Dr Filip GÓRSKI
filip.gorski@put.poznan.pl
Poznan University of Technology
Chair of Management and Production Engineering

RAPID MANUFACTURING LABORATORY

FDM TECHNOLOGY FOR EVAPORATIVE CASTING METHOD

Team members
- Dr Radosław WICHNIAREK
- MSc. Eng. Wiesław KUCZKO
- MSc. Eng. Przemysław ZAWADZKI
- MSc. Eng. Paweł BUŃ
- MSc. Eng. Adam DUDZIAK
- MSc. Eng. Radosław PASZKIEWICZ

PLAN OF THE PRESENTATION

1

Introduction – RP laboratory background

2

Industrial and medical examples

3

3D printing in foundry – problems
Concepts & examples

4

3D printing for evaporative casting

5

FDM + evaporative casting
Case study

6

Conclusions and summary

POZNAN UNIVERSITY OF TECHNOLOGY FACULTY OF MECHANICAL ENGINEERING

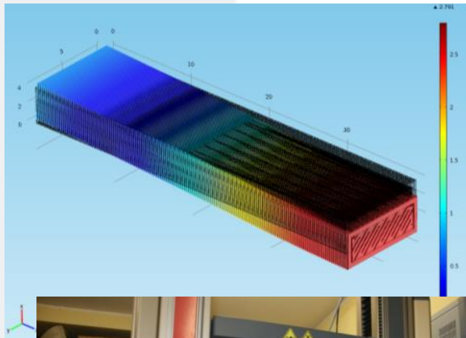
Chair of Management and Production Engineering (KZIP):

- 25 academics
- 4 laboratories
- supervision of Management and Production Engineering study course

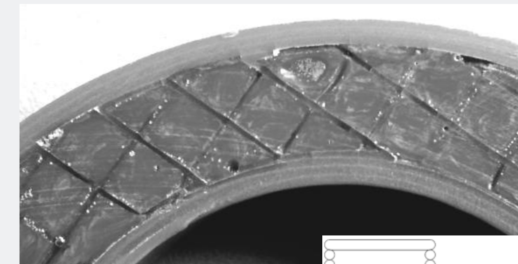
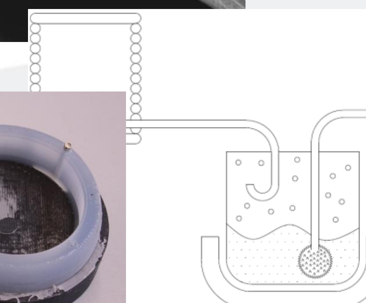
3 research groups:

- **RP – VR – CAD**
- Production Management
- Quality Management

RAPID MANUFACTURING LABORATORY – KZIP






RESEARCH AND DEVELOPMENT PROJECTS

INDUSTRIAL & MEDICAL PROTOTYPES AND SHORT SERIES

DEVELOPMENT OF 3D PRINTING PROCESSES

EQUIPMENT – FUSED DEPOSITION MODELLING

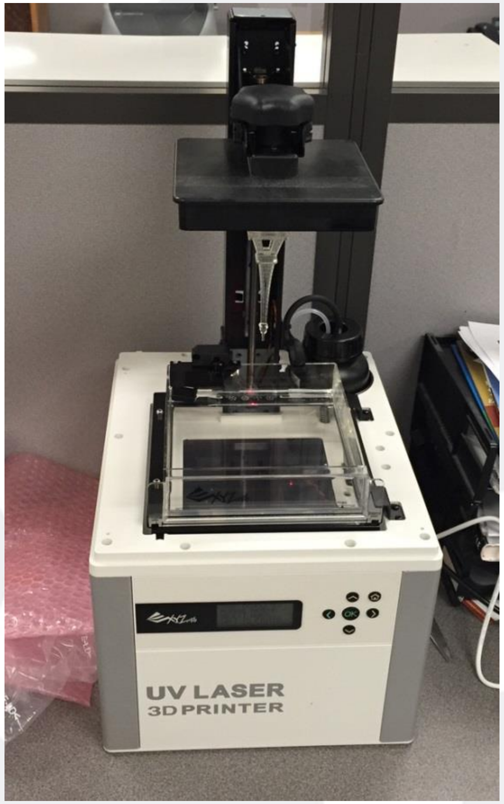
<-**Stratasys Dimension BST 1200**

- ABS material
- breakaway support
- 0,254mm and 0,33mm layer
- 254 x 254 x 305 mm workspace
- heated chamber

Makerbot Replicator 2X ->

- ABS, PLA, HIPS, NinjaFlex
- breakaway & soluble support
- 0,1 – 0,3 mm layer
- 246 x 152 x 155 mm workspace
- heated table

EQUIPMENT – 3D PRINTING, SLA, VC



3D Printing – Z400, Z310

- 203 x 254 x 203 mm workspace
- 0.08 – 0.1 mm layer
- materials – ceramic powder + organic binder

SLA - Nobel 1.0

- 128 x 128 x 200 mm workspace
- 0.025 – 0.1 mm layer
- materials – acrylic resins

