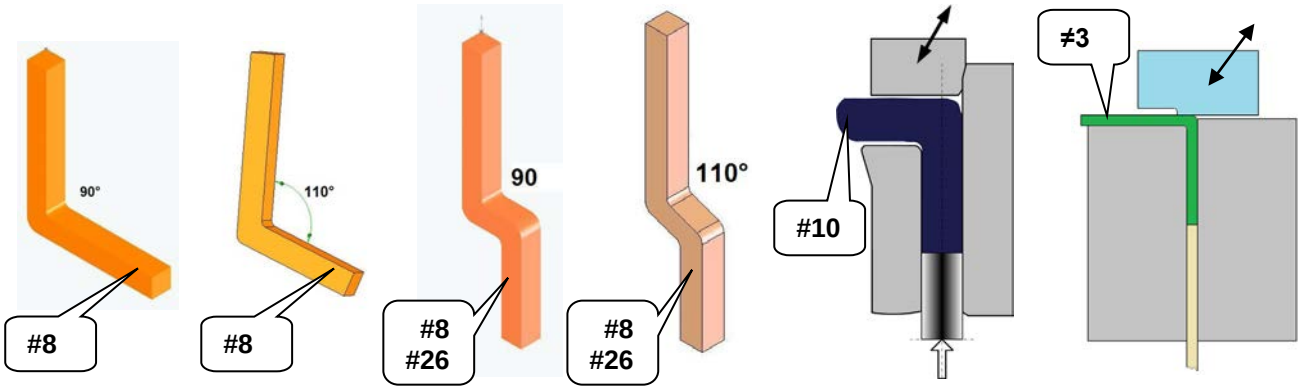
SPD facilities

for grain refinement



EQUIPMENT in the UFGTechLAB workshop for hybrid SPD
(**hbrd**SPD = **pre**SPD + SPD + **post**SPD)

Schematics of hybrid SPD developed for production of UFG sheets

(I) **pre**SDP	(II) SPD	(III) **post**SPD
CUTN + FORM	ECAP + EXTR	UPST + RLNG

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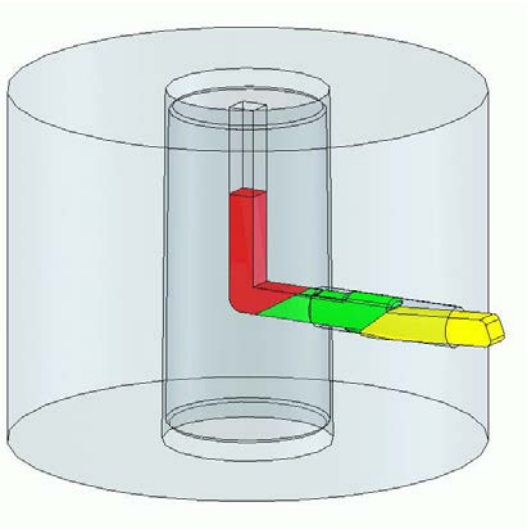
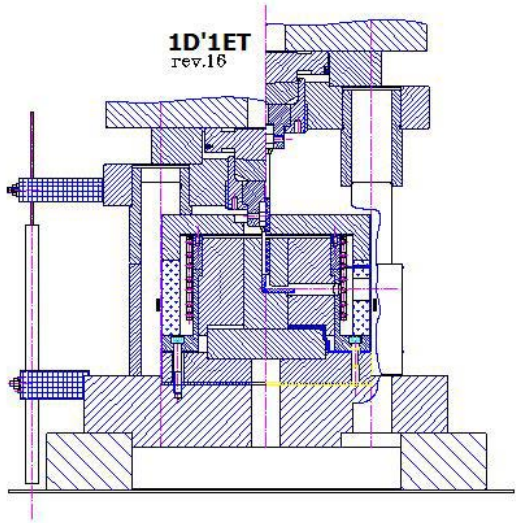
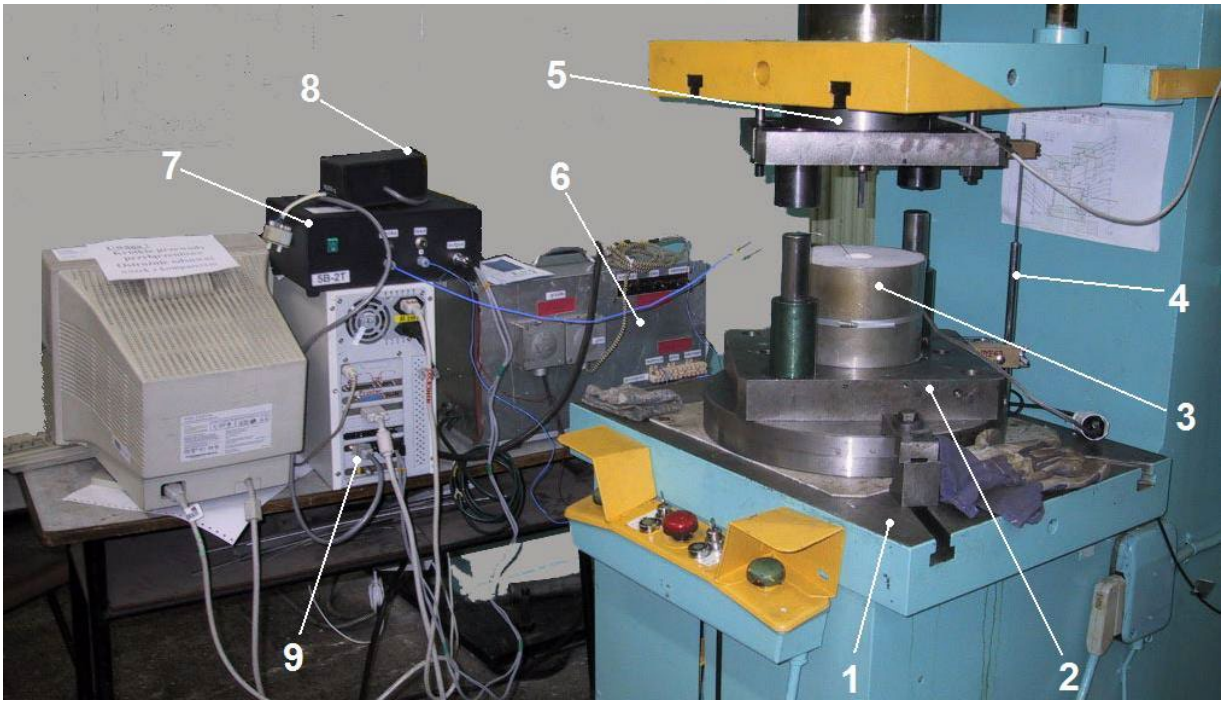
Classical Equal Channel Angular Pressing for Grain Refinement







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

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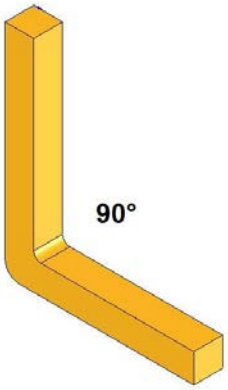
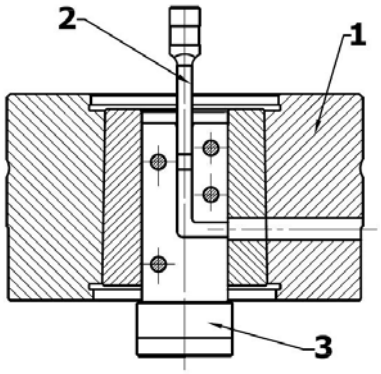
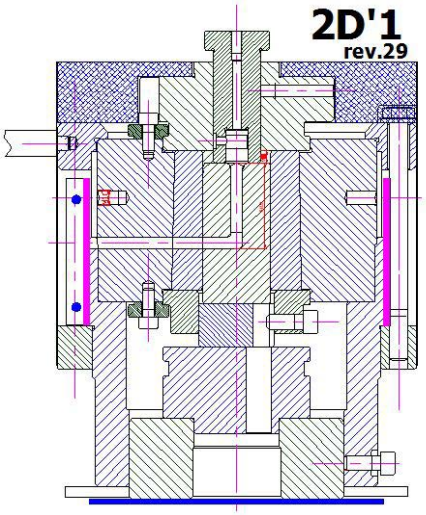




1-prestressed die
2-punch
3-base plate



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

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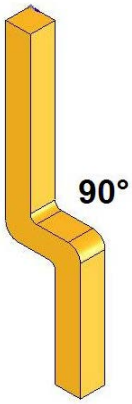

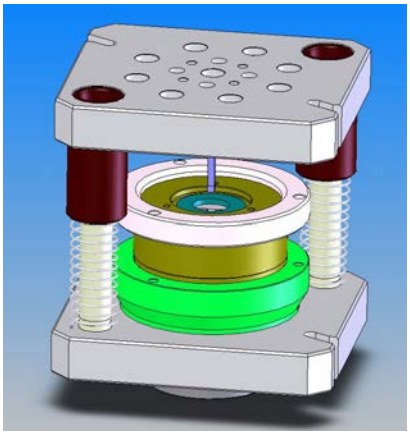

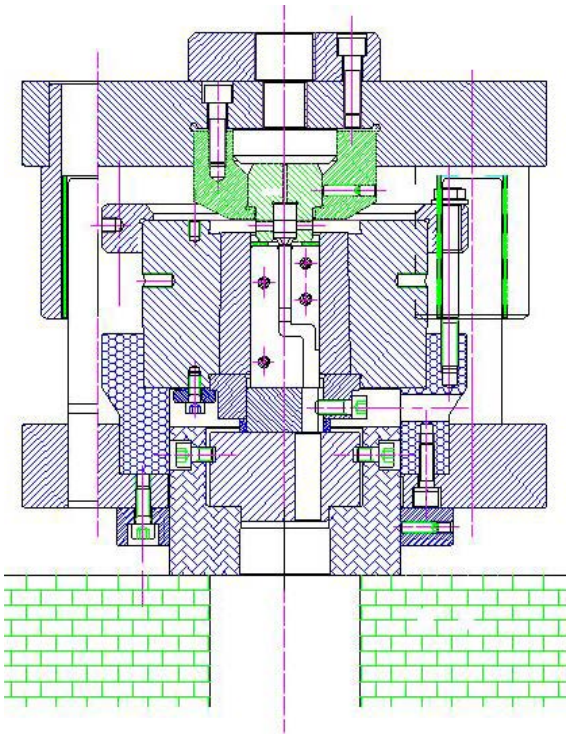

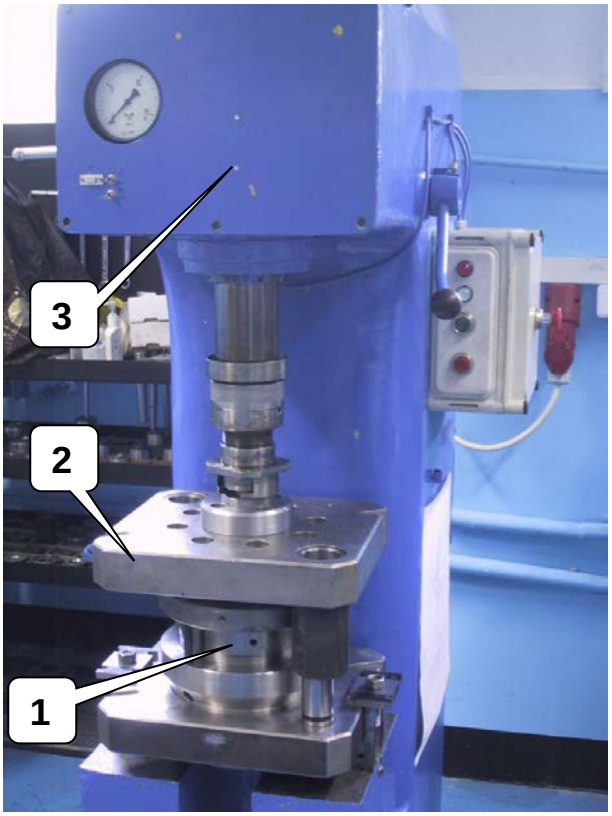

ECAP rig for **8 mm × 8 mm** billets (channel 2×90°, size: #8, metal forming type: shearing):
1--ECAP tool (140'2) for intense shear straining at room temperature, 2--die set plates with pin-bushing guiding system, 3--120 kN hydraulic press PH12

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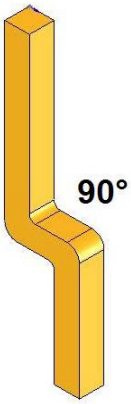

