Finite Element Analysis of Induction Heating Process Design for SMART Foundry 2020

(SMART=Sustainable Metal casting using Advanced Research and Technology)

Presented By:

Himanshu Singh

PhD Scholar VNIT Nagpur

hsingha01@hotmail.com

Modules of the project

1. Casting design and simulation
2. Automatic mold fabrication
3. Efficient melting and direct pouring
4. Metal matrix processing
5. Data sensing, analytics and optimization

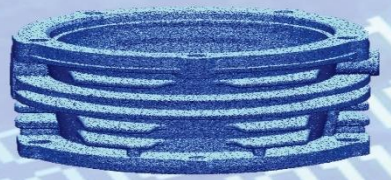
hsingha01@hotmail.com

SMART
Sustainable Metalcasting by Advanced Research and Technology

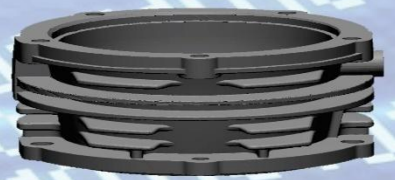
3D Scanning for Reverse Engineering

Creation of 3D models without CAD: Rapid manufacture of spare parts

3D Scanner



Cloud of points



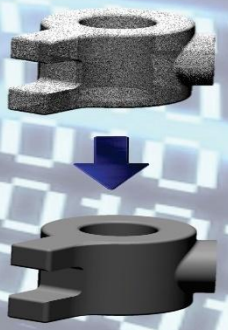
CAD model

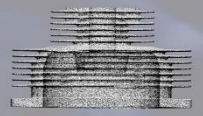
Existing objects can be scanned to create a Cloud of Points, which are 'stitched' into a CAD model.

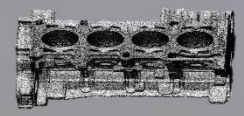
This is useful to 'reverse engineer' parts for which drawings may not exist, like an old car or valuable equipment.

Tripod-mounted systems scanning rotating objects give less than 0.1% error.

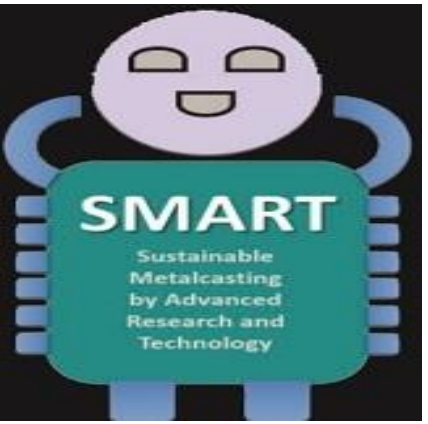
Hand-held and phone based scanning is less accurate, but costs much less, making it widely accessible.