<- **Vacuum Casting: MCP-HEK 4/01**

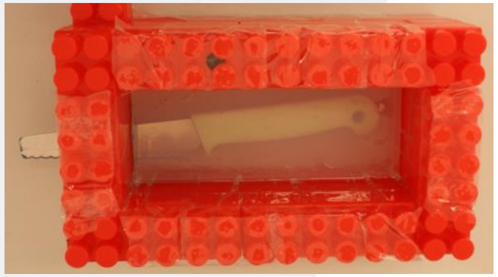
Workspace: 450x425x530 mm

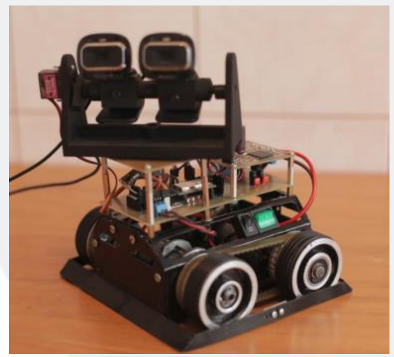
Vacuum: lower than 100 mPa

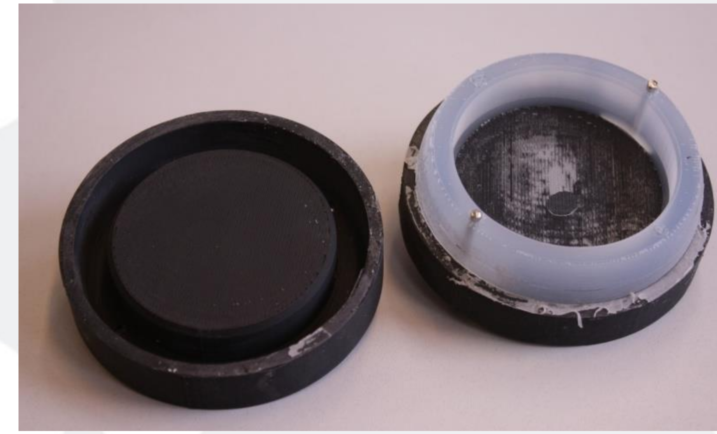
SCOPE OF WORK

- RAPID MANUFACTURING LABORATORY
  - OPTIMIZATION OF ADDITIVE MANUFACTURING PROCESSES
    - FEA CALCULATIONS
    - EMPIRICAL STUDIES
  - RAPID PROTOTYPING FOR ENGINEERING
    - VIRTUAL REALITY DEVICES
    - PROTOTYPES OF NEW PRODUCTS FOR INDUSTRY
  - MEDICAL PRODUCTS
    - MID-SURGERY SUPPLIES
    - PROSTHESES, ORTHOSES
    - EDUCATIONAL PROTOTYPES
    - PRE-SURGERY VISUAL AIDS
  - RAPID PROTOTYPING IN FOUNDRY
    - NEW MATERIALS
    - NEW PROCESSING METHODS

INDUSTRIAL PROTOTYPE EXAMPLES







YORK

BLACK RED WHITE

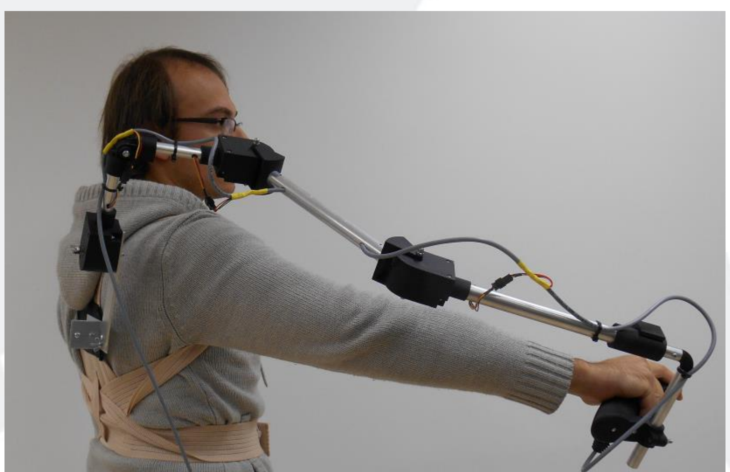
KOMPANIA PIWOWARSKA

AKWA

SOLARIS

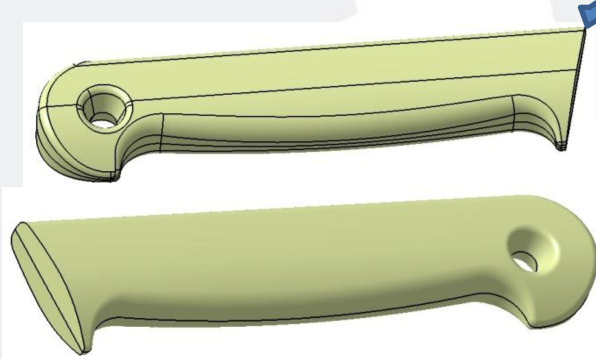
Amica

hawle



INDUSTRIAL CASE STUDY EXAMPLE - KNIVES

- **Iterative design optimization**
- Multi-material products – small prototype series
- Used techniques: Fused Deposition Modelling, 3D printing, Vacuum Casting



design (CAD)