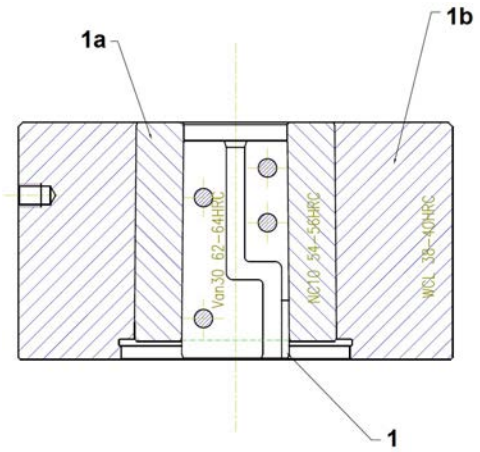

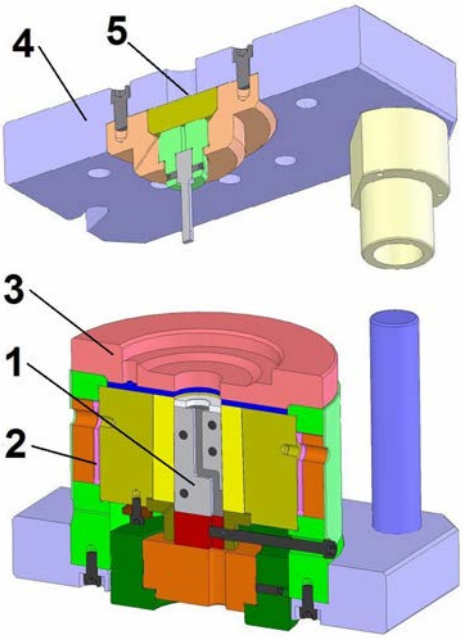

ECAP rig for **8 mm × 8 mm** billets (channel 2×90°, size #8, metal forming type: shearing):
1-segmented die insert, 1a-innner prestressing ring, 1b-outer prestressing ring, 2-electrical heater, 3-ceramic plate, 4-die set plates with pin-bushing guiding system, 5-coupling shank, 6-ECAP tool (160'2et),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

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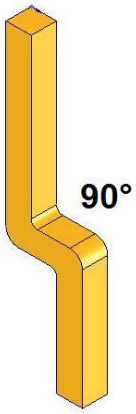
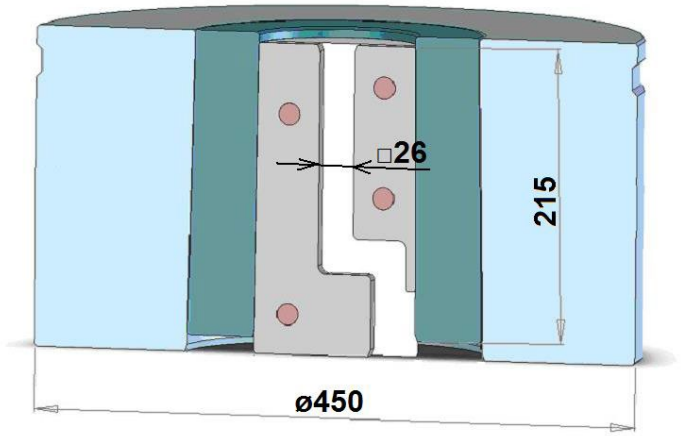
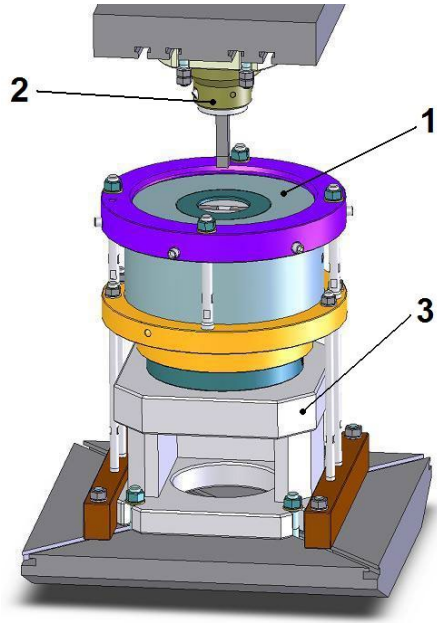
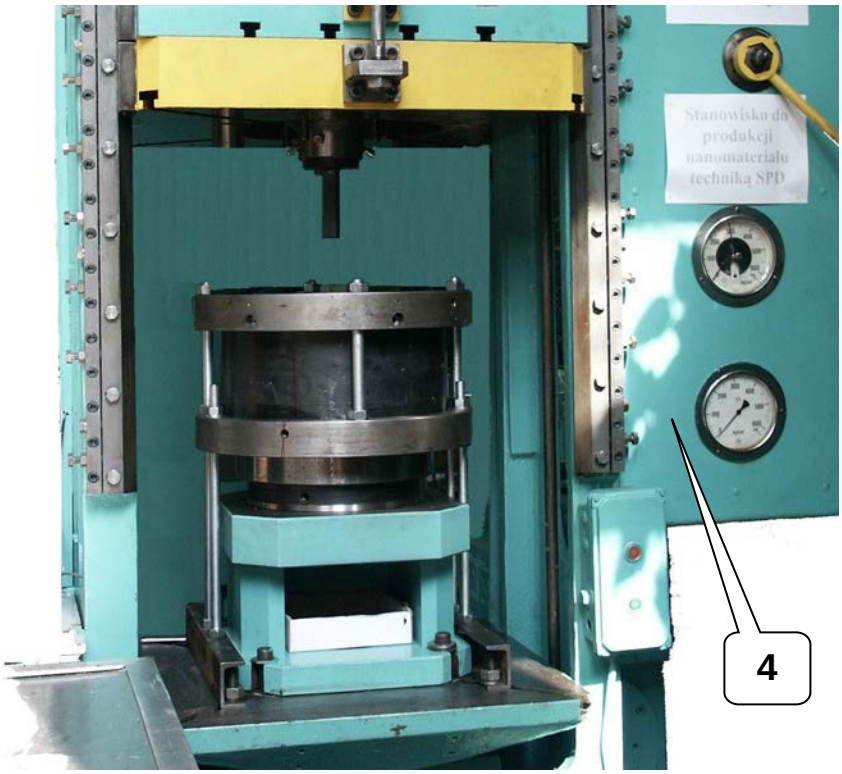
Scale up Equal Channel Angular Pressing for Grain Refinement









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, 2--punch holder,
3--base block, 4--1000 kN hydraulic press MPH100

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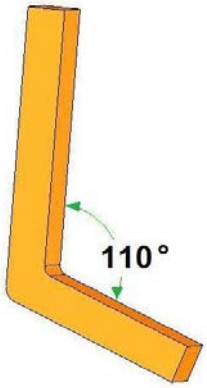
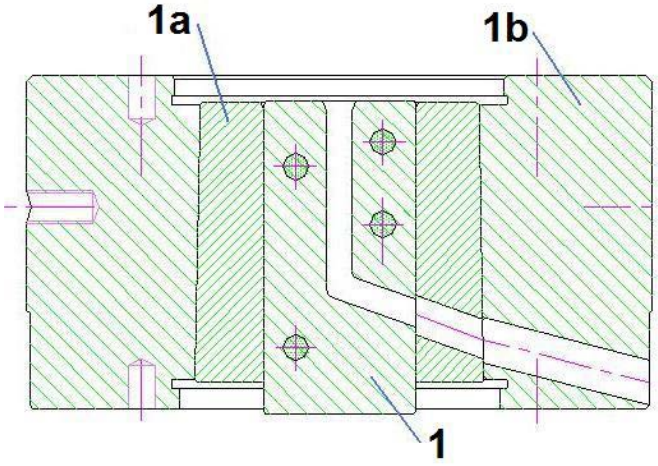
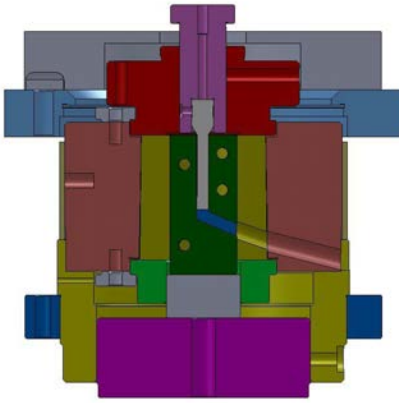
Equal Channel Angular Pressing for Grain Refinement



8 mm **× 8** mm
max.temp. **400 °C**





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

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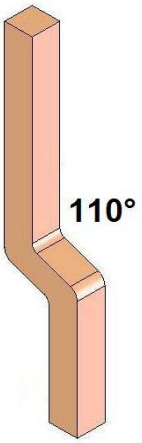

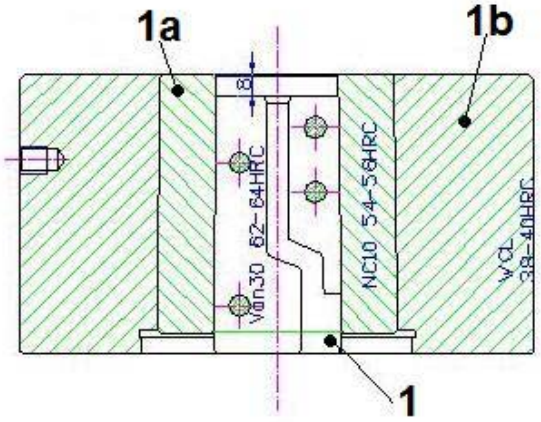

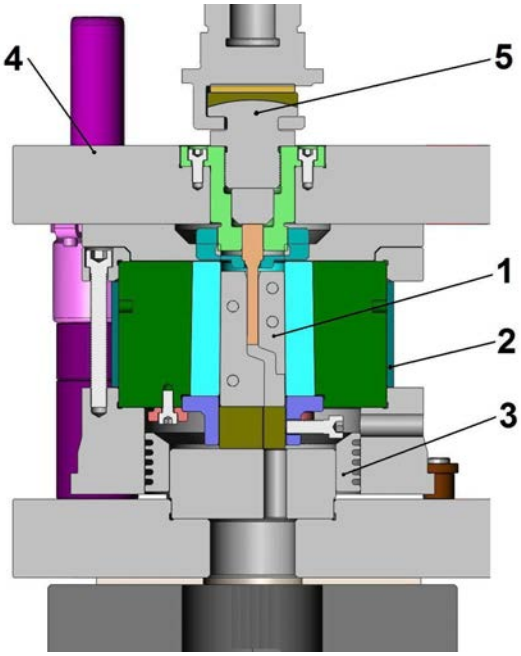

ECAP rig for **8 mm ×8 mm** billets (channel 2×110°, size: #8, metal forming type: shearing):
1-segmented die insert, 1a-innner prestressing ring, 1b-outer prestressing ring, 2-electrical heater, 3-water cooling ring, 4-die set plates with pin-bushing guiding system, 5-coupling shank, 6-ECAP tool (11zet),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