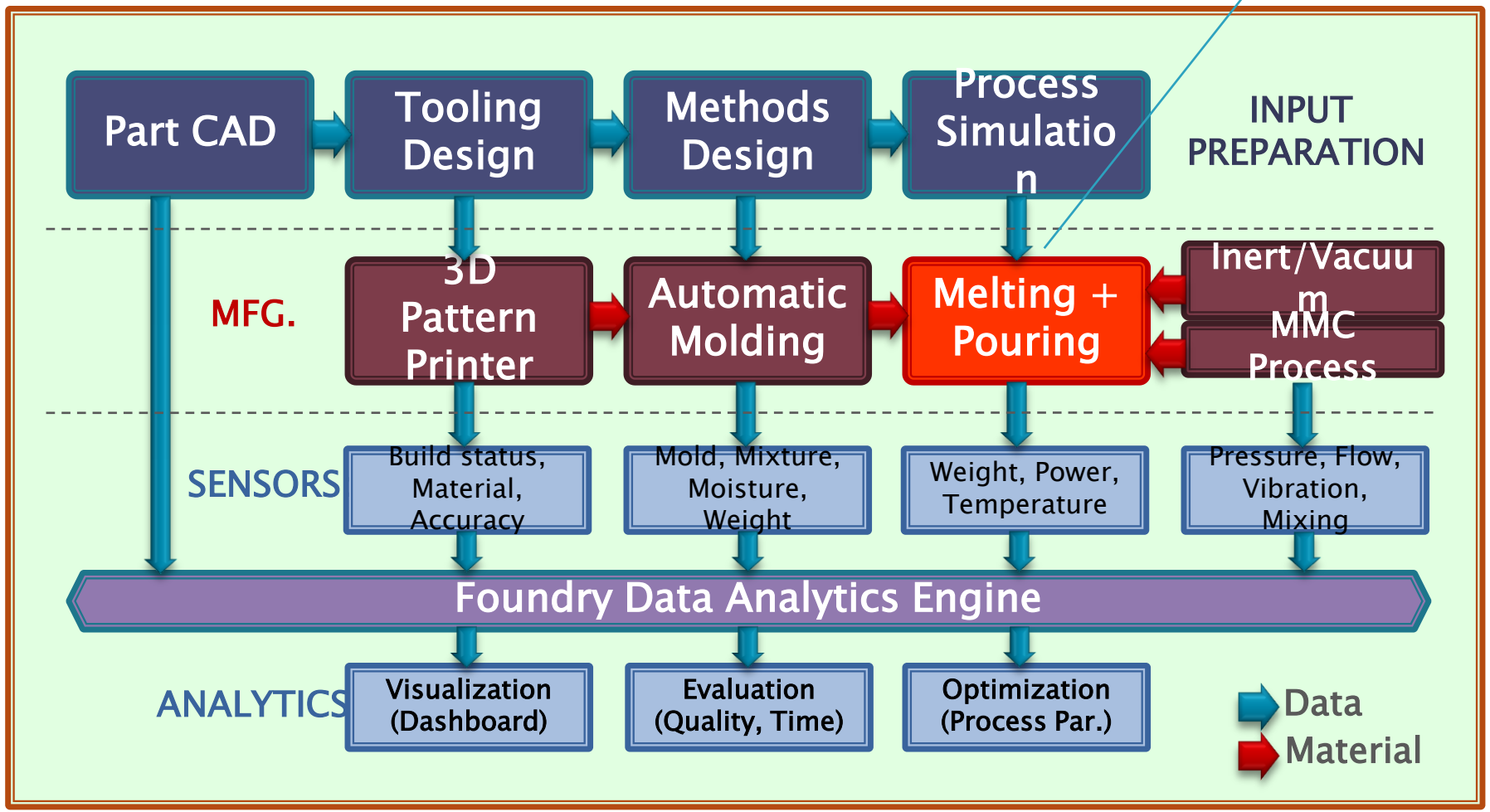


hsingha01@hotmail.com



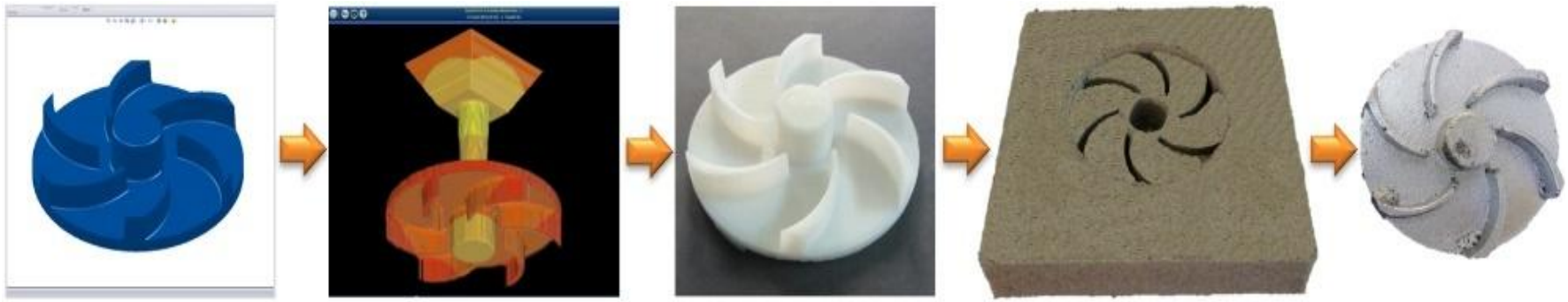
SMART Foundry 2020

COMSOL Analysis



hsingha01@hotmail.com

Steps:



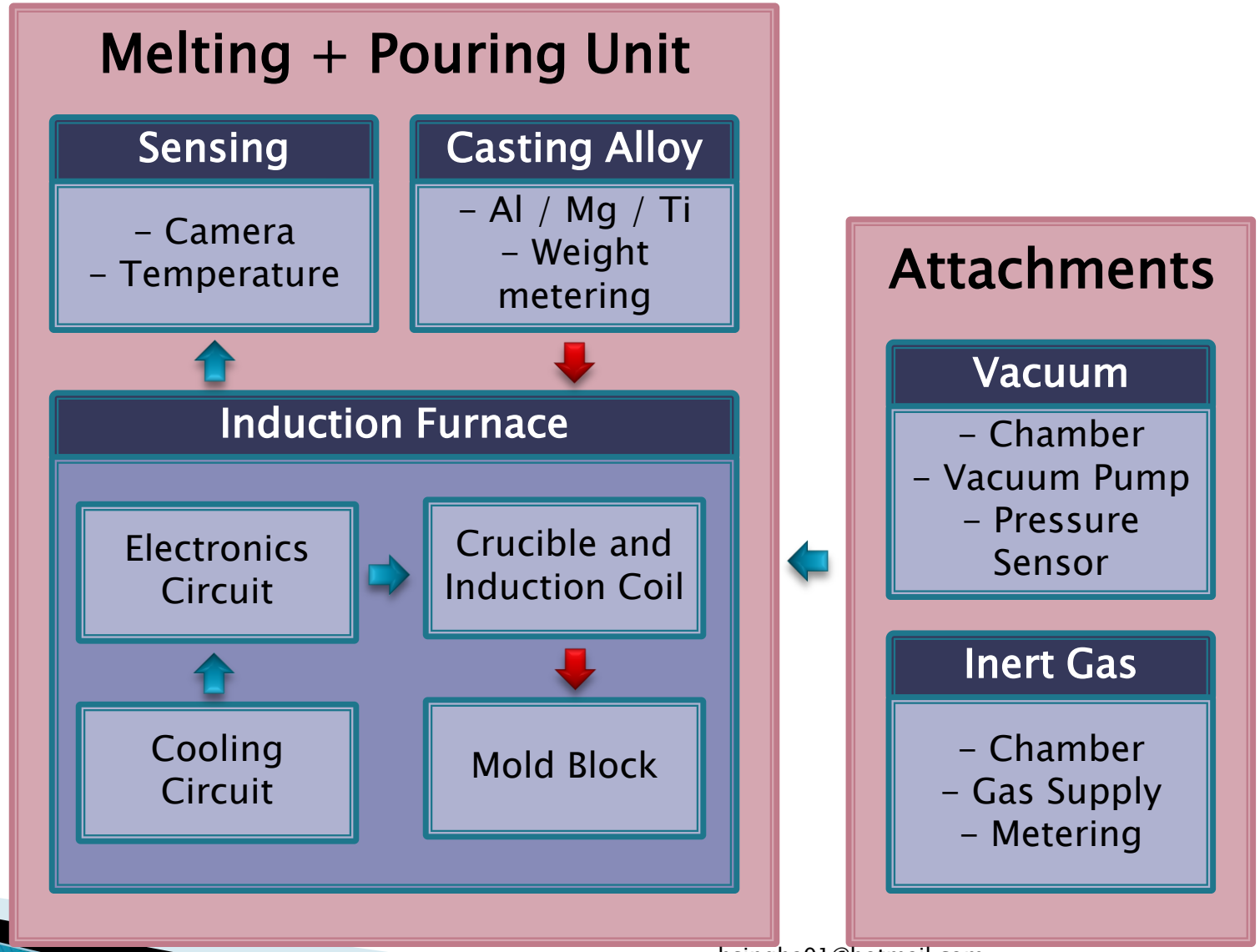
hsingha01@hotmail.com

Area to be Explored

- Melting + Pouring

hsingha01@hotmail.com

Module : Melting and Direct Casting



hsingha01@hotmail.com

Induction Furnace @ VNIT Nagpur

hsingha01@hotmail.com

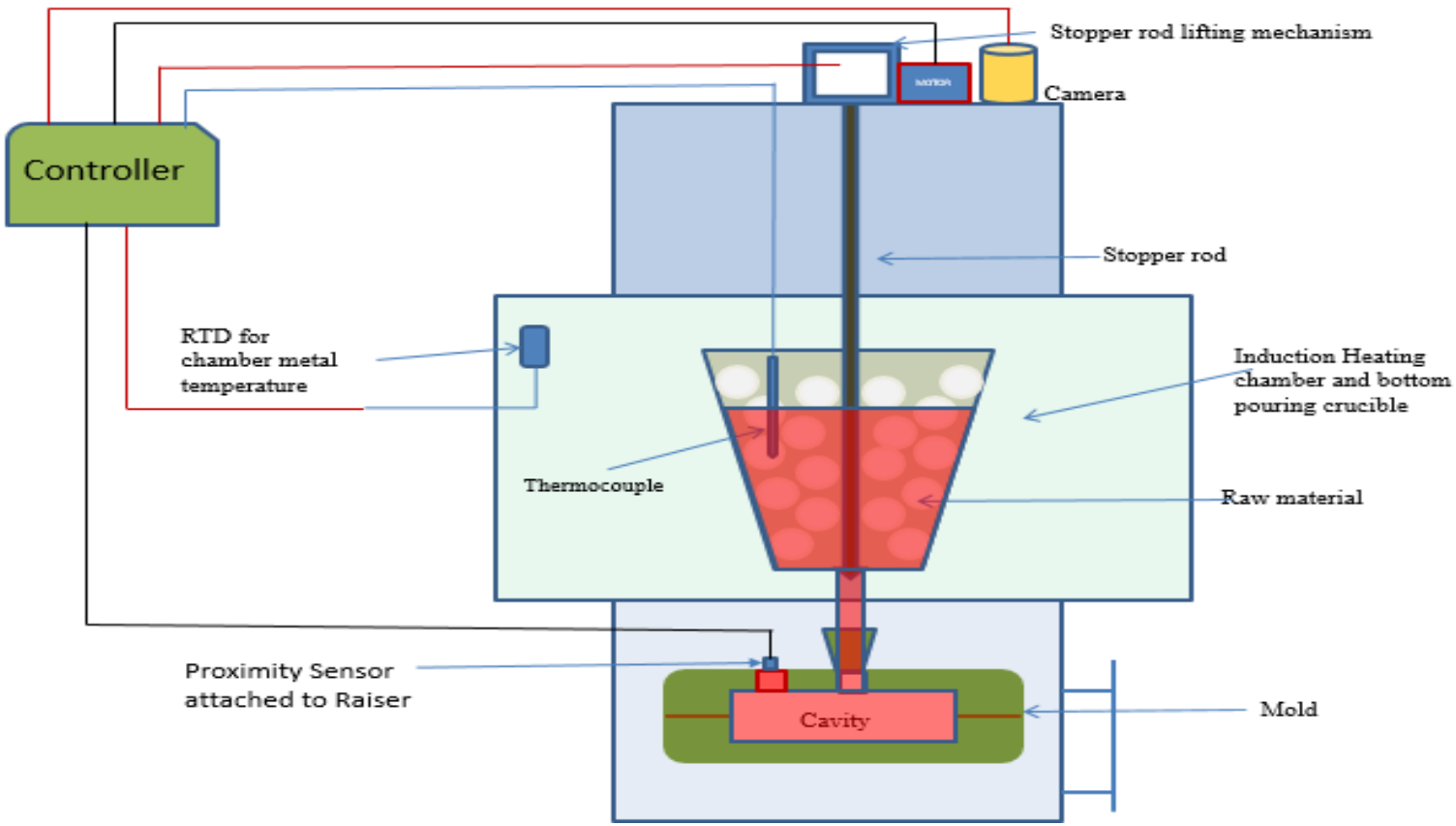
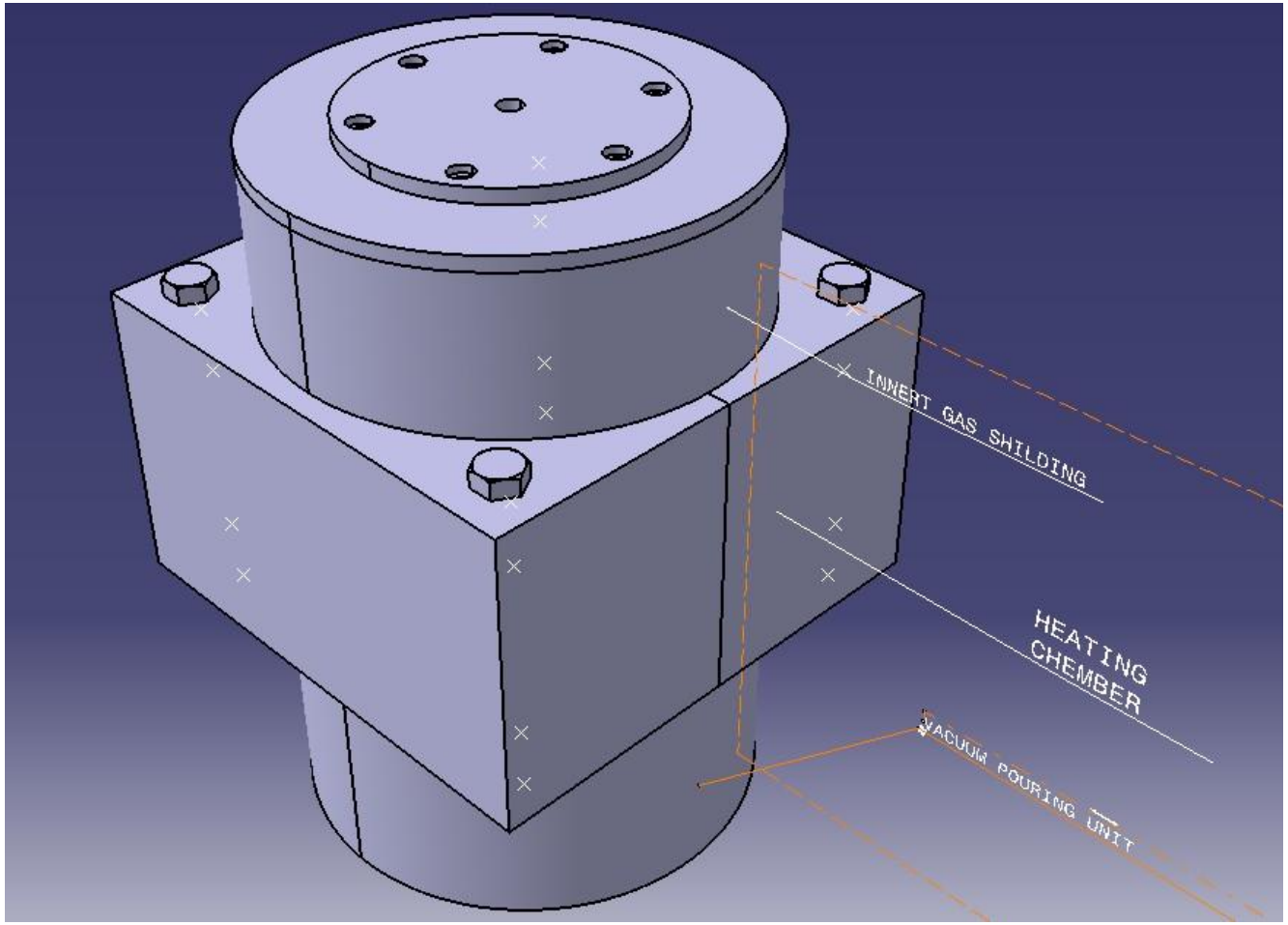