3D print - handle

prototyping – whole product

introducing design changes

silicone mold making

short batch of casted products + final product

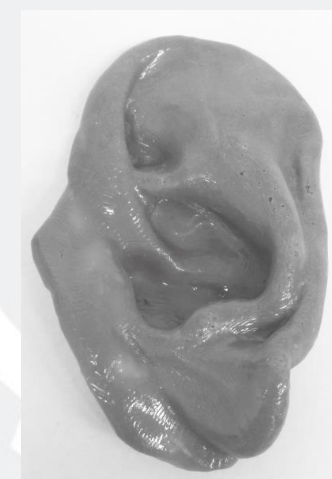
MEDICAL PRODUCT EXAMPLES

Wrist orthosis

Leg prosthesis

Knee implant prototype

Pre-surgery kidney visualization



Ear prosthesis

3D-PRINTED INDIVIDUALIZED MEDICAL PRODUCTS

MEDICAL CASE STUDY EXAMPLE

Procedure

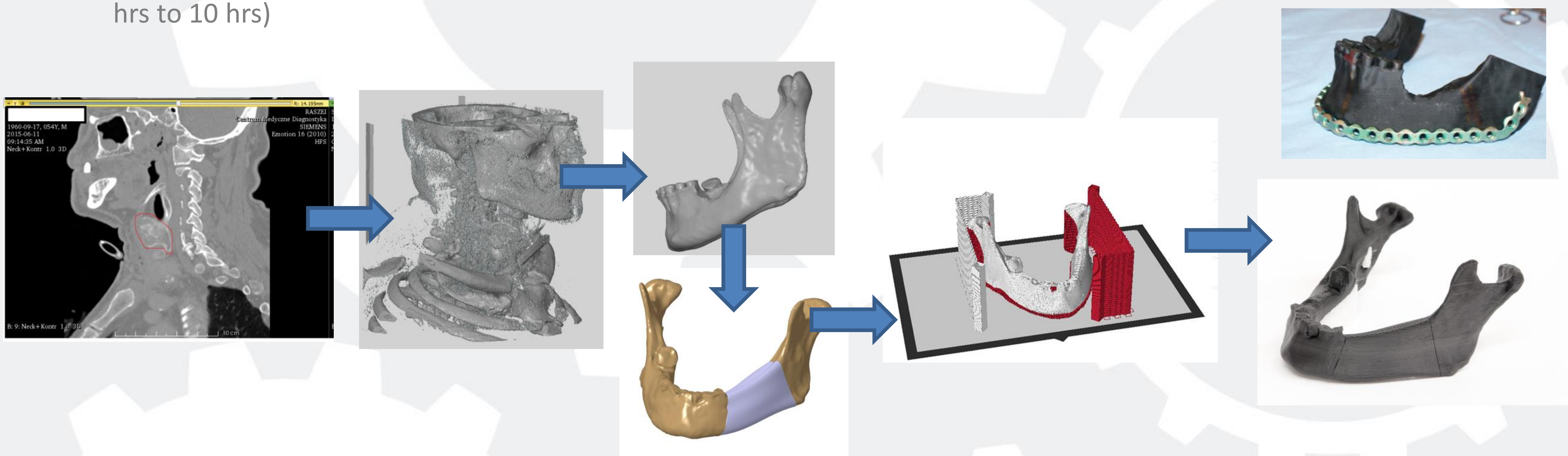
Mandibular reconstruction in cancer patients, using auto-transplantation techniques

Product

Plastic template for pre-surgery (shaping of titanium plates) and mid-surgery (cut proper shape out of patient own tissues in shorter time)

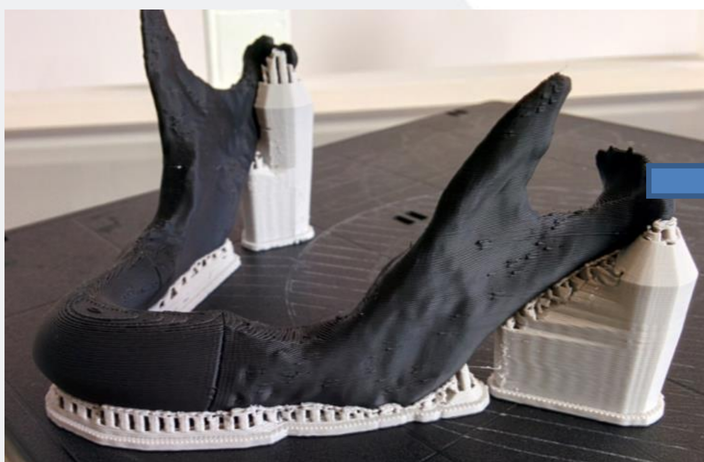
Effects

Shortening of surgery time up to 2 hours (from 12 hrs to 10 hrs)