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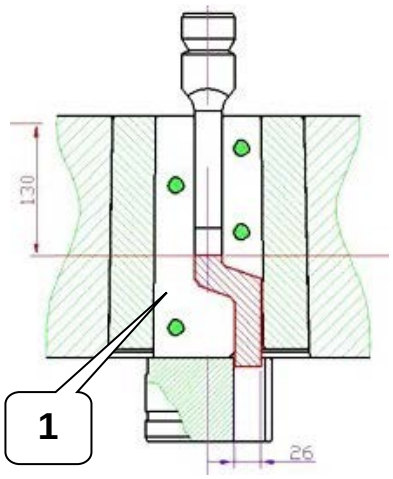
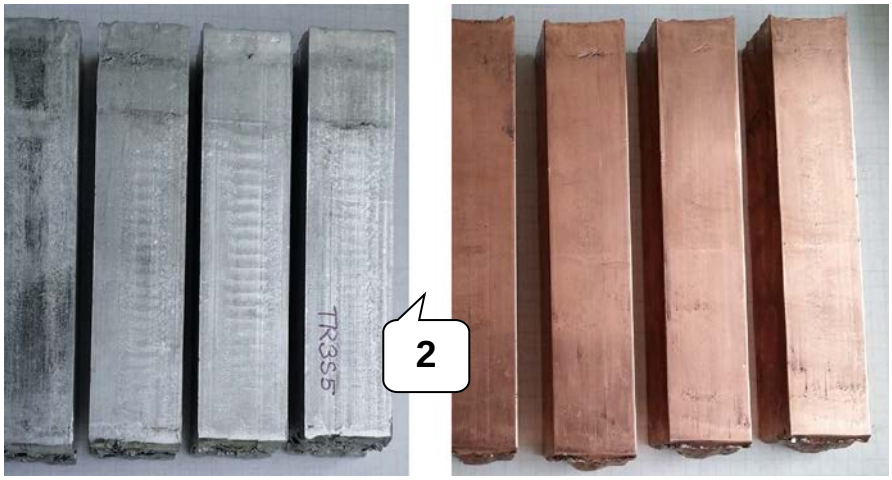
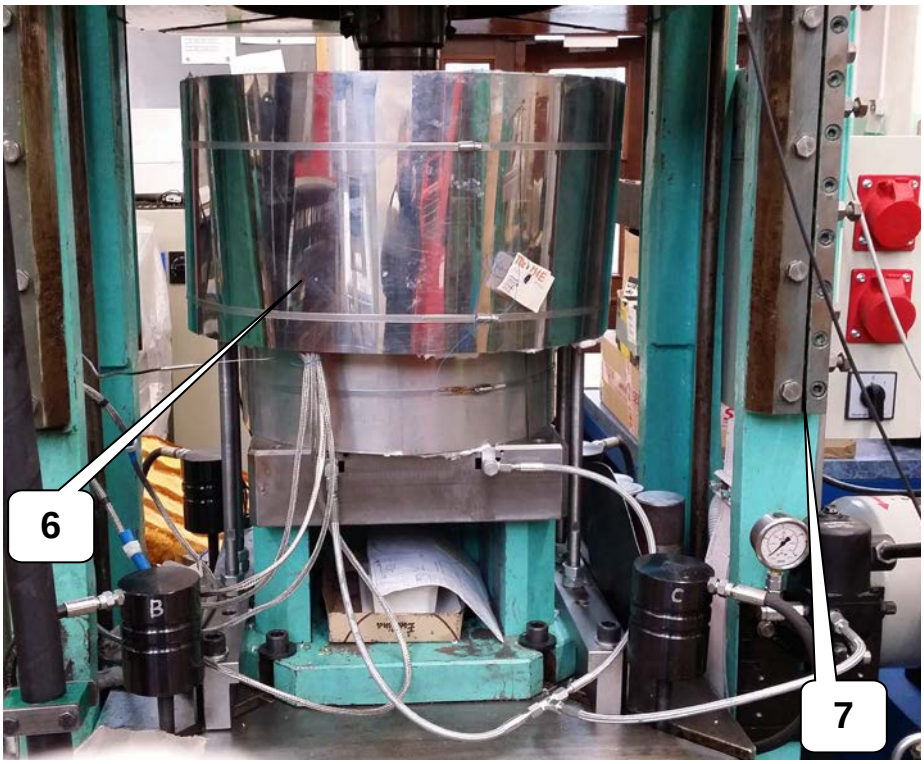
Scaled up Equal Channel Angular Pressing for Grain Refinement







ECAP rig for **26 mm × 26 mm** billets (channel 2×110°, 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

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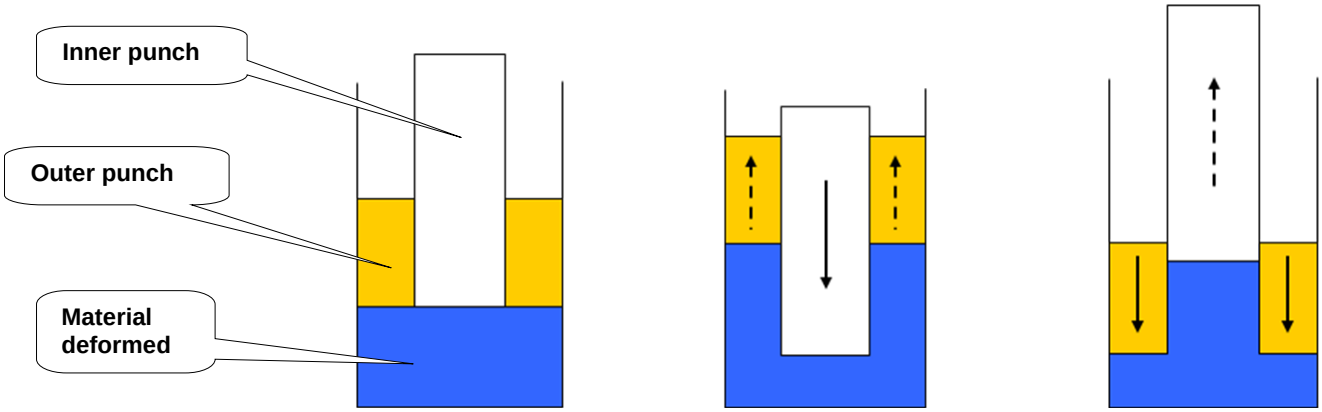
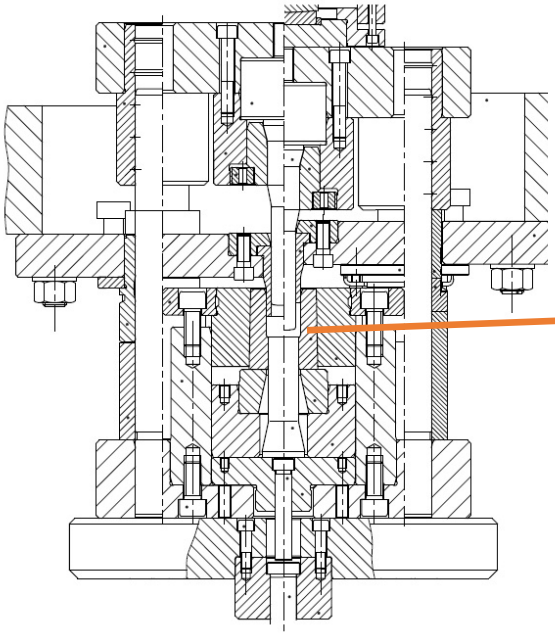
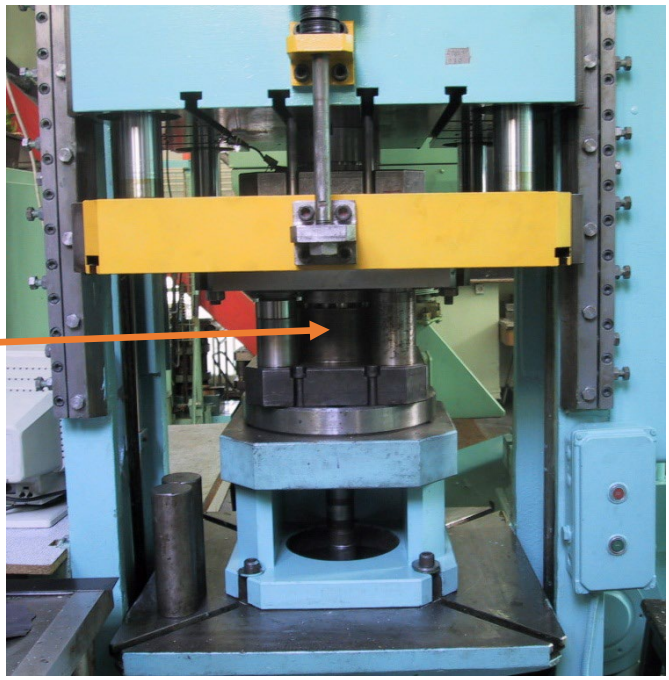
Nanostructuring bulk metals by SPD

Cyclic Backward Extrusion (CBE)







ECAP-like rig for cups or short tubes (dimension of a cup: ø33/ø23×33 [mm]); metal forming method: cold shearing during a cup backward extrusion (processing at the 1000 kN double acting hydraulic press MPH100)

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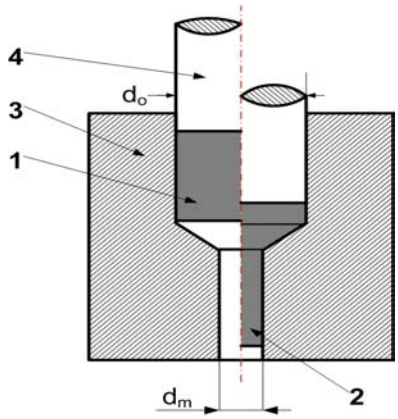
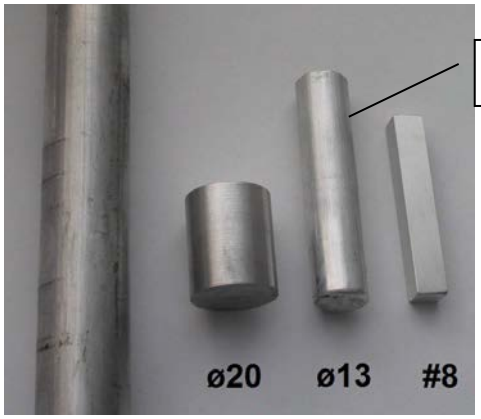
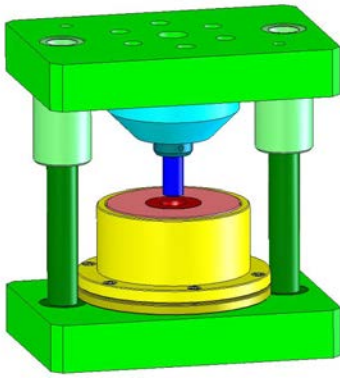
Initial Strain Hardening before ECAP (for billet size #8)