Fig. Induction melting with direct pouring and data acquisition

hsingha01@hotmail.com

Induction Furnace CAD Model



hsingha01@hotmail.com

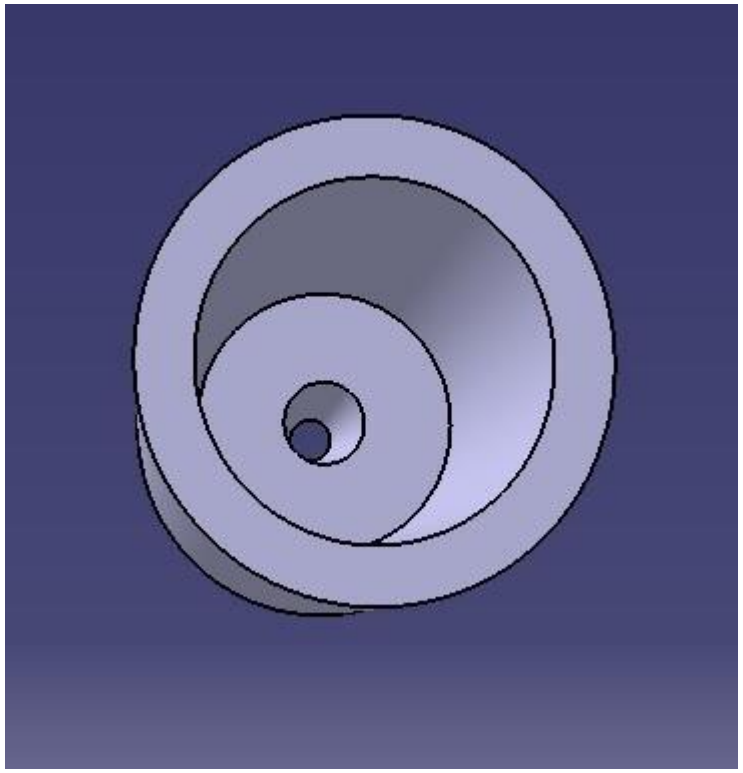


Figure 2 Bottom Pouring Crucible

Figure 3 Crucible with Tapping Rod

hsingha01@hotmail.com

COMSOL

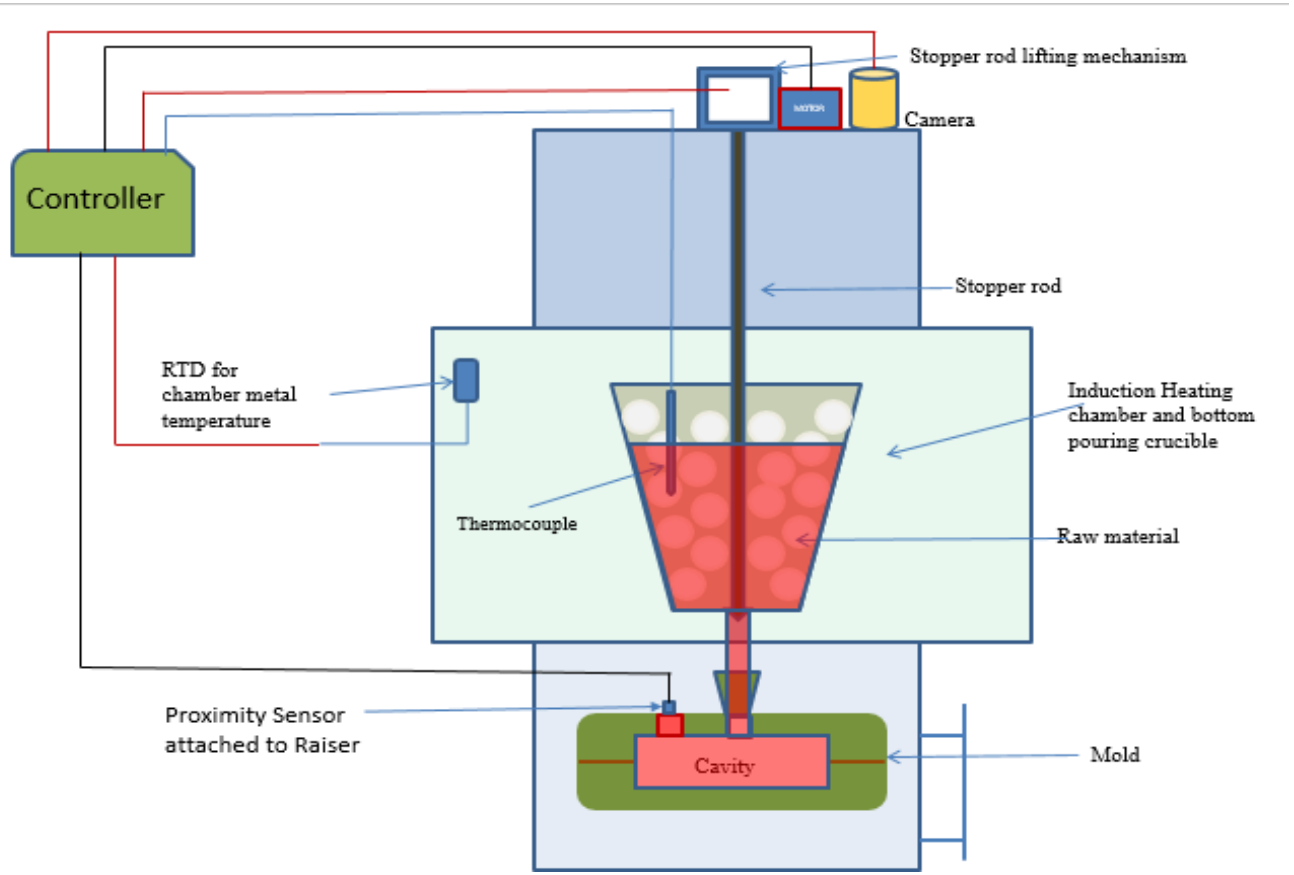
- Numerical model Validation
- Main features of the model
- Geometry & Meshing
- Governing equations and Boundary Conditions
- Numerical results
- Conclusions

hsingha01@hotmail.com

It is a high temperature vacuum distillation furnace used for recovery of heavy metals

Functions :

- Melt and consolidate of heavy metals
- distill the volatile metals and salts
- operate in inert containment box
- heat reasonably fast while being capable of holding temperature