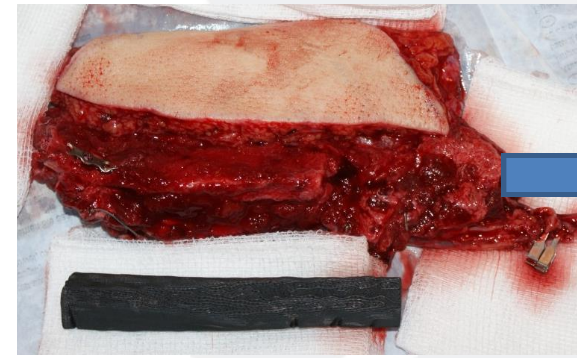
3D-PRINTED INDIVIDUALIZED MID-SURGERY SUPPLIES ON THE BASIS OF CT SCANS

MEDICAL PRODUCT – USE IN TREATMENT



3D PRINTED PART

PLASMA STERILIZATION



AUTO-TRANSPLANT

RECOVERY

RAPID PROTOTYPING IN FOUNDRY - PROBLEMS

3D PRINTING FOR FOUNDRY

PATTERNS

- **Fused Deposition Modelling / powder 3D printing** – too weak patterns for mechanical thickening of molding sands (single use patterns)
- **Vacuum Casting** – complex and requires qualifications
- **Selective Laser Sintering**, **PolyJet** – very expensive

MOLDS

- **3D printing** in **molding sand** – very expensive
- **Selective Laser Melting** for multi use molds – very expensive
- **Fused Deposition Modelling** – only for non-metals or metals with melting point below ~120°C, too weak for multi use

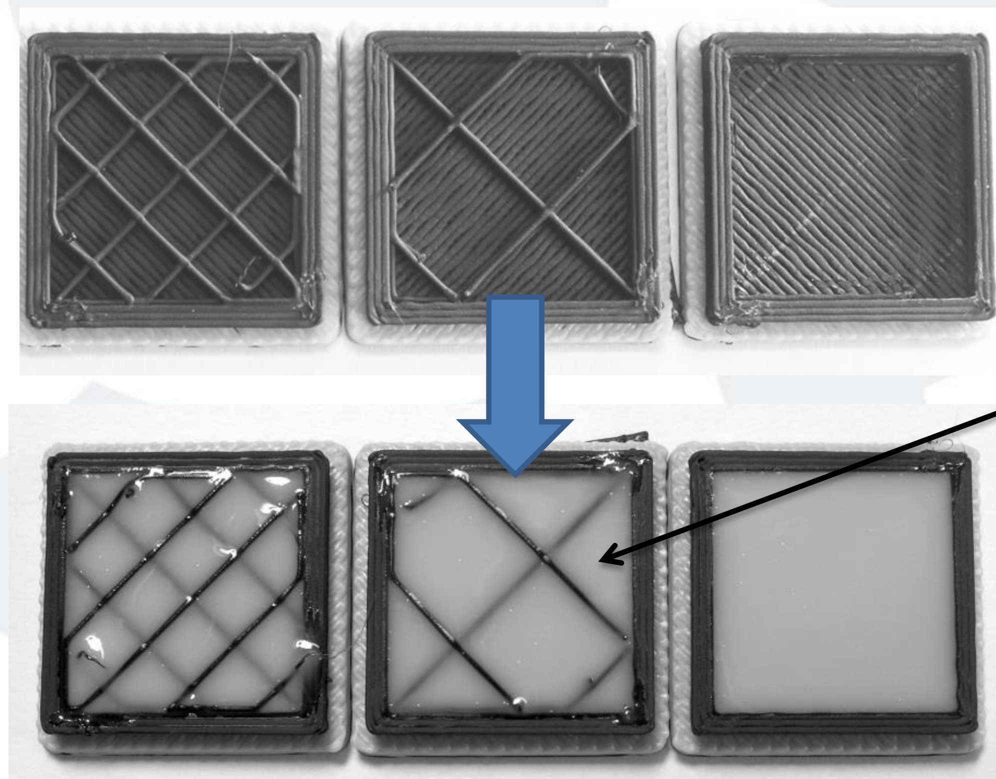
premise: with basic approach, pure FDM technology not useful for commercial foundry processes, other 3D printing – expensive and difficult

studies: how to expand / adjust FDM process to make it help in casting processes?

COMPOSITE FDM PARTS FOR FOUNDRY - CONCEPT

To obtain greater strength and maintain low cost and time:

make FDM parts **composite** – fill the hollow inside of the part produced using sparse filling with a liquid, chemically hardened polyurethane resin.