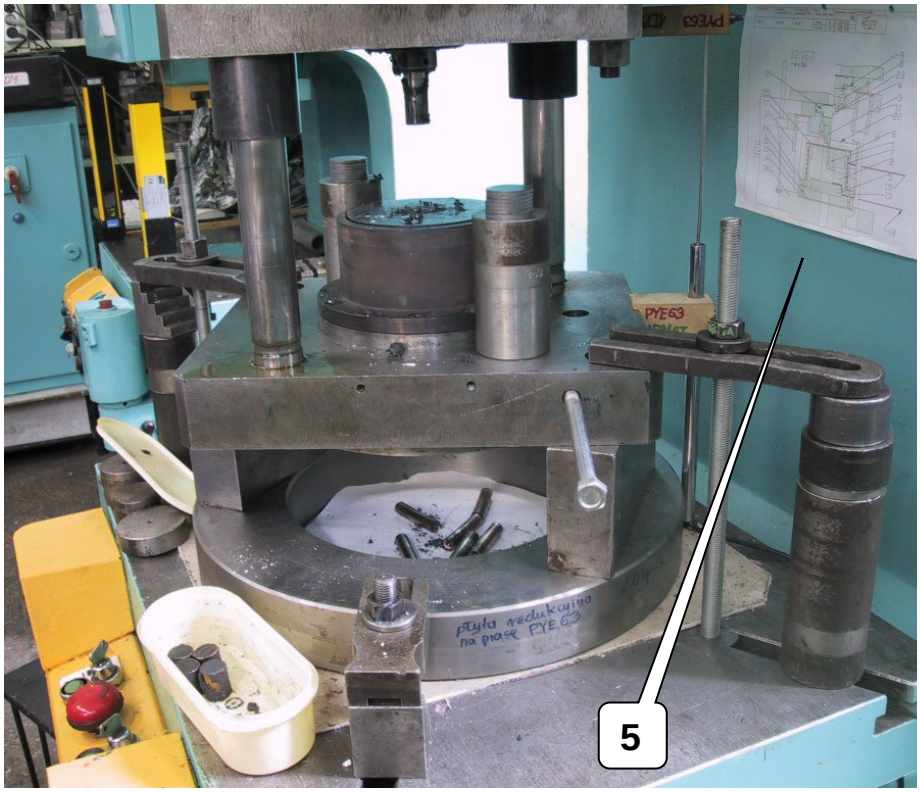




ε =0.86



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

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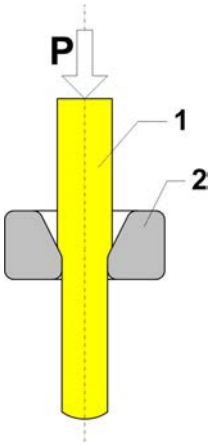
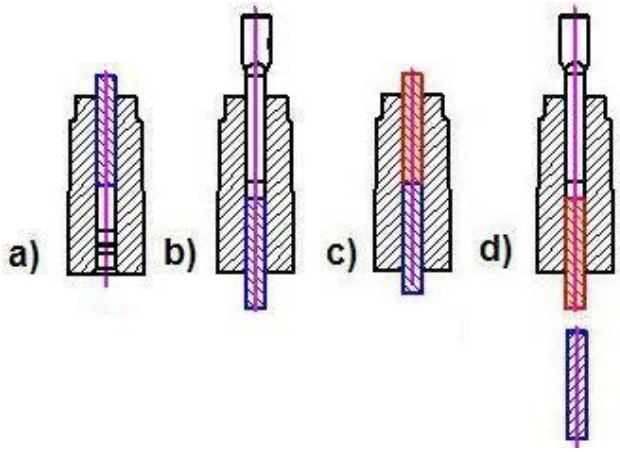
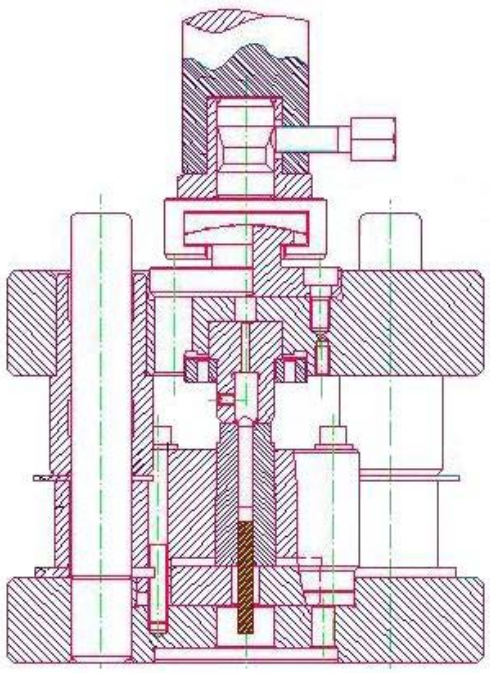
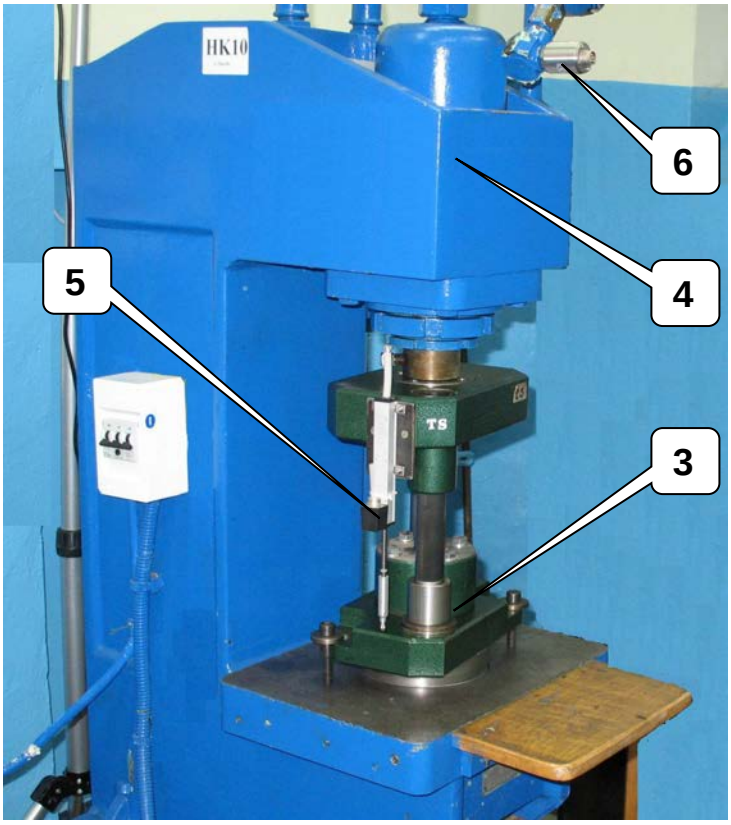
Reduction of Billet's Cross-Section Area before ECAP







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

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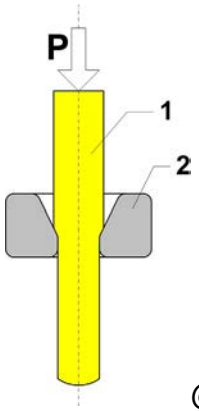
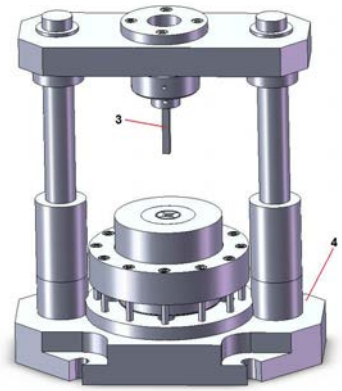
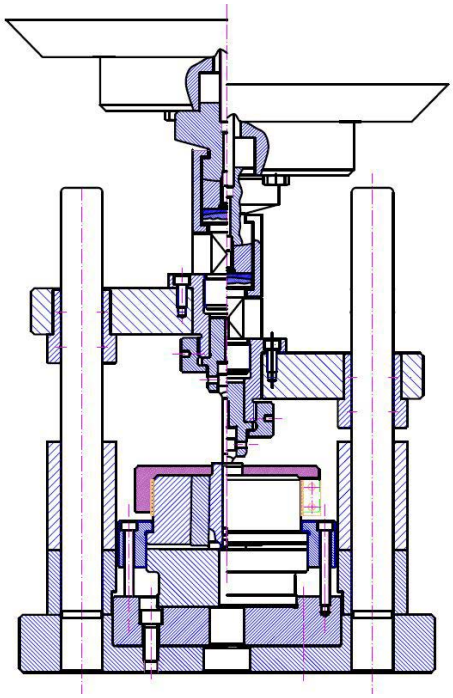
Reduction of Billet's Cross-Section Area before ECAP

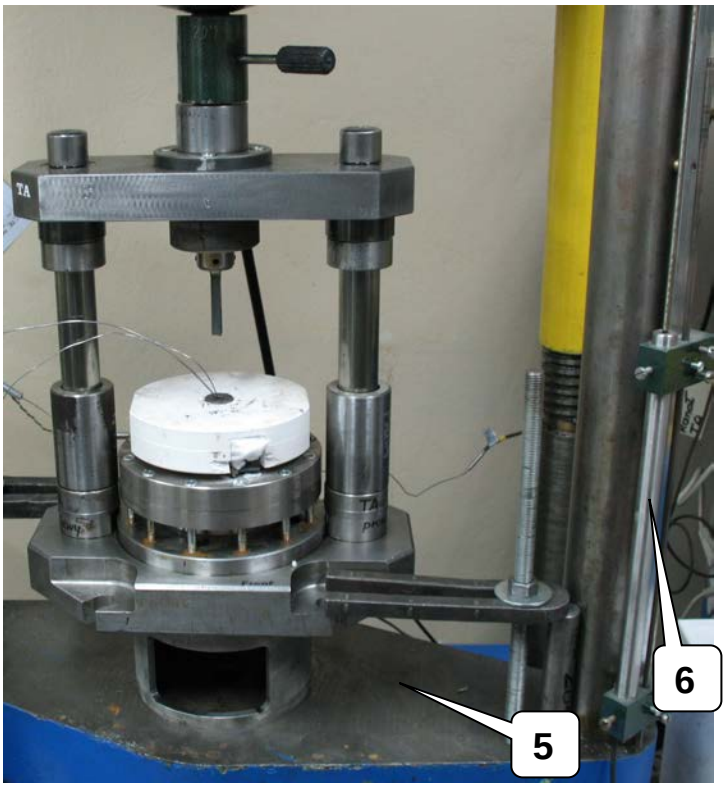


@ ET





Design of tooling



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

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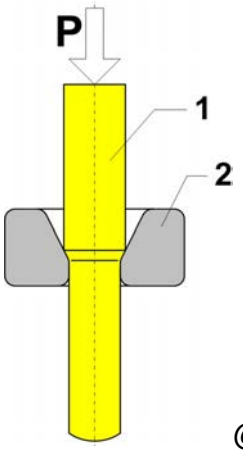
(Scaled up) Reduction of Billet's Cross-Section Area before ECAP



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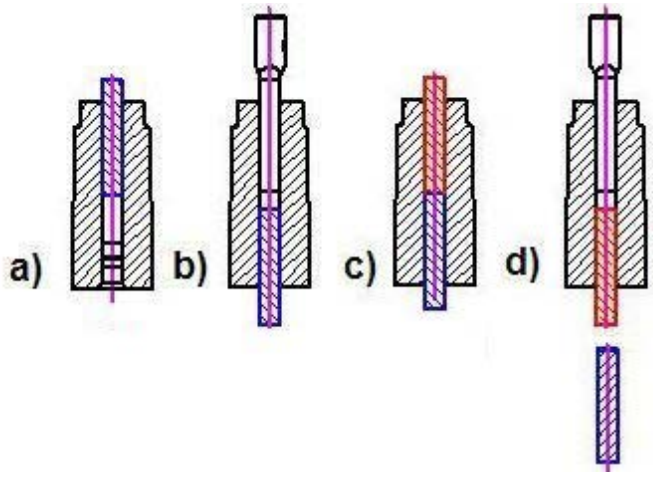

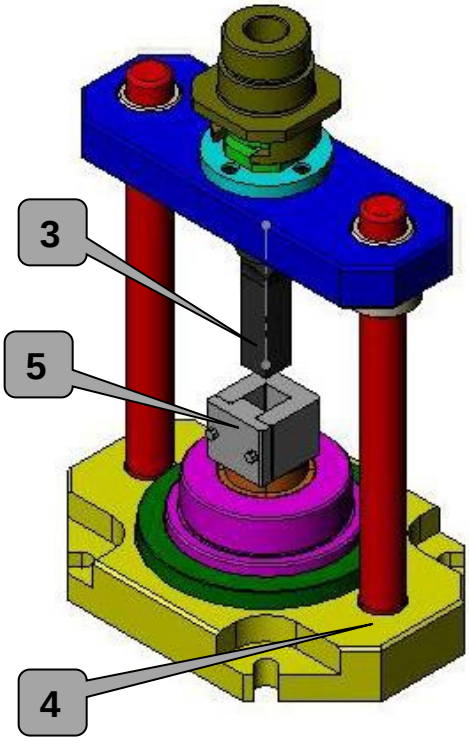

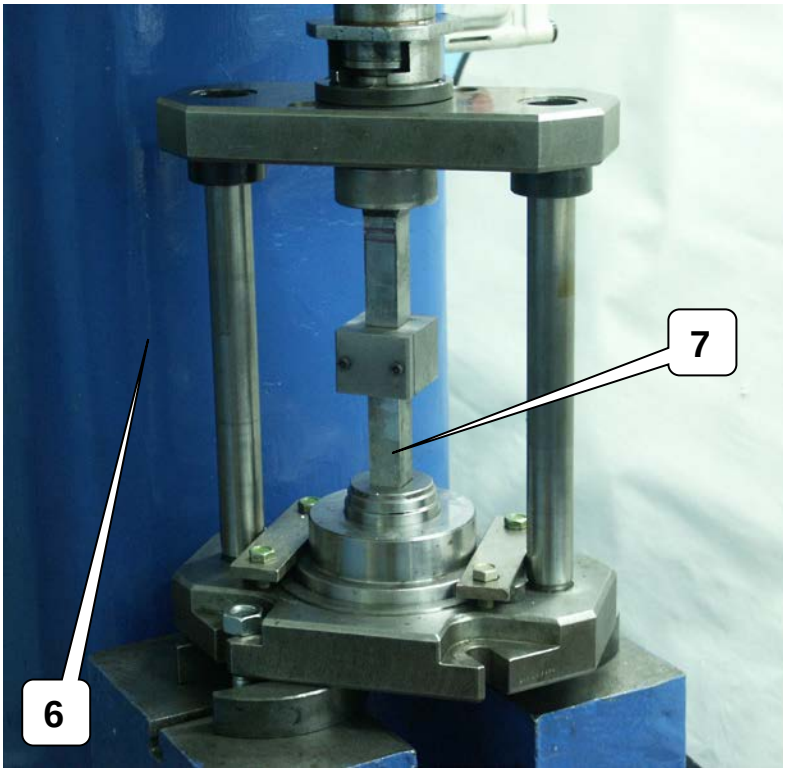

EXTR rig for reducing the ECAP billets (size #26, metal forming method: cold open die extrusion): 1–26×26 [mm] billet after ECAP, 2–segmented die insert, 3–punch, 4–die set plates with pin-bushing guiding system, 5–clamping device for the uneven bit of the ECAP billet, 6–120 kN hydraulic press PH12,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