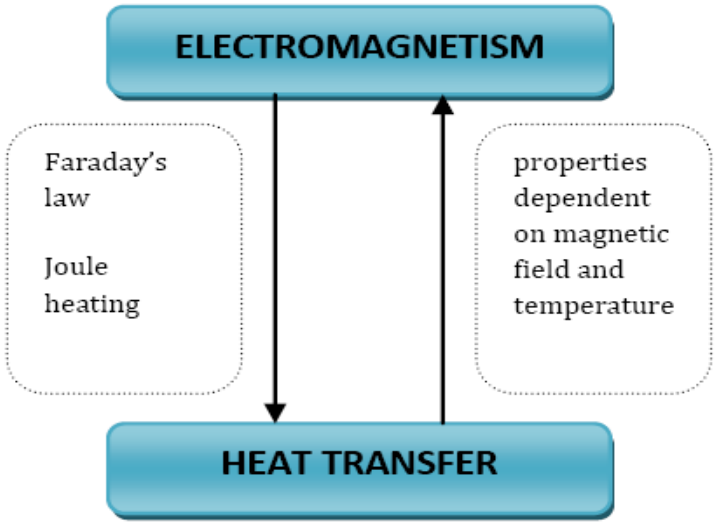


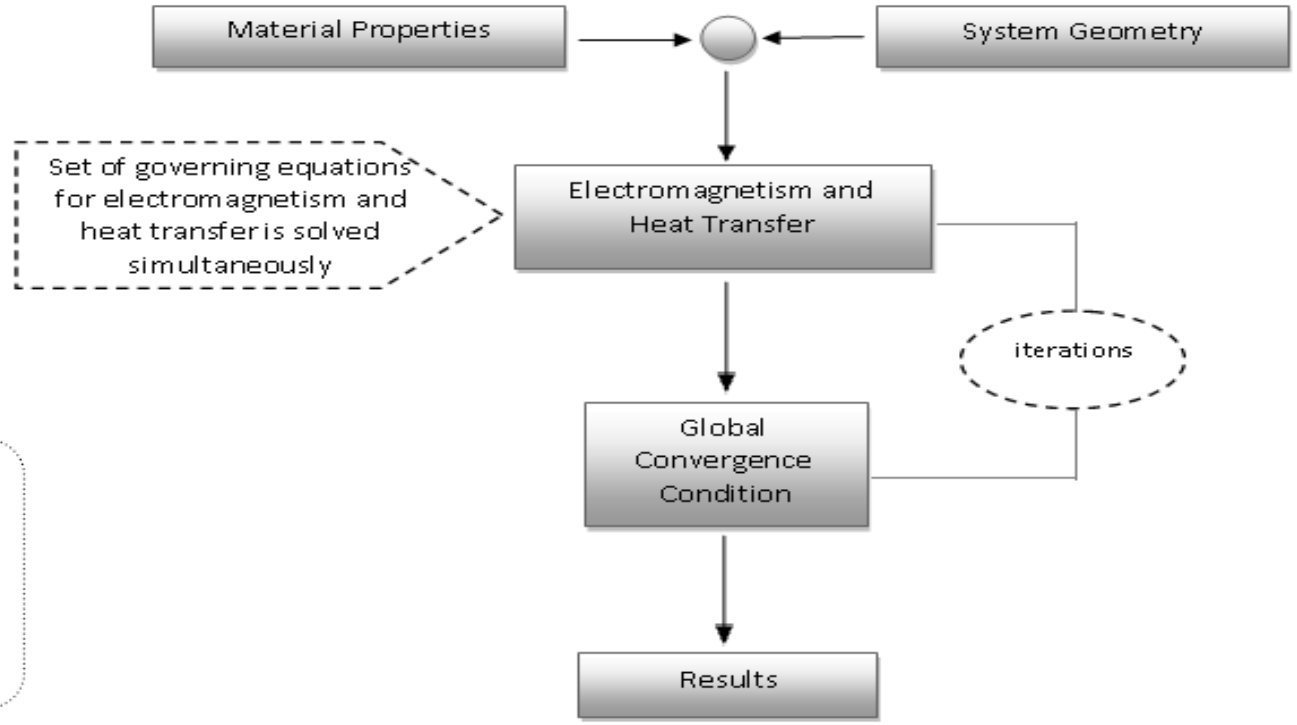
hsingha01@hotmail.com

COMSOL Modules

- **Tightly coupled phenomena**
- **Non linear**

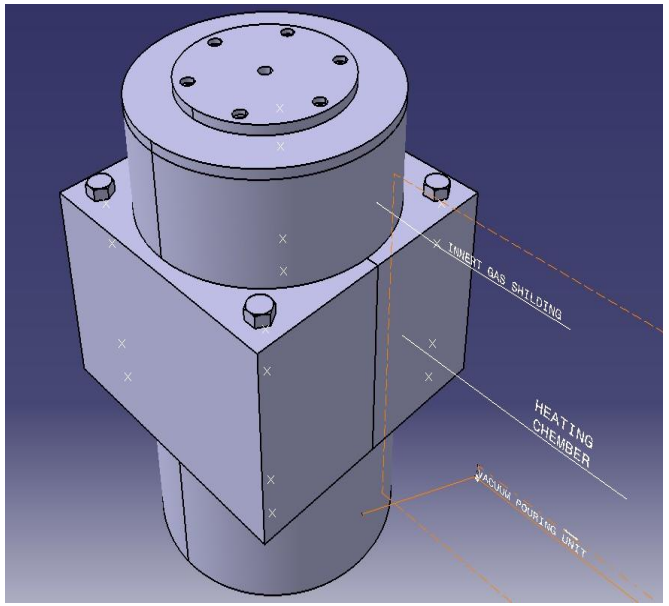
μ(T, ω), σ(T), C(T), k(T

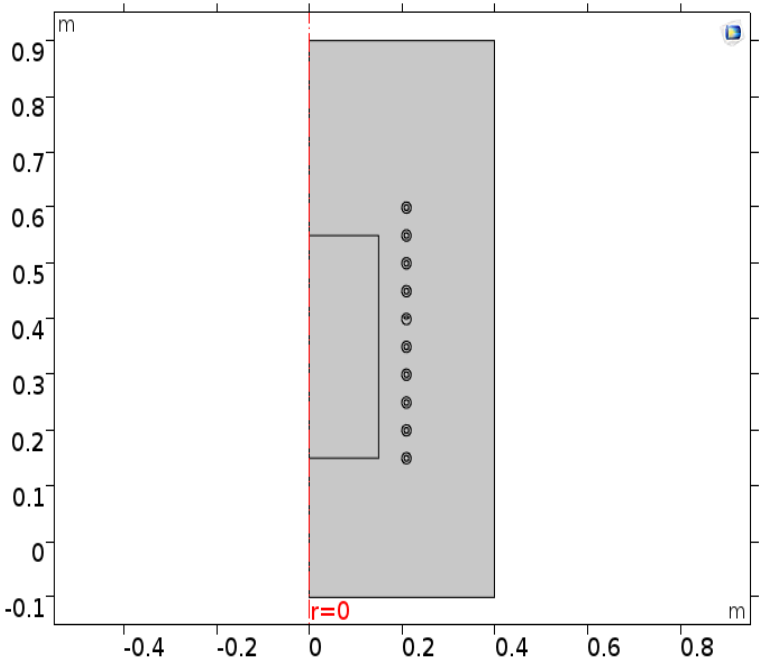




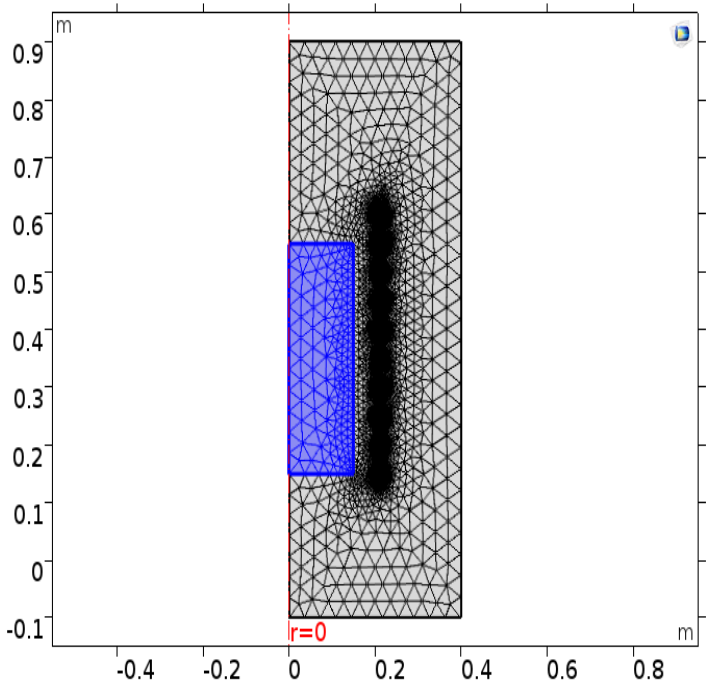
hsingha01@hotmail.com

Geometry in COMSOL
2D Axis Symmetric



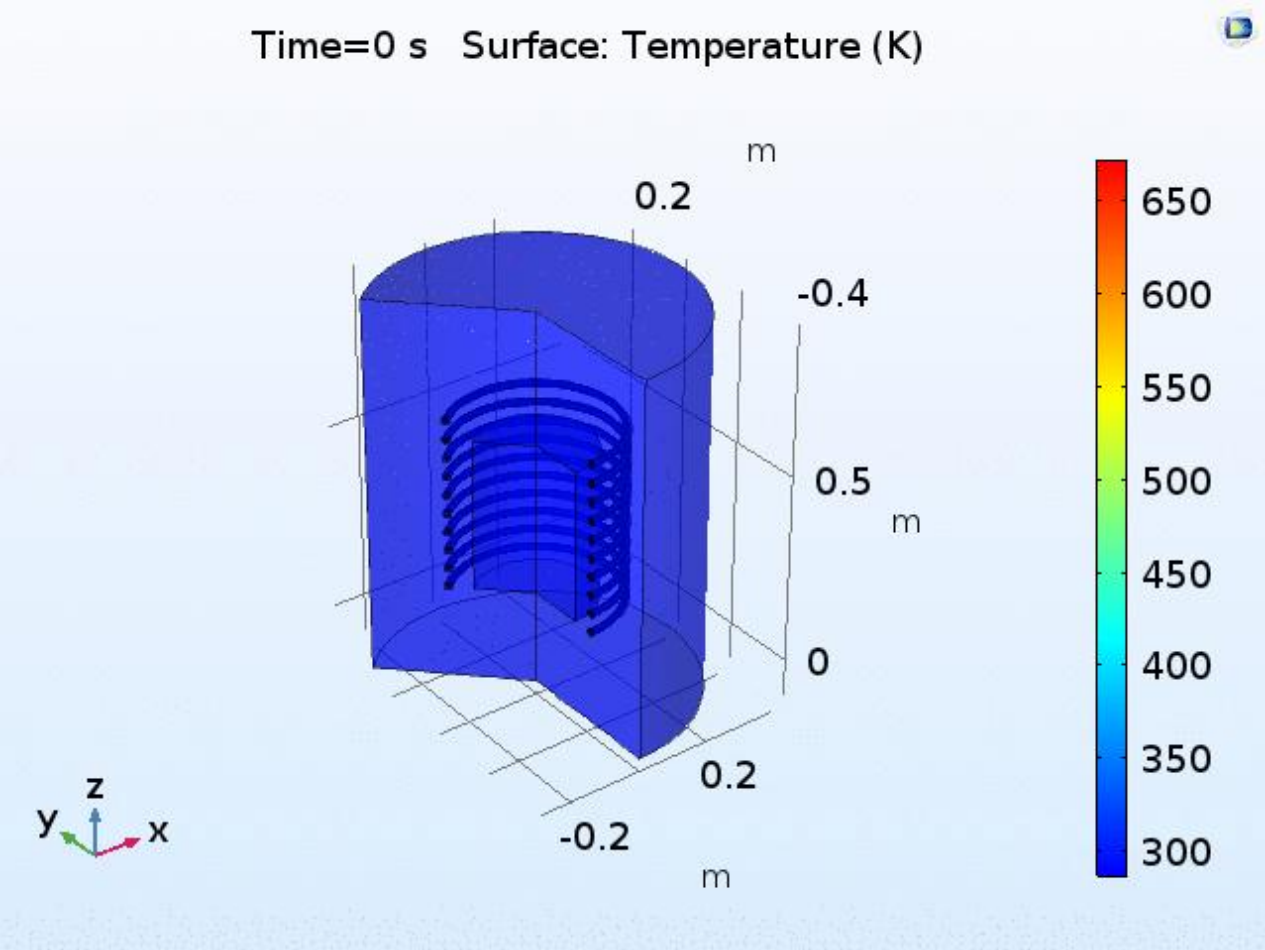


Fine Meshing



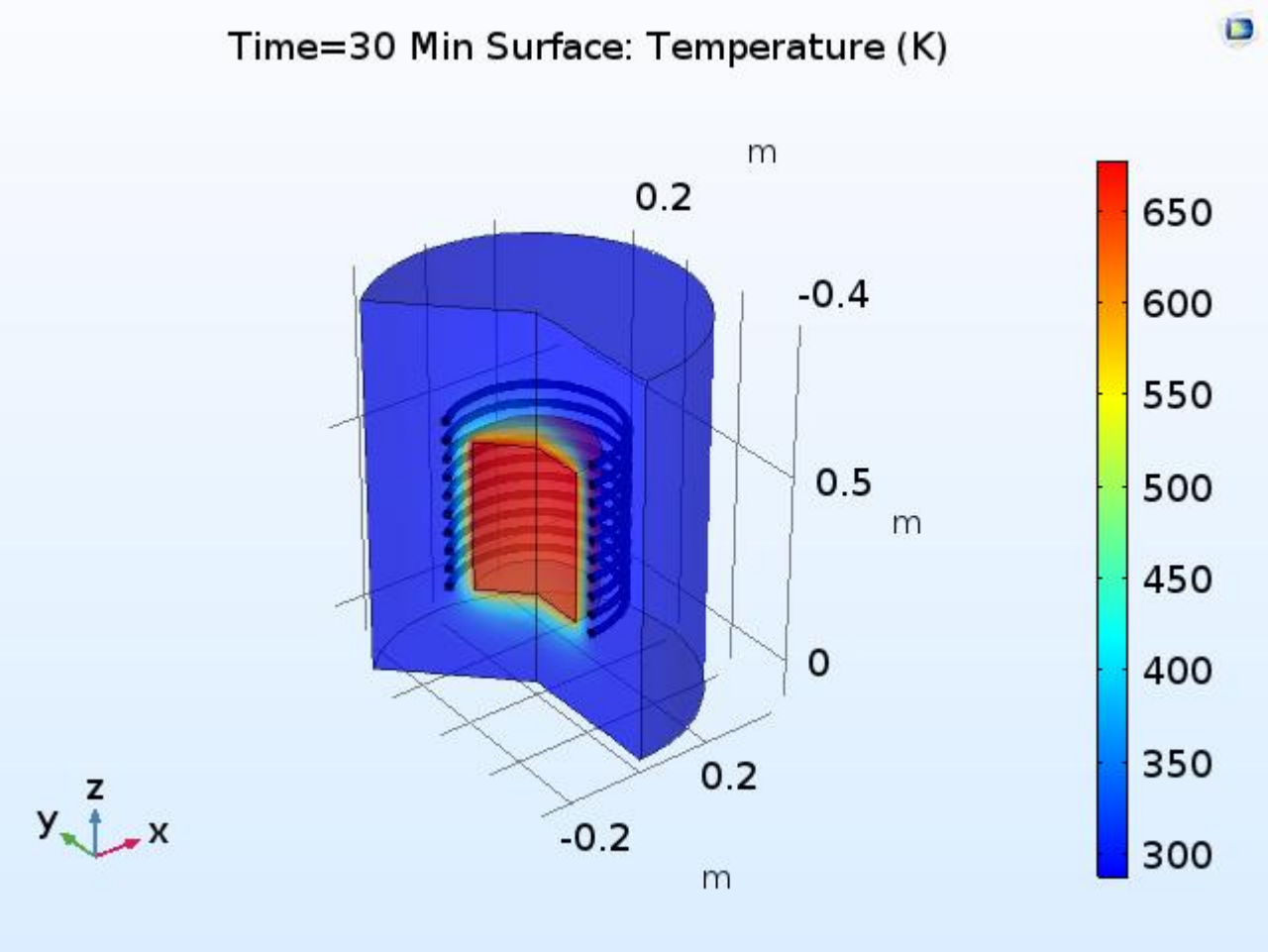
hsingha01@hotmail.com

Temperature Profile