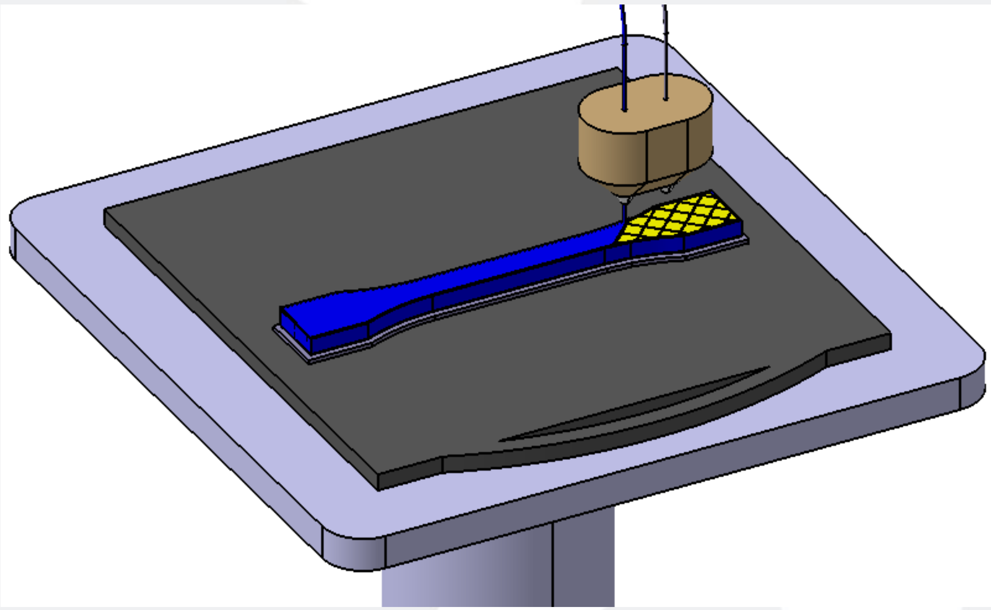


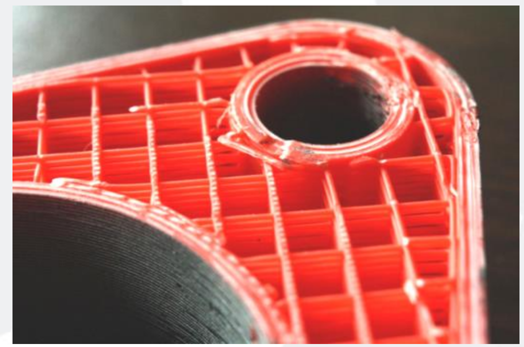
Liquid resin inside empty spaces

patented process

MAIN CONCEPT – COMPOSITE FDM PARTS

Resin filling – during 3D printing process (before closing of final layers)

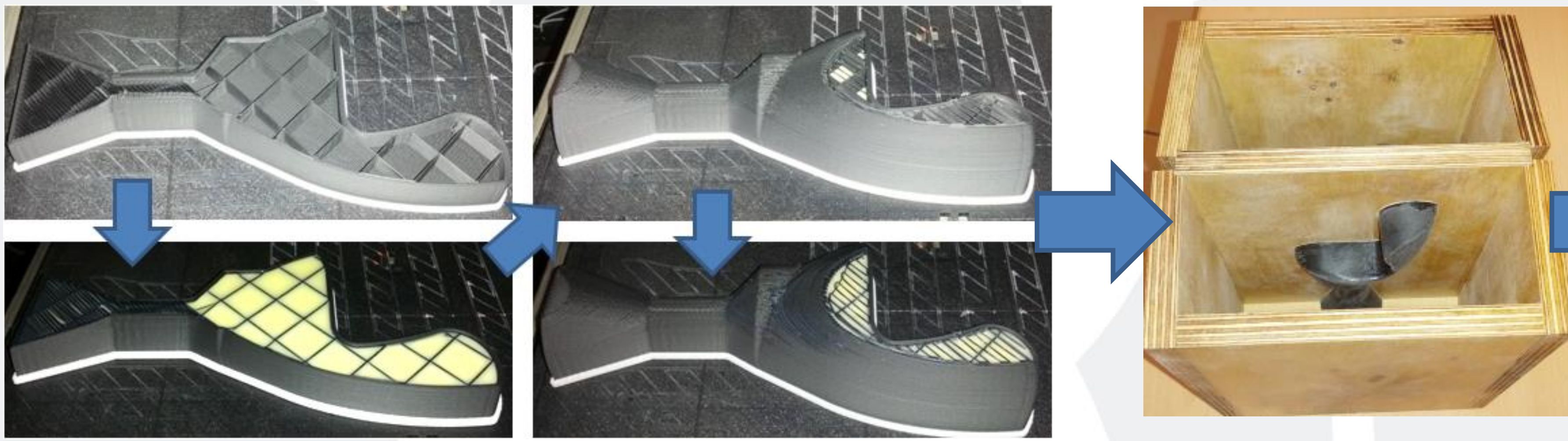




Possible second method – pressure injection after layer deposition – processing problems