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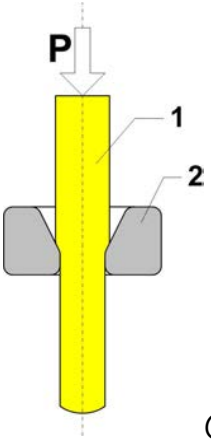
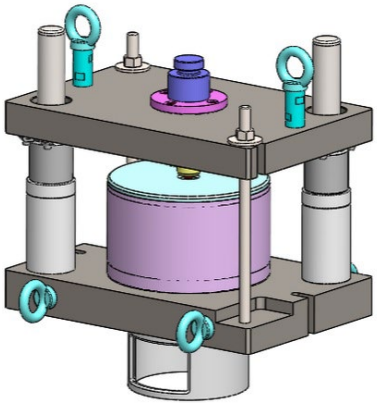
Reduction of Billet's Cross-Section Area before ECAP



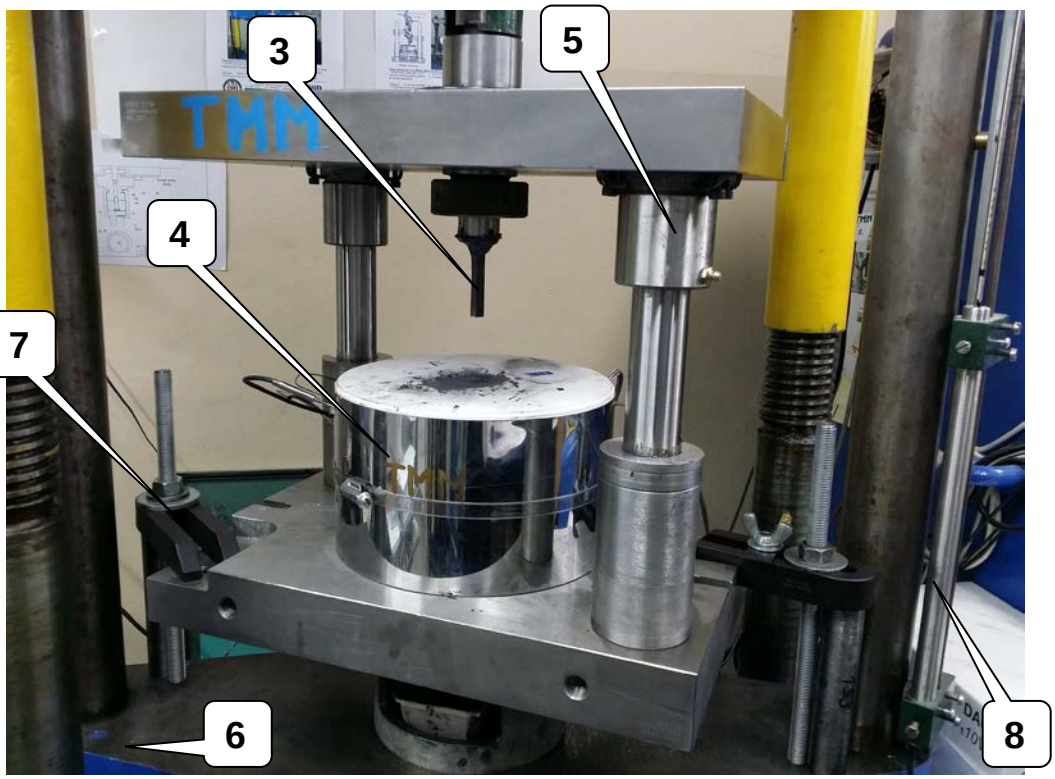
@ ET

Assembled die set (shown in closed position)



← 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

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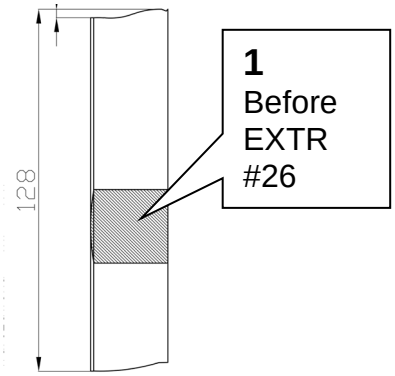
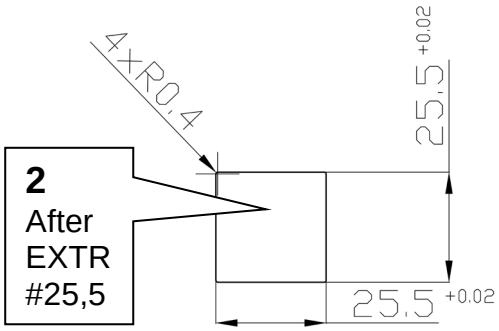
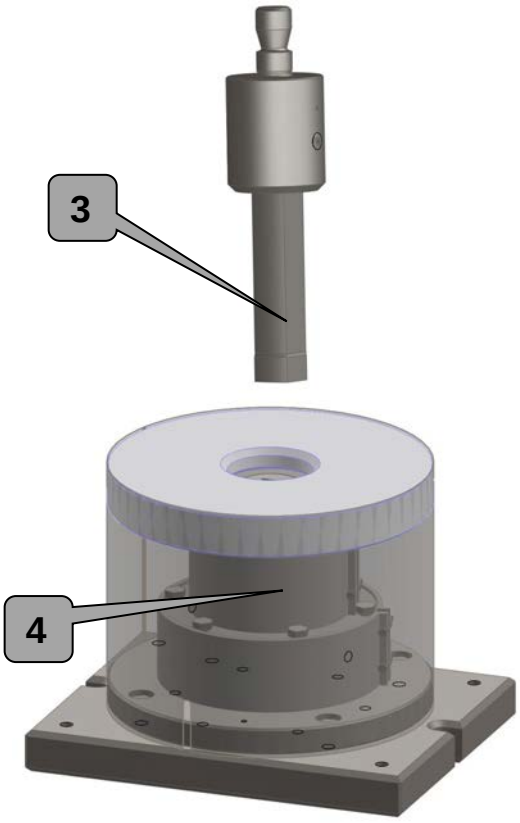
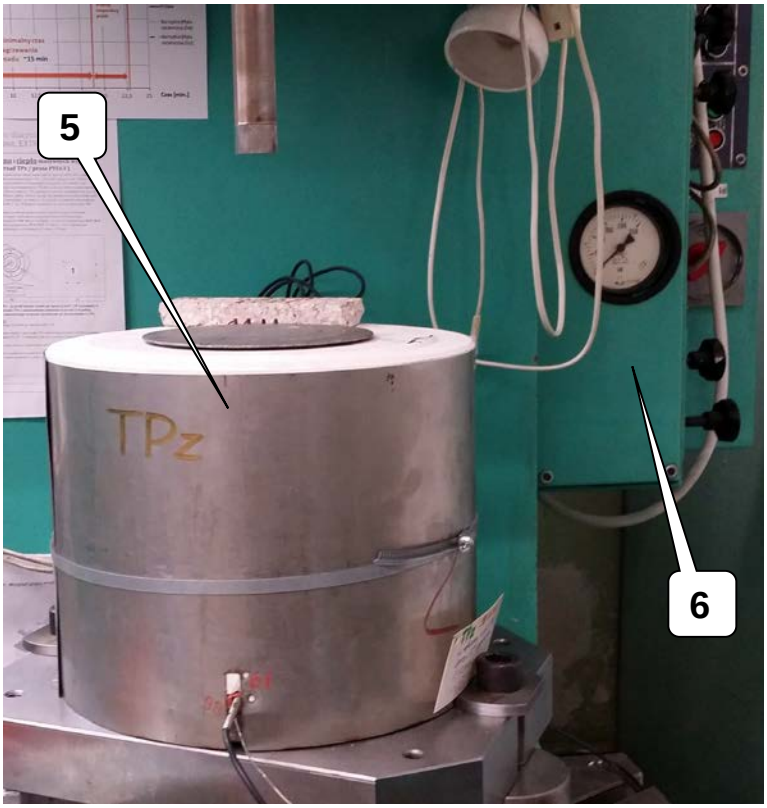
(Scaled up) Reduction of Billet's Cross-Section Area before ECAP









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

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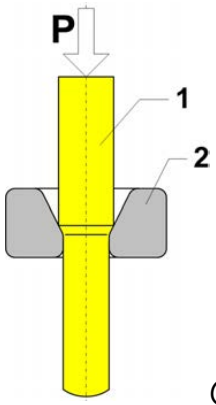
Reduction of Billet's Cross-Section Area before I-ECAP



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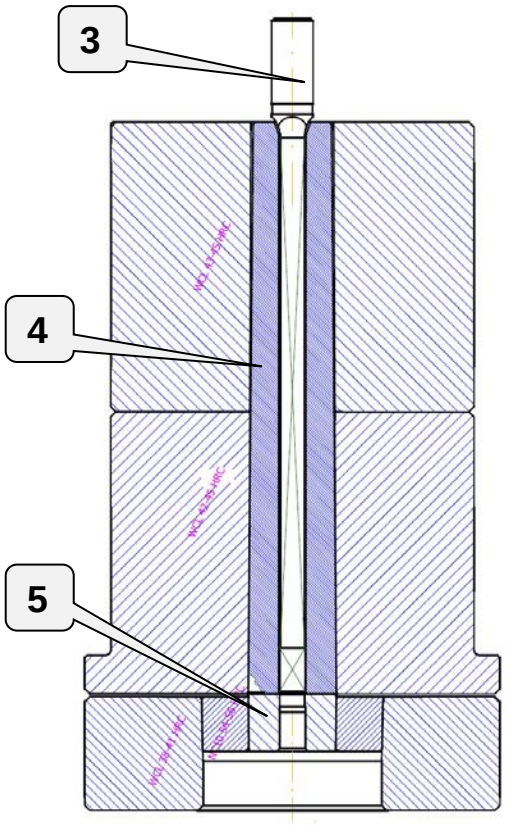

EXTR rig for reducing the long I-ECAP billets (size #**10**, metal forming method: cold open die extrusion): 1–#10 [mm^2] billet after ECAP, 2– reducing die, 3–punch, 4–prestressed die container, 5–prestressed die insert, 6–frame of the 120 kN hydraulic press PH12, 7–press table

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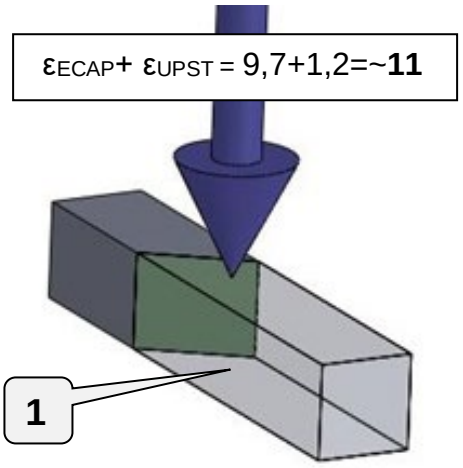
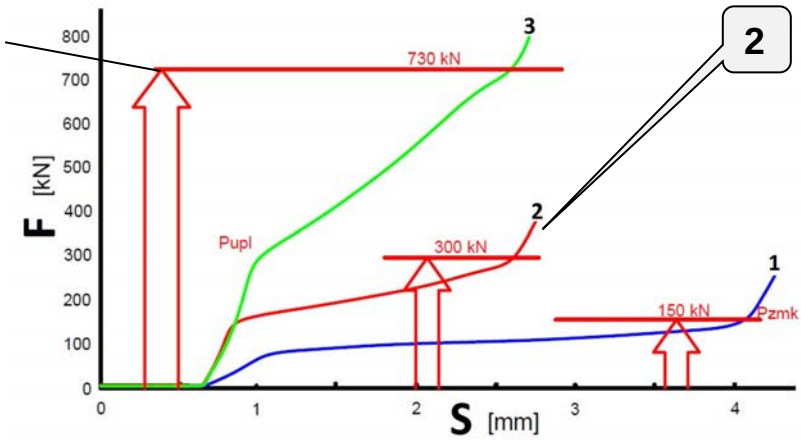
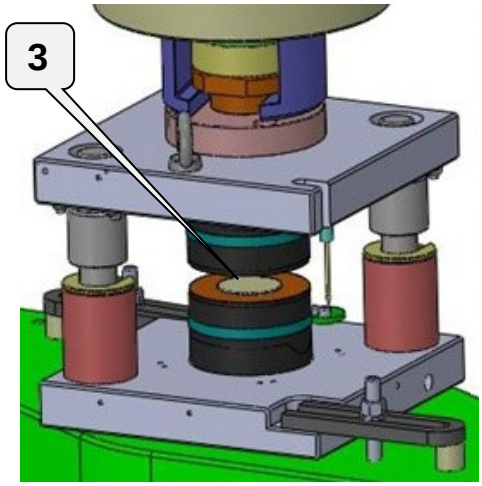
3 stage upsetting of ECAP billets (size #8) for 1mm UFG plates