hsingha01@hotmail.com

Temperture Profile

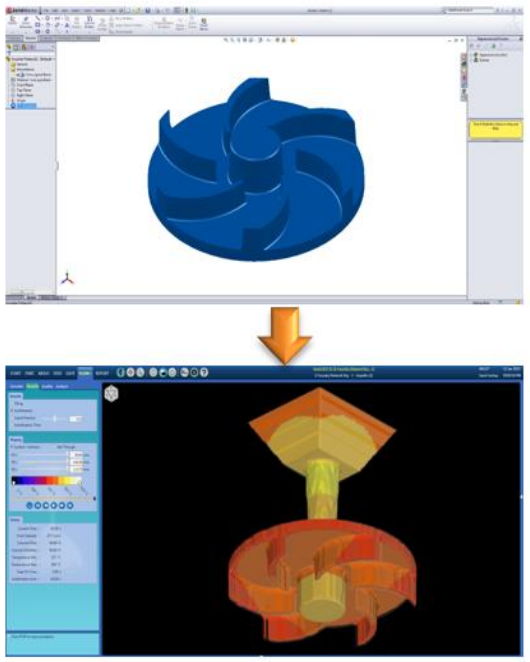


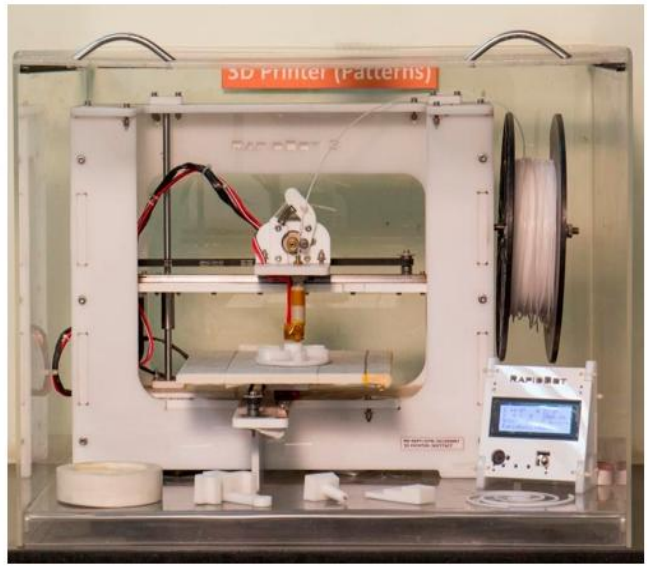
hsingha01@hotmail.com

Conclusions

- Transient Thermal analysis of mock-up induction furnace is being carried out in
- this study which is highly important for operation and control of the process.
- Preliminary model : it will aid in improving the design.
- The results of this study have shown that the temperature of the crucible rises to 1500 oC in 2 hours of heating time at frequency of 8 kHz and current of 400 A. copper is likely to melt under these conditions.
- The studies reveal that copper-liner is effective in reducing the electromagnetic coupling between the coil and the vessel and thus prevents vessel from getting heated up by this effect.
- The coil temperatures are above the acceptable temperature of copper material, hence different cooling technique is to be adopted.
- These results will be compared with the experimental results which will be obtained during the operation of mock up facility.

hsingha01@hotmail.com





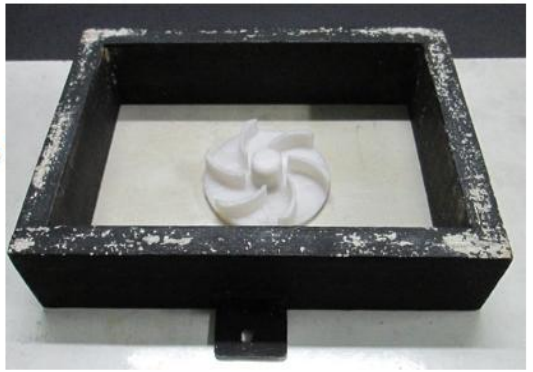
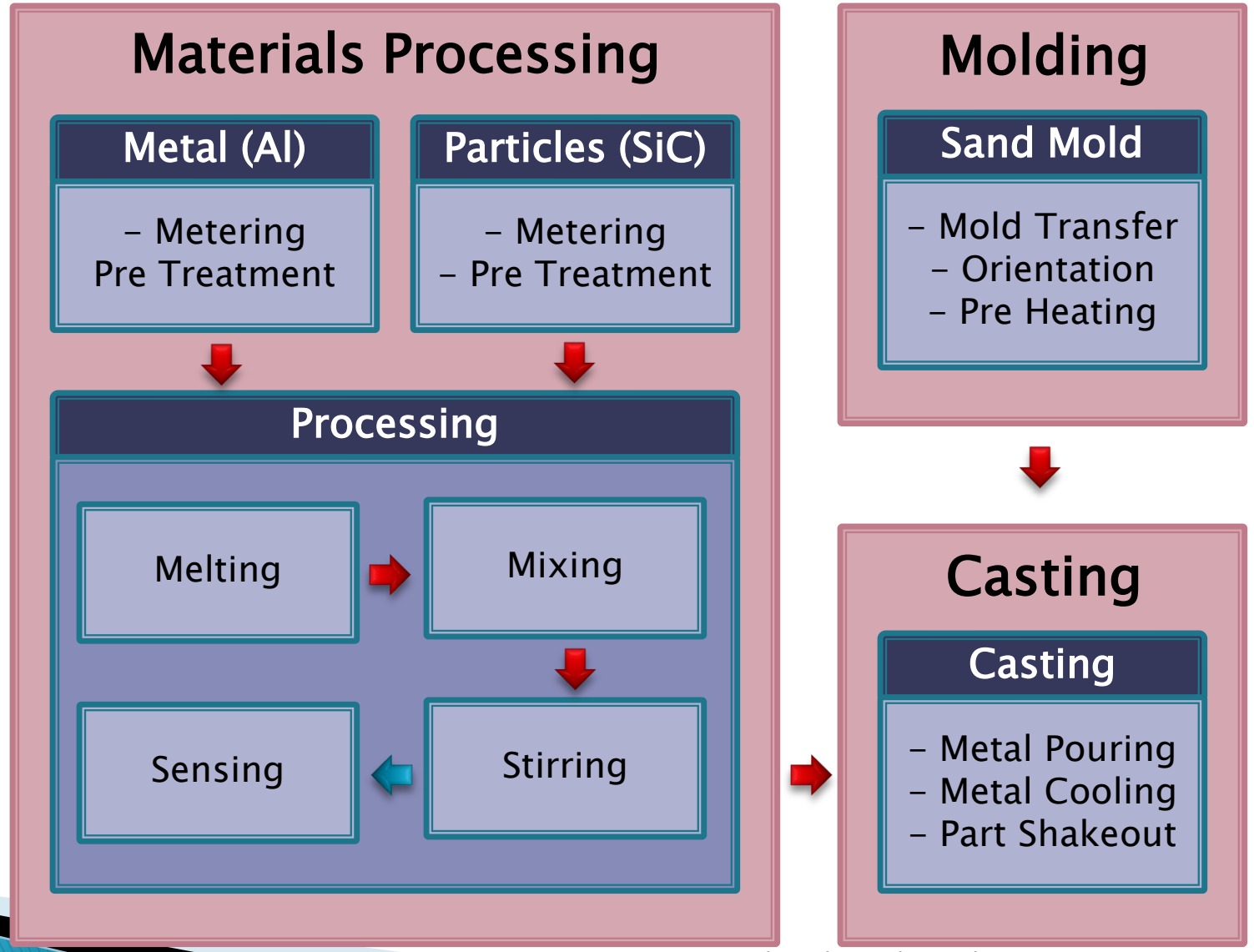


Fig. Low cost rapid manufacturing methodology developed with industry partners

hsingha01@hotmail.com

Module D: Metal Matrix Processing & Casting



hsingha01@hotmail.com

Data Sensing and Analytics

Sensing

Pattern Printing
- Build Status
- Unit Temperature
- Spool Balance

Mold Fabrication
- Pattern Id
- Sand Weight
- Moisture

Melting, Pouring
- Metal Weight
- Temperature
- Mold Status

Data Analytics and Control

Dashboard (Status Visualization)
- Pattern Printing
- Mold Fabrication
- Melting, Pouring
- Cameras

Predictions
- Internal Defects
- Mech. Properties

Suggestions
- Process Parameters (preferable/avoidable ranges)

Automatic Process Control
- Adjustments
- Warning, Stop

hsingha01@hotmail.com

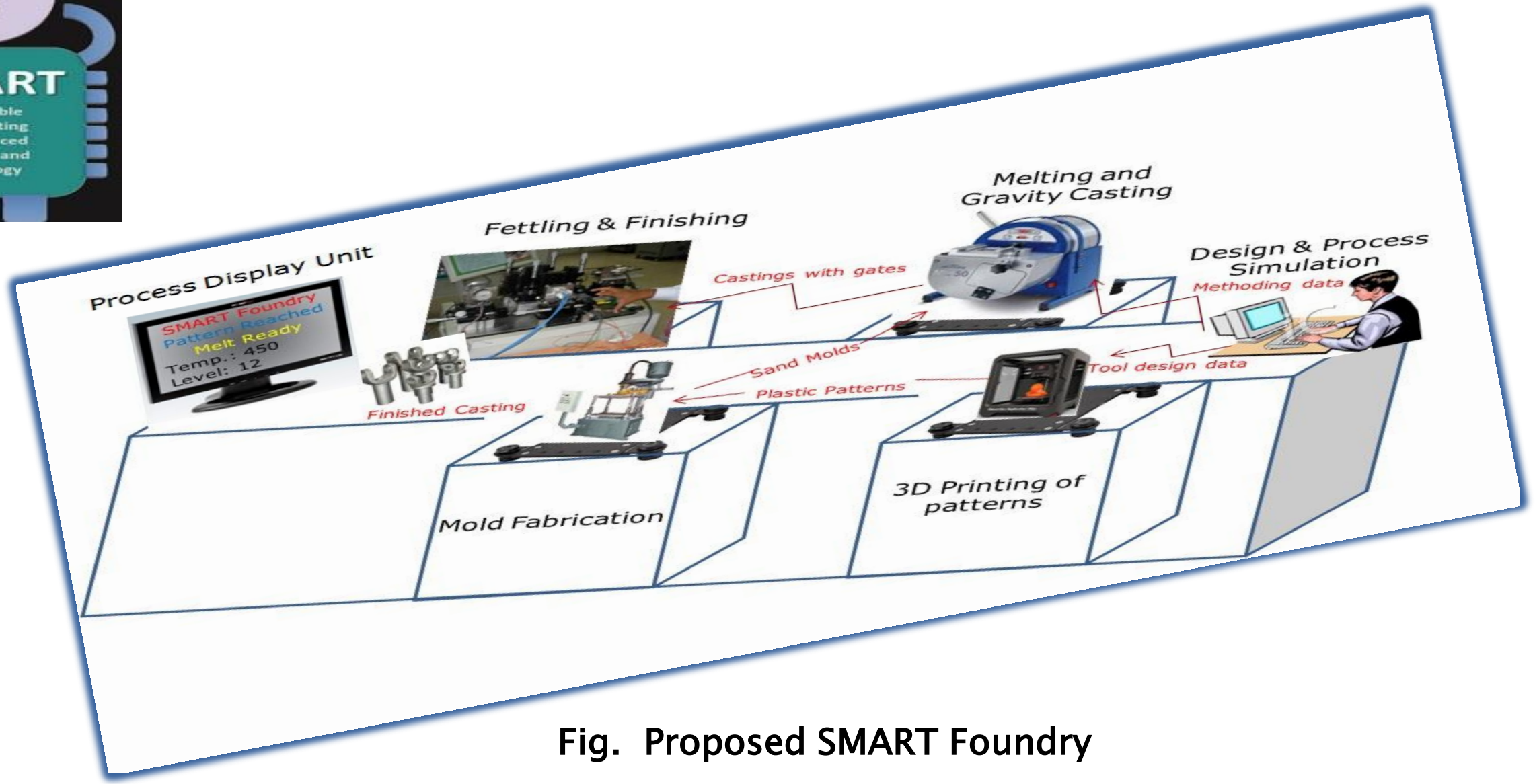