COMPOSITE FDM - CASE STUDIES IN FOUNDRY

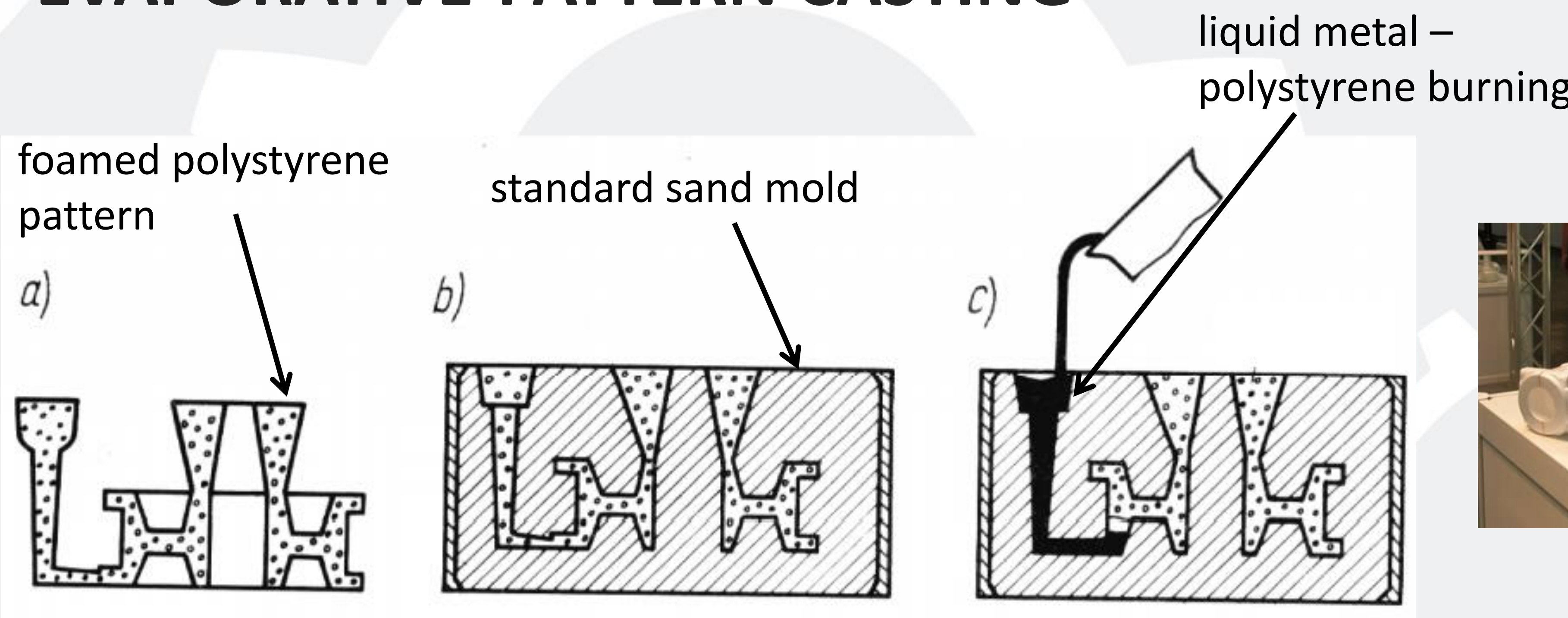
Composite FDM manufacturing (ABS + resin) – used for commercial products manufactured in Rapid Manufacturing Laboratory in Poznan



Pattern for bronze casting of water tap element

Mold for injection molding of orthopaedic shoe inserts

EVAPORATIVE-PATTERN CASTING



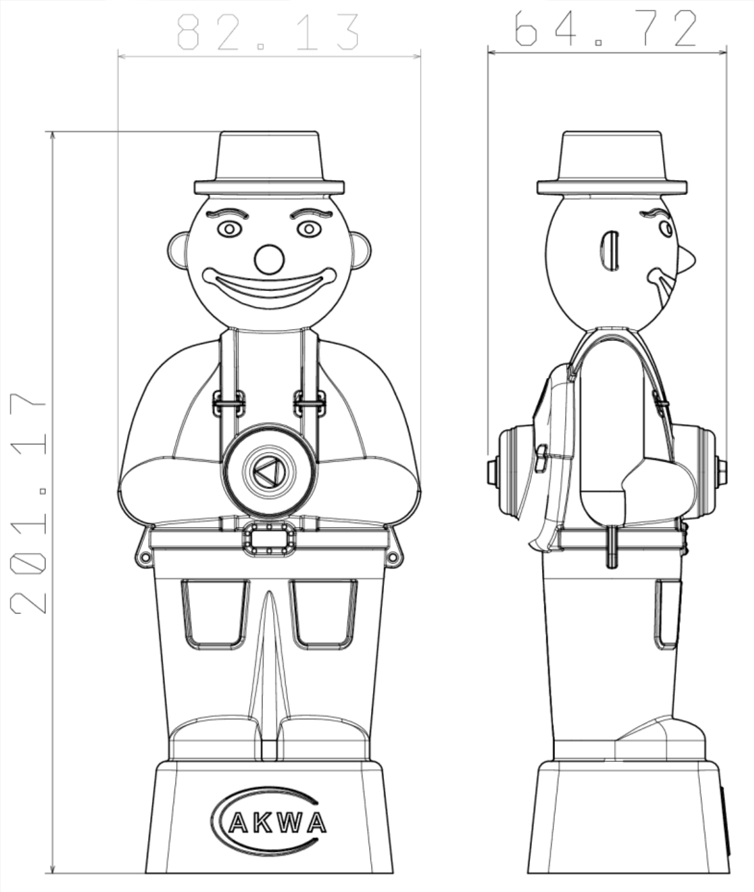
Requirements towards the pattern:

- strong enough to withstand sand mold preparation
- lightweight enough to burn out during liquid metal pouring and not prevent metal flow

Used material – polystyrene foam.

is it possible to build lightweight, durable and accurate polystyrene patterns using low-cost 3D printing?