#8 → ≠1

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

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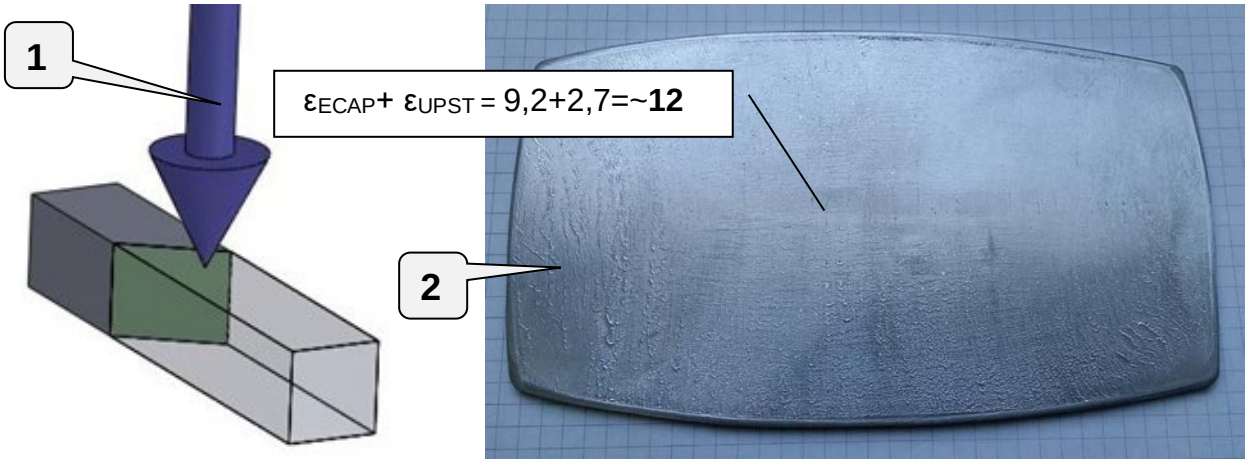
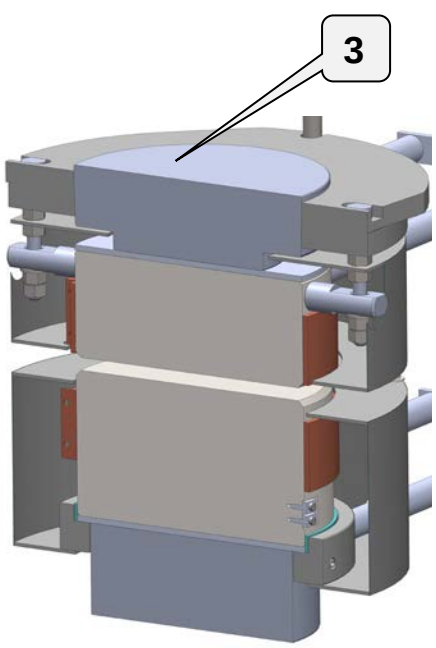
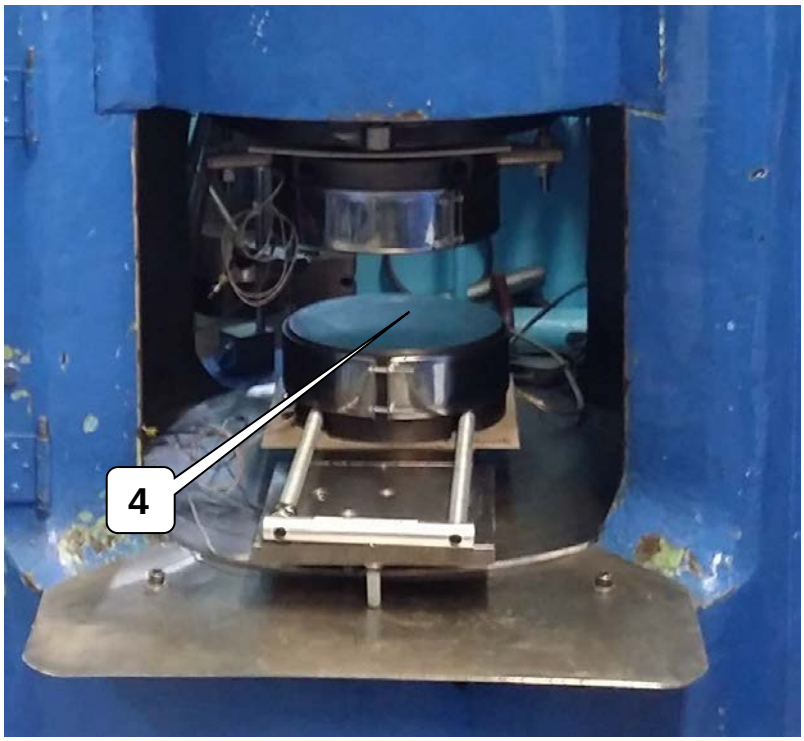
Multi-stroke flat-die upsetting #26 bars after ECAP to obtain flat rods (thickness ≠3) for subsequent rolling UFG sheets





#26 → ≠3



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

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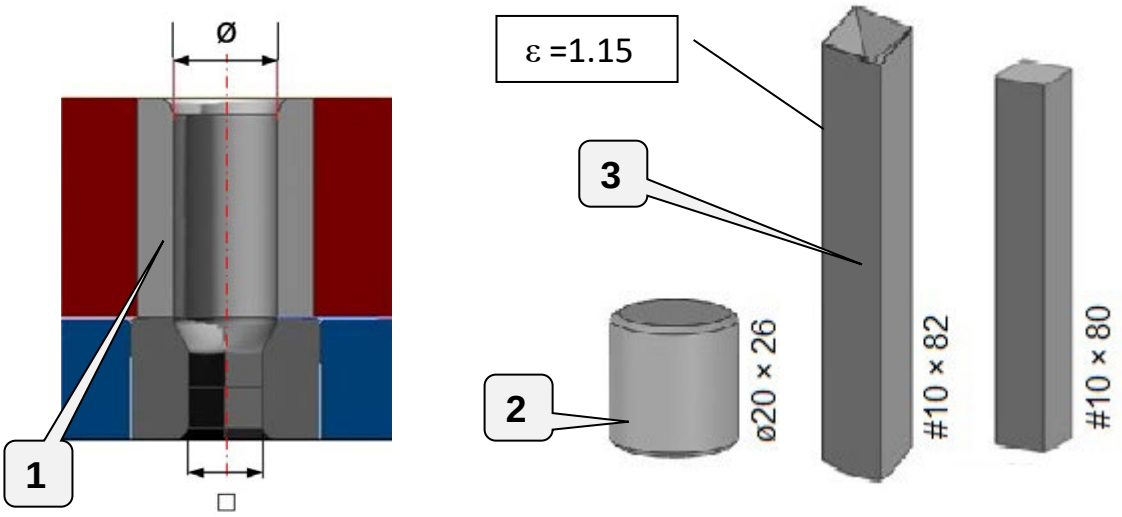
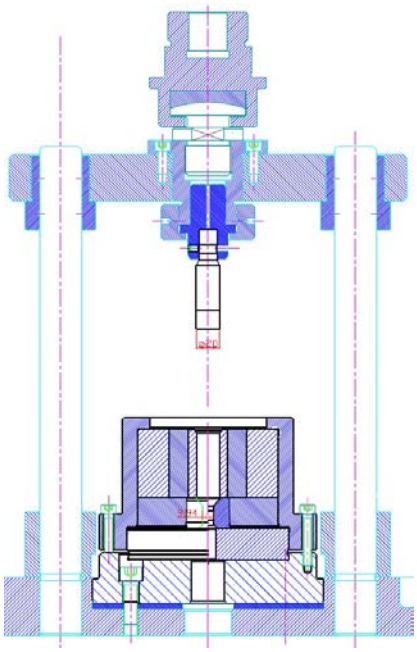
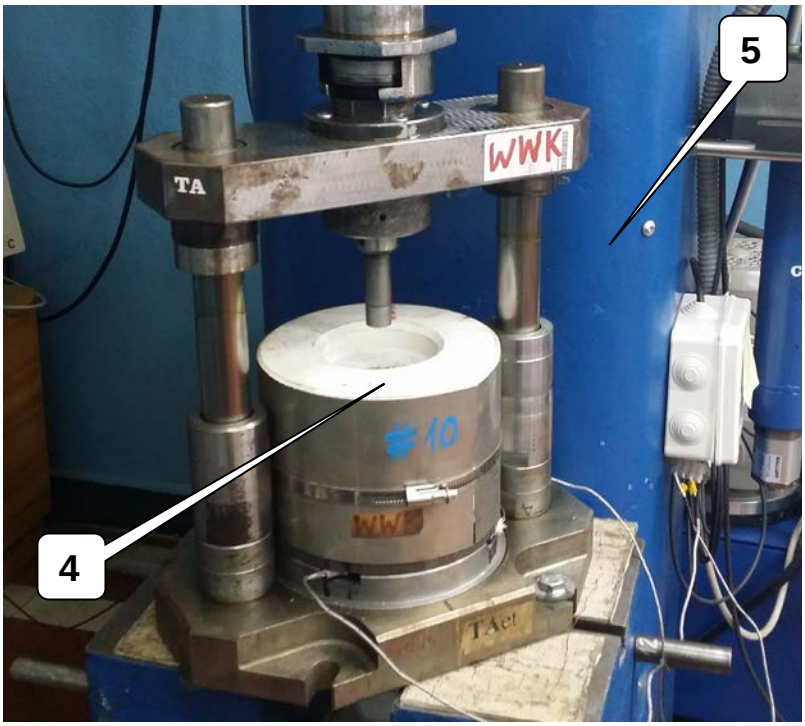
Square billets (size #10) for ECAP with initial strain hardening





ø20 → #10



FORM rig (ø20 → #10 mm) for shaping the ECAP billets (size #10, metal forming method: forward extrusion at elevated temperature): 1–prestressed die for extrusion, 2–ø20 mm billet for extrusion, 3–extruded #10 [mm^2] work-piece for ECAP billet (size #10), 4–extrusion tooling WWK, 5–120 kN hydraulic press PH12

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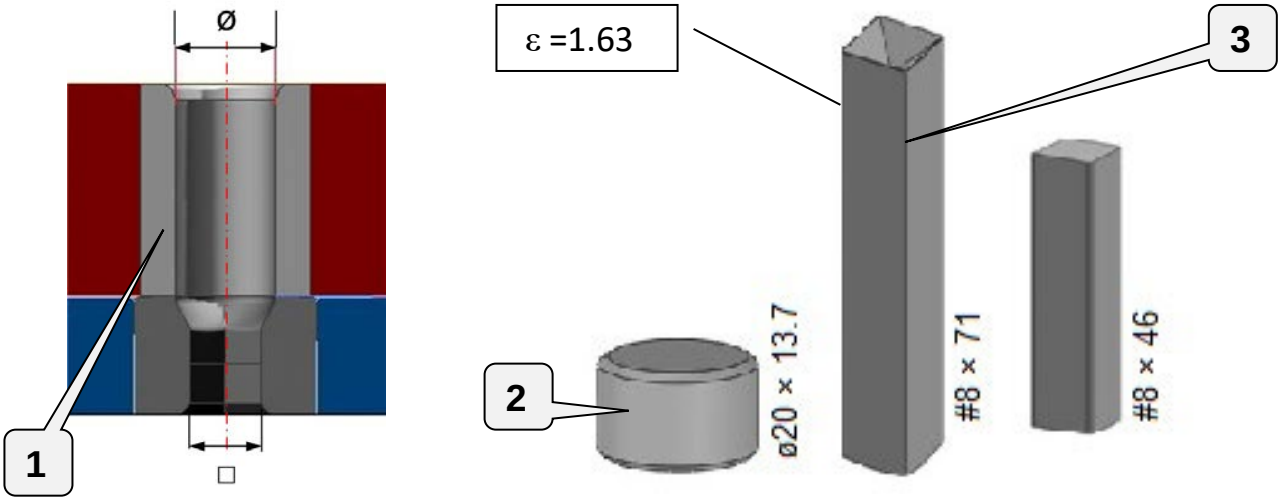
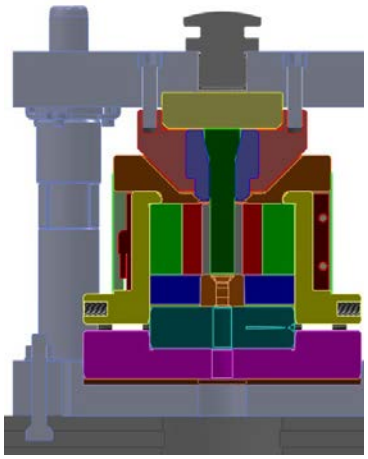
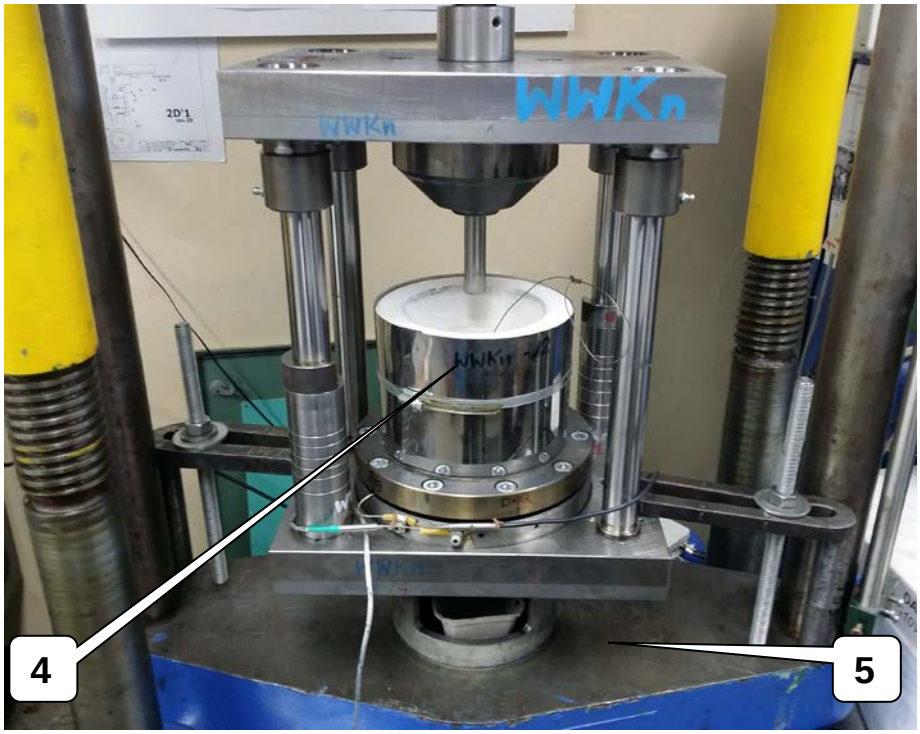
Square billets (size #8) for ECAP with initial strain hardening





