and 26mm×26mm ECAP billets:

1--induction power supply, 2--remote heat station, 3--water cooled induction-heating coil made of copper tubing, 4--heat exchanger for water-cooling system

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

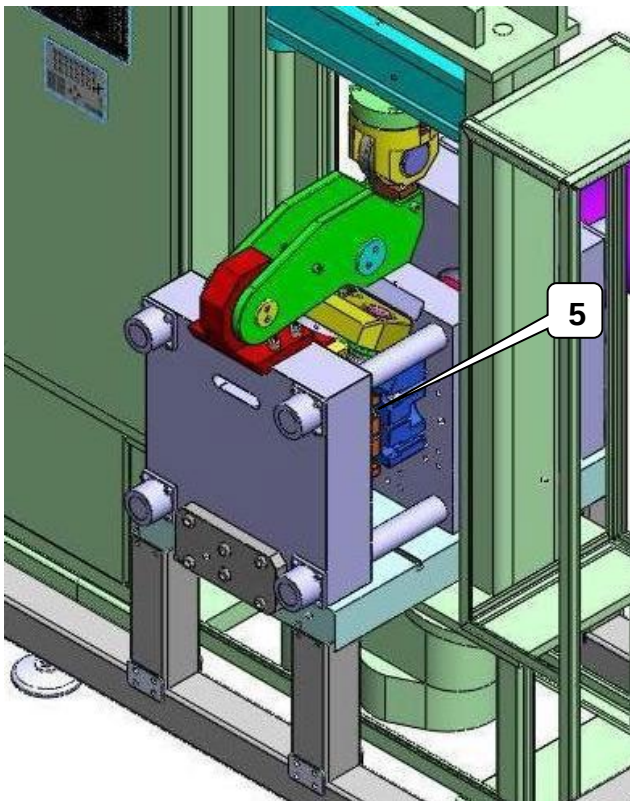
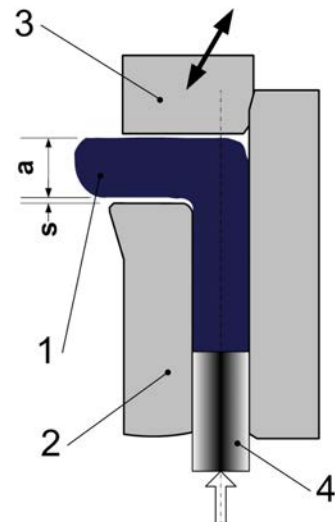
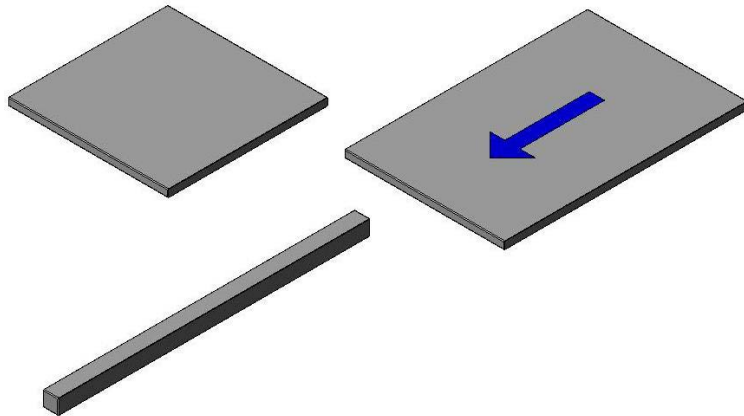
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Special ISx machine for incremental ECAP of bars and plates



I-ECAP rig (bars $\rightarrow 10 \times 10 \times 205$ [mm], plates $\rightarrow 3 \times 62 \times 105$ [mm]):

1--billet, 2-- die insert, 3--punch, 4--pusher, 5—tool set

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

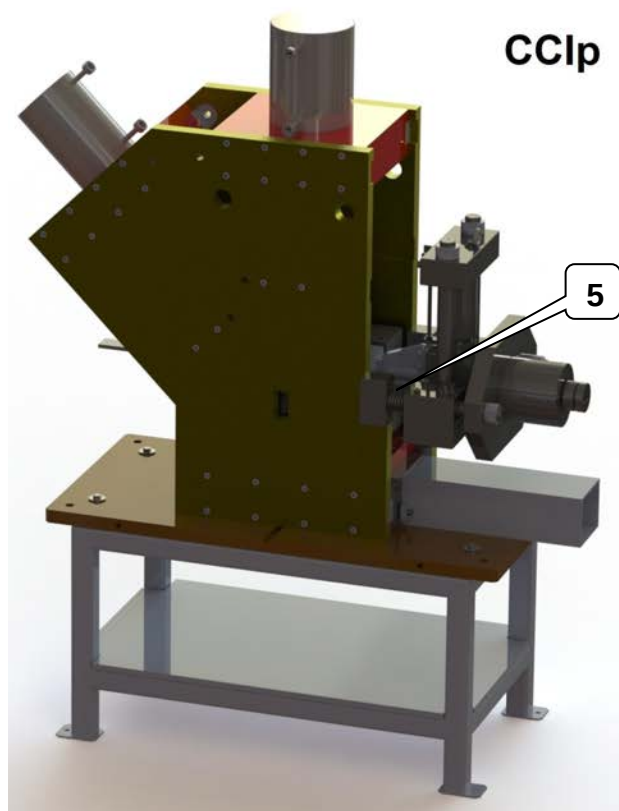
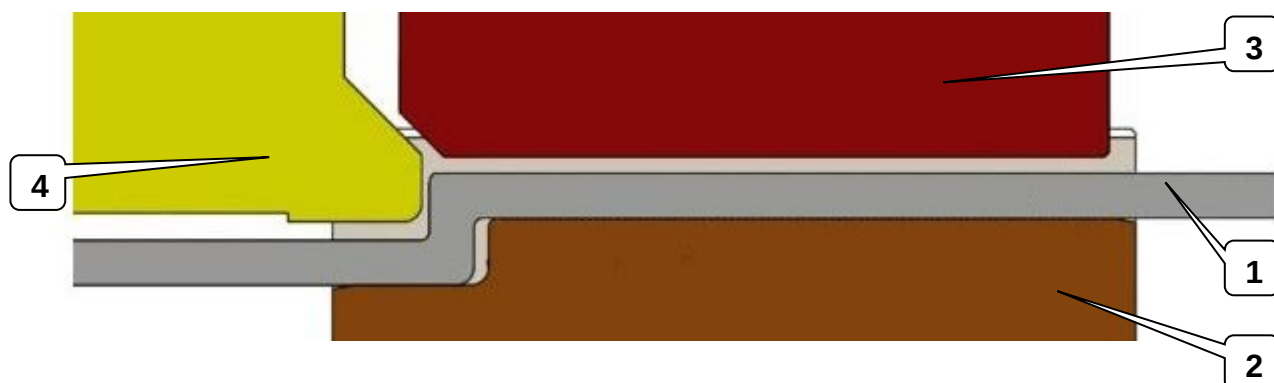
Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering

Hydraulically driven special CClp machine for incremental ECAP of flat bars



I-ECAP rig (cross-section of bars $\rightarrow 10 \times 50$ [mm], length $\rightarrow$ infinitely long):

1--billet, 2-- die, 3--clamp, 4--punch, 5--feeder, 6--HPSU

CONTACT: dr hab. inż. Lech OLEJNIK, prof. PW

Email: lech.olejnik@pw.edu.pl



DEPARTMENT of METAL FORMING and CASTING

Narbutta 85, PL 02-524 Warszawa, Poland

Tel + 4822 849 9437, + 4822 849 9797

<https://www.mt.pw.edu.pl>



Faculty of Mechanical and Industrial Engineering