STUDY MODEL FOR CASTING



- Scaled model of water hydrant
- Complex shape with many small features

METHODOLOGY OF STUDIES

1) DESIGN

- CATIA model on basis of 3D scan of the real object
- Division of model into separate parts for more effective manufacturing
- Tesselation and STL file generation

2) MANUFACTURING

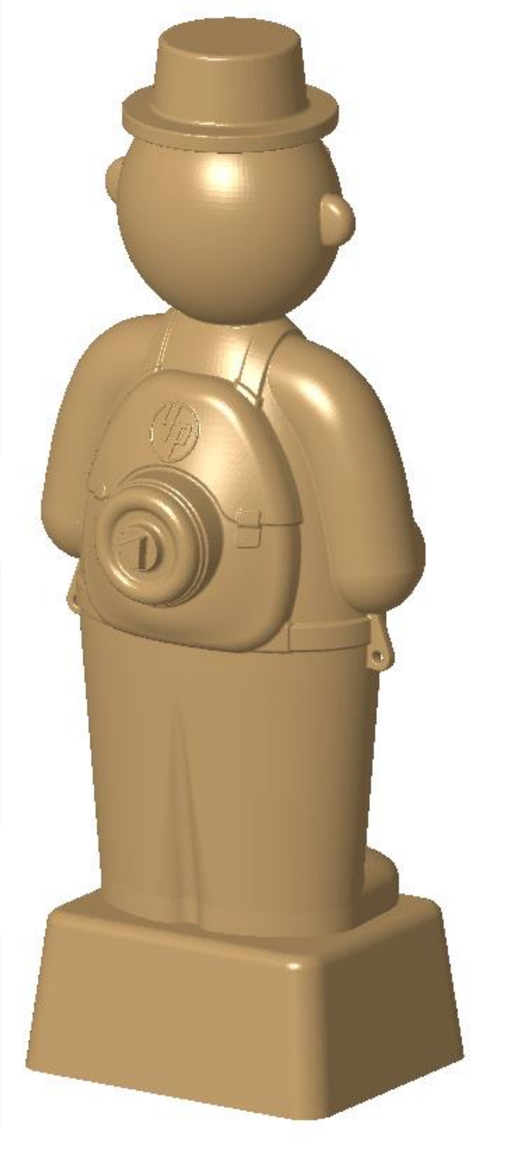
- MakerBot Replicator 2X
- HIPS material
- Very low infill
- No support structures
- Layer thickness 0.3 mm
- Two different approaches to process parameters

3) CASTING

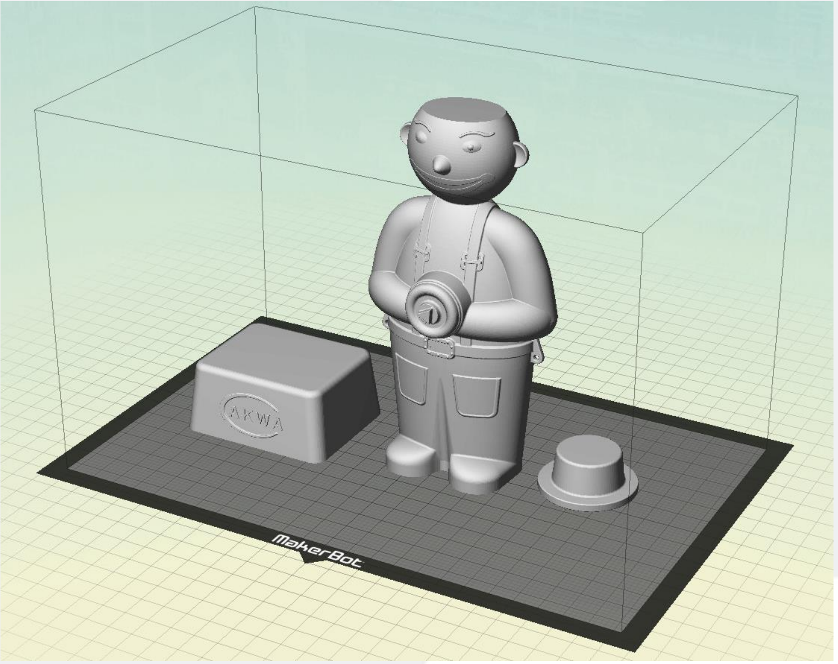
- GJS500-7 cast iron
- Evaporative-pattern casting
- Sand mold
- Blow-through by carbon dioxide (hardening) – no mechanized thickening
- Two different approaches – model upside down and model in upright position