ø20 → #8



FORM rig (ø20 → #8 [mm]) for shaping the ECAP billets (size #8, metal forming method: forward extrusion at elevated temperature): 1—prestressed die for extrusion, 2—ø20 mm billet for extrusion, 3—extruded #8 [mm^2] work-piece for ECAP billet (size #8), 4—extrusion tooling WWKn, 5—400 kN hydraulic press ZD40

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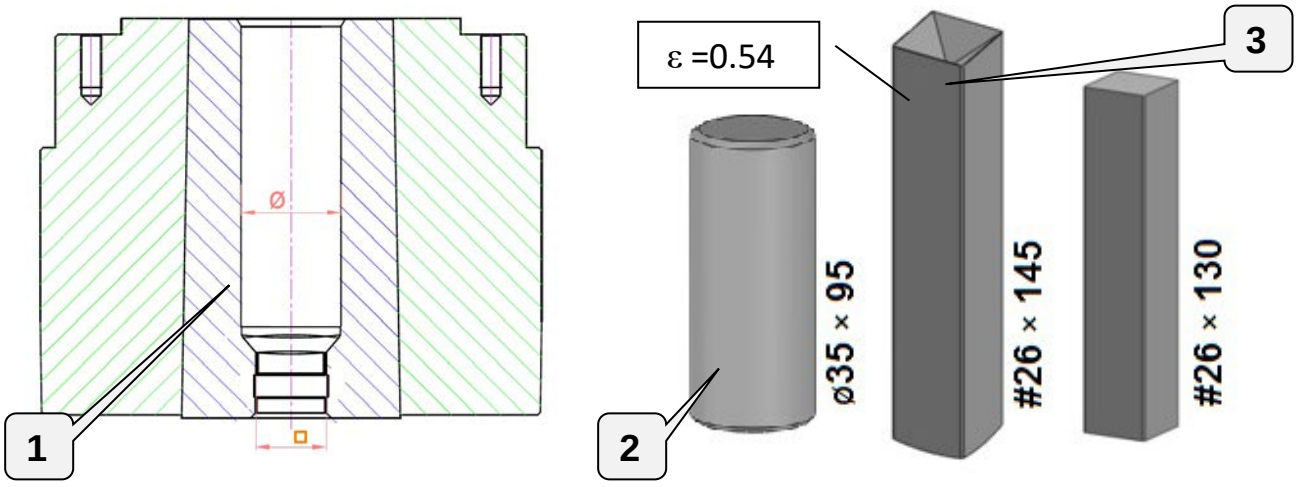
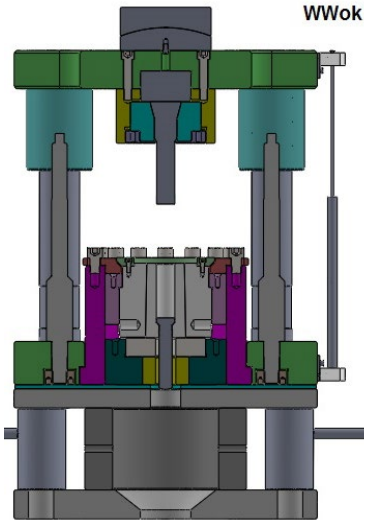
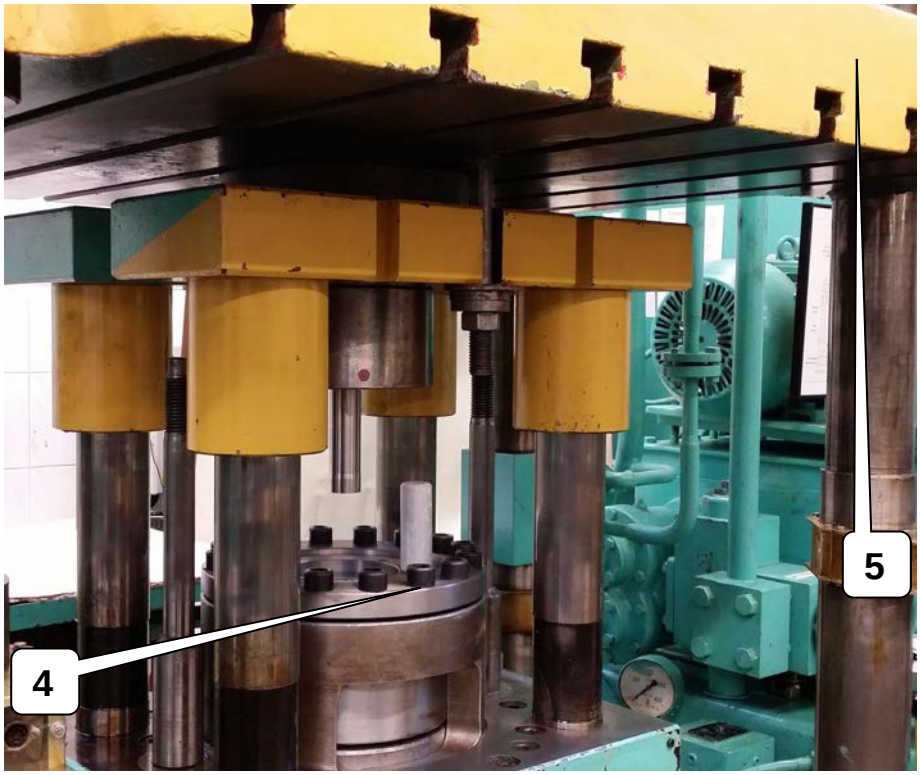
Strain hardened billets for ECAP (square bars, size #26)





ø35 → #26



FORM rig (ø35 → #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–ø35 mm billet for extrusion, 3–extruded #26 [mm^2] work-piece for ECAP billet (size #26), 4–extrusion tooling WWok, 5–2500 kN hydraulic press PYS250

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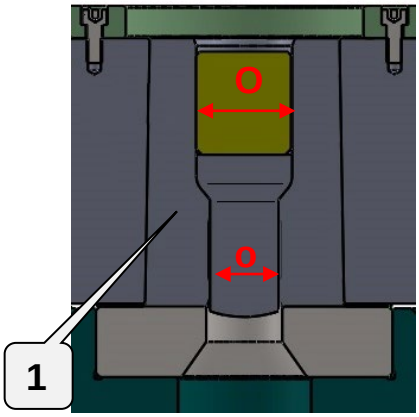
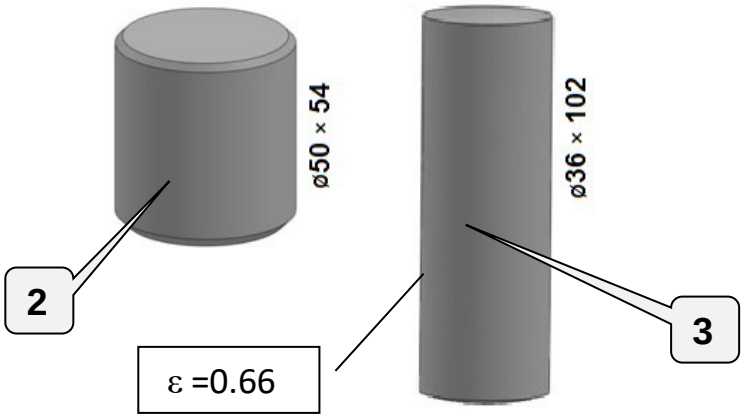
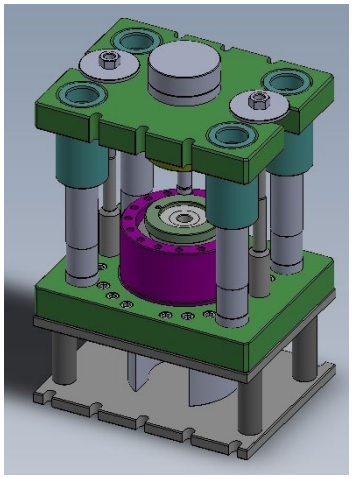
Reduction of billet size with initial strain hardening





WWoo



ø50 → ø36

FORM rig (ø50 → ø36 mm) for pre-shaping the ECAP billets (size #26, metal forming method: cold forward extrusion): 1–prestressed die for extrusion, 2–ø50 mm billet for extrusion, 3–extruded ø36 mm work-piece for further extrusion, 4–extrusion tooling WWoo, 5–2500 kN hydraulic press PYS250

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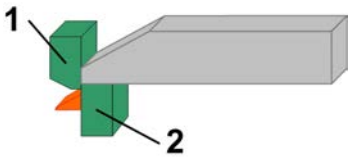
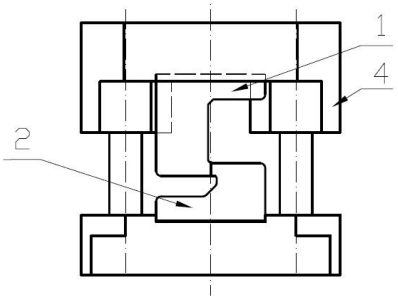
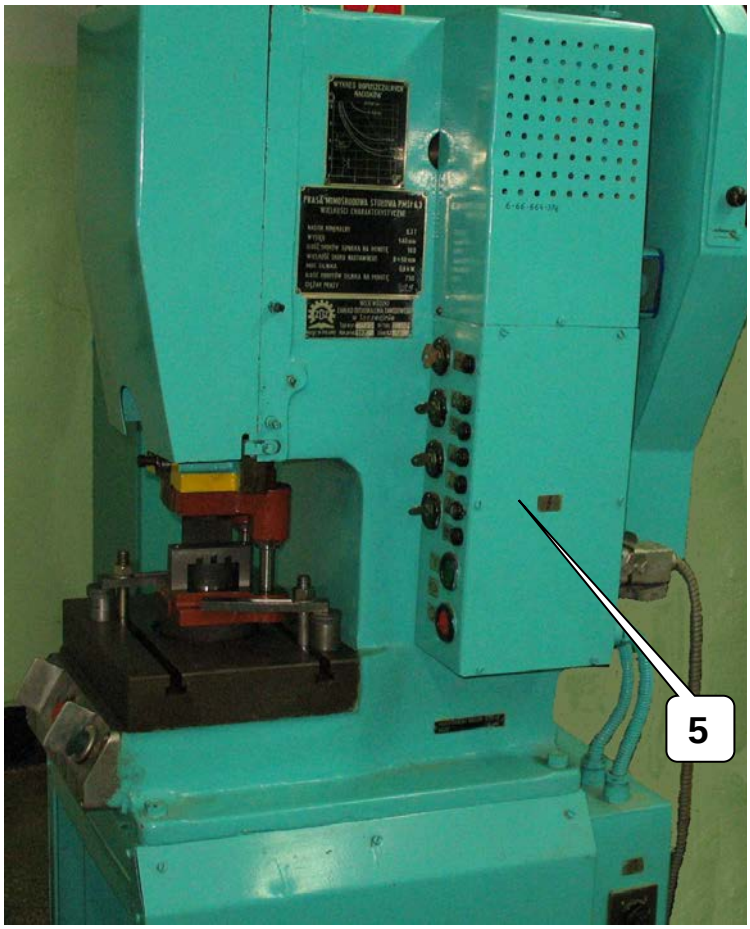
Cropping of Billet's Sharp Ends after ECAP