CASE STUDY - CAD DESIGN

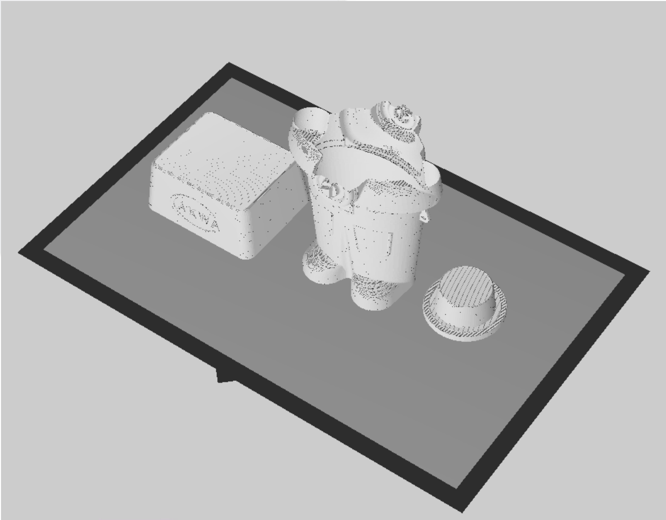
- CATIA 3D model
- Tesselation to STL file – division into three parts: base, body and hat



FDM PROCESS PREPARATION

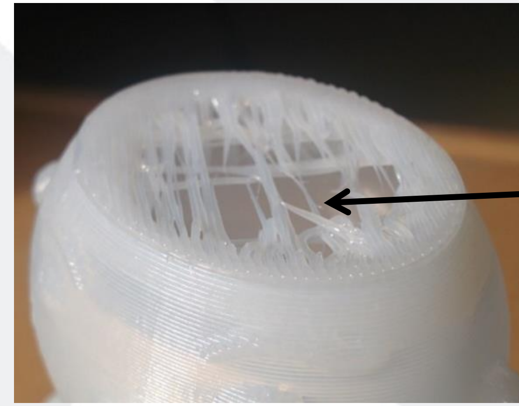


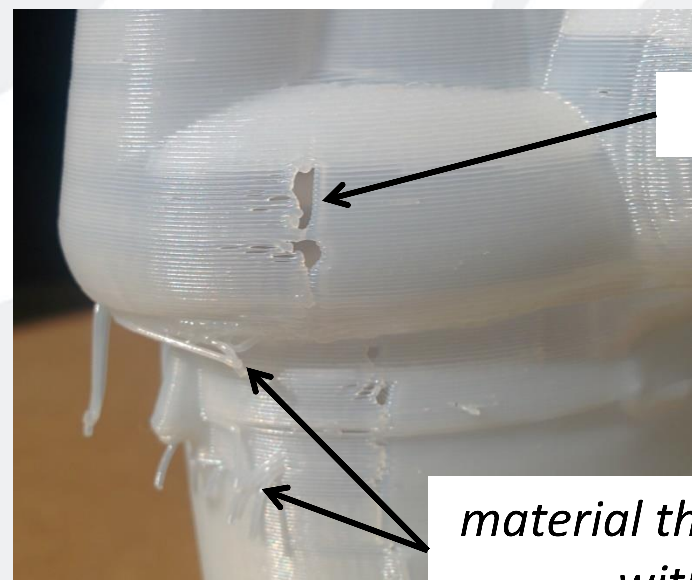
- Two approaches: 2 shells + 5% infill (initial, #1), 1 shell + 0% infill (verified, #2)
- HIPS material with standard processing parameters for MakerBot software (no changes in temperatures and speeds)
- No support – impossible to remove without damaging the part



No.	Layer thickness [mm]	Infill [%]	No. of shells	Weight [g]	Man. time [min]
#1	0.3	5	2	78	283
#2	0.3	0	1	35	140

RESULTS - MANUFACTURING





- Approach #1 – no visible major shape errors
- Approach #2 – errors as presented, caused by 1 shell, machine inaccuracy and lack of stiffness

MOLD MAKING PROCESS

- Approach #1 – upside down
- Approach #2 –as presented

gating system cut out of foamed polystyrene

manual sand filling of a molding box

blowing through the sand with CO2

final mold

CASTING PROCESS

- Approach 1 (2 shells, 5% infill) – failed (clogged mold, unfull casting)
- Approach 2 (1 shell, 0% infill) – success (pattern burned and pushed out of the mold completely)

CASTING RESULTS

- Approach #1 – no casting obtained
- Approach #2 – casting obtained, acceptable quality as evaluated by the receiving foundry
- Material structurally correct, no potentially damaging porosities or shrinkage cavities
- Model needs further processing – grinding, machining etc.

CONCLUSIONS

Main conclusions from realized industrial studies:

- polystyrene 3D printed pattern for cast iron foundry – **viable option**
- possibility to obtain very cheap and complex-shaped patterns

Process characteristics - limitations:

- recommended infill: 0% (hollow part), layer shells: 1, layer thickness: 0,3 mm
- no support possible with current approach
- division into sub-parts required for better efficiency
- poor accuracy, shape errors due to machine instability
- highly sensitive process, requires supervision

Possible future study directions:

- different materials
- different shapes
- various processing parameters for better accuracy

SUMMARY

3D printing + foundry = efficiency increase

FDM + new approaches = commercial possibilities

open source 3D printing = extension of manufacturing scope, limitations of accuracy and strength

THANK YOU

FOR ATTENTION