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

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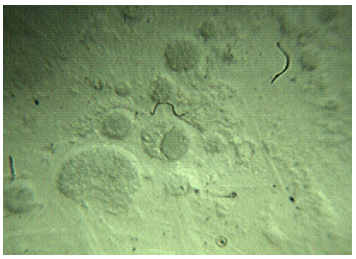
Precision Induction Heating Equipment for ECAP billets

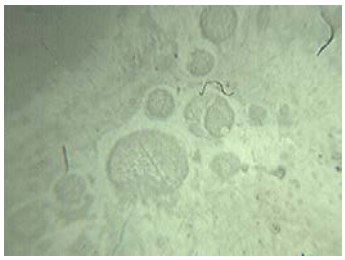


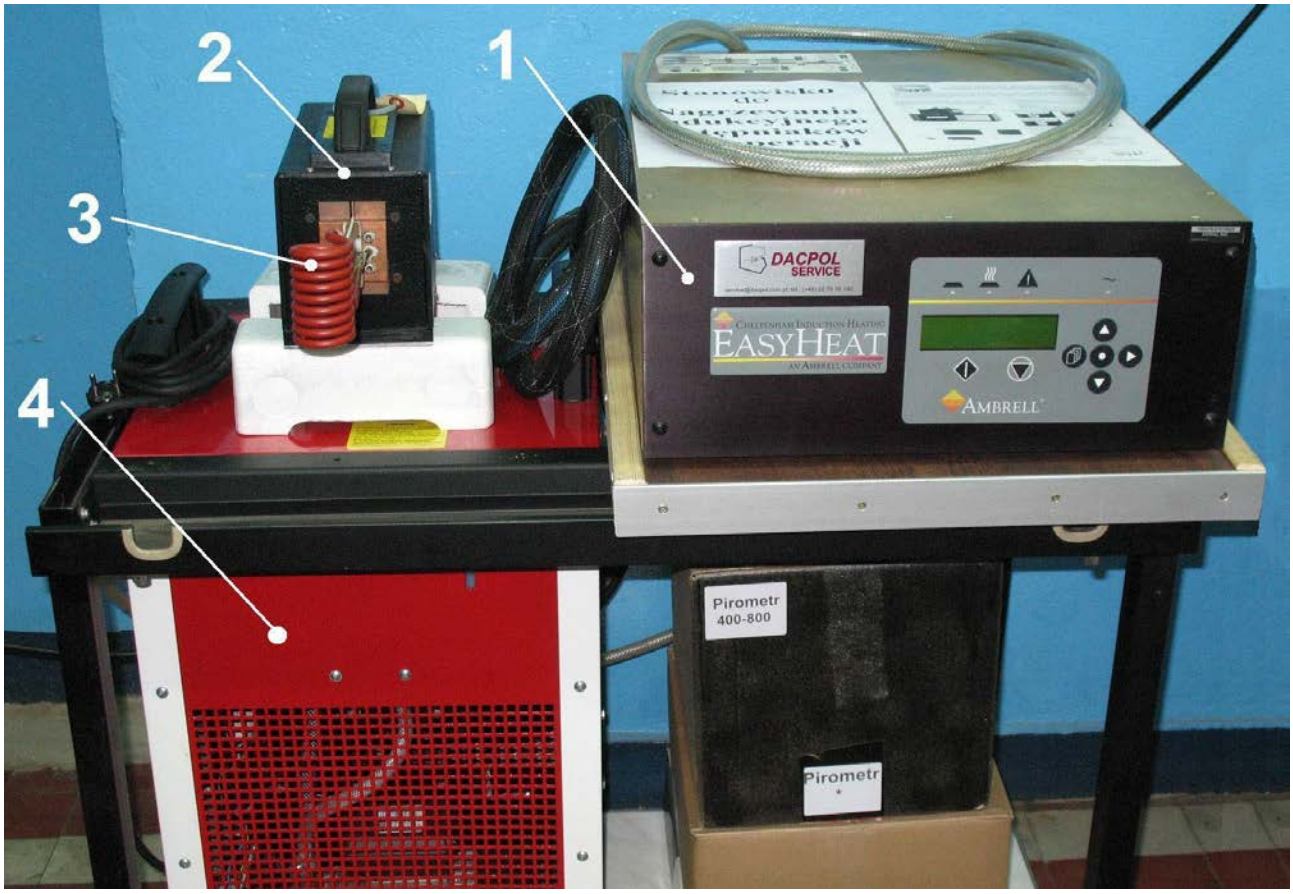
Surface of the ECAP billet

(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

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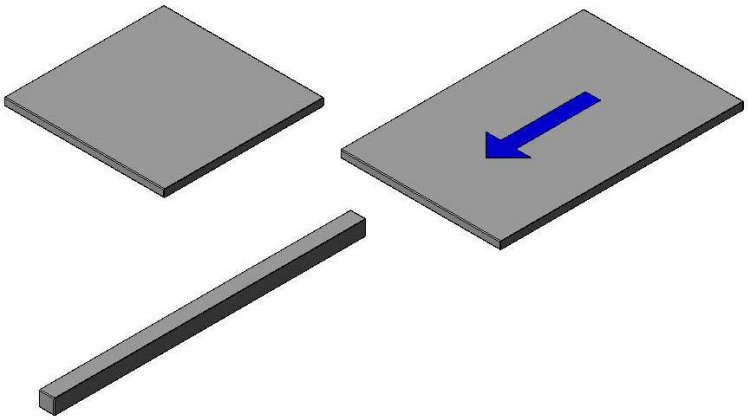
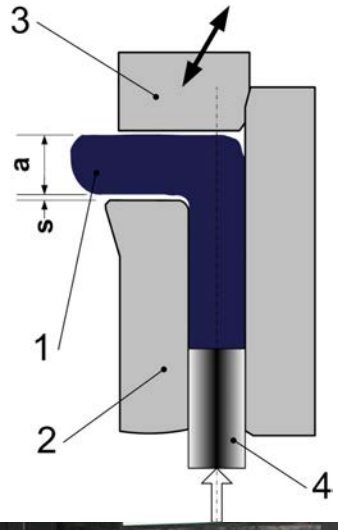
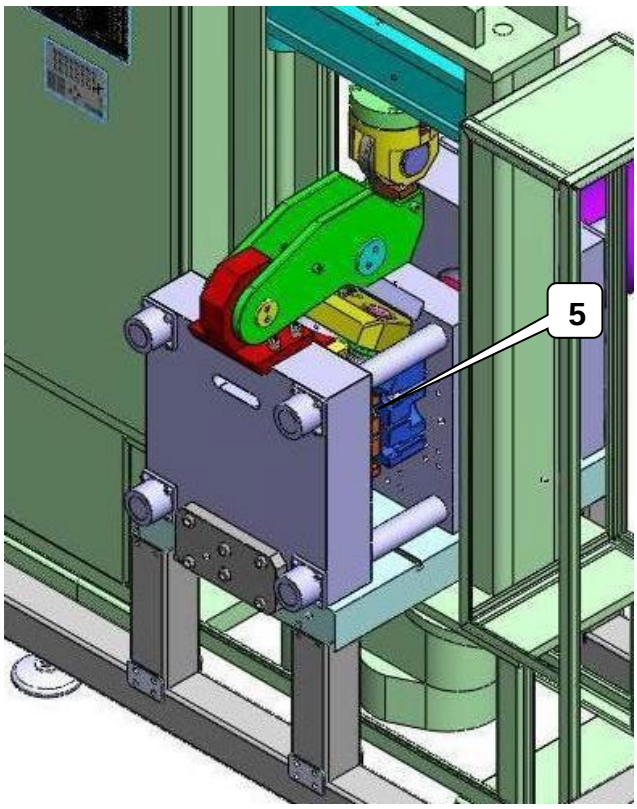
Special ISx machine for incremental ECAP of bars and plates







I-ECAP rig (bars → **10 × 10 × 205** [mm], plates → **3 × 62 × 105** [mm]):
1--billet, 2-- die insert, 3--punch, 4--pusher, 5—tool set

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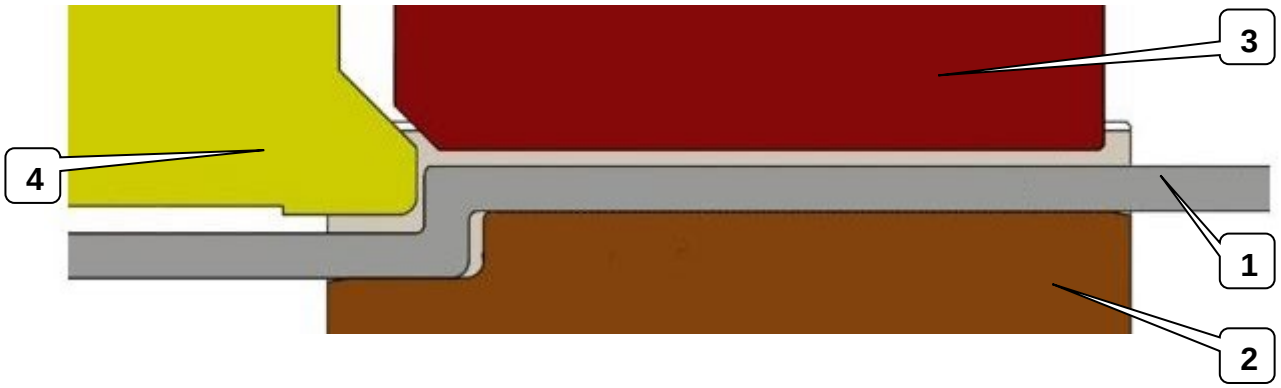
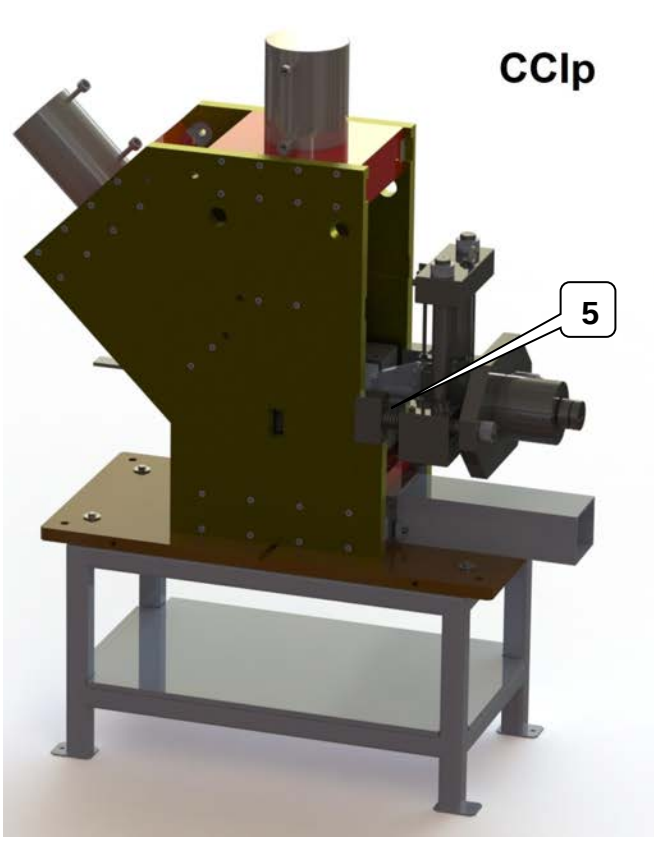
Hydraulically driven special CCIp machine for incremental ECAP of flat bars





I-ECAP rig (cross-section of bars → **10 × 50** [mm], length → **infinitely long**):
1--billet, 2-- die, 3--clamp, 4--punch, 5—feeder, 6—HPSU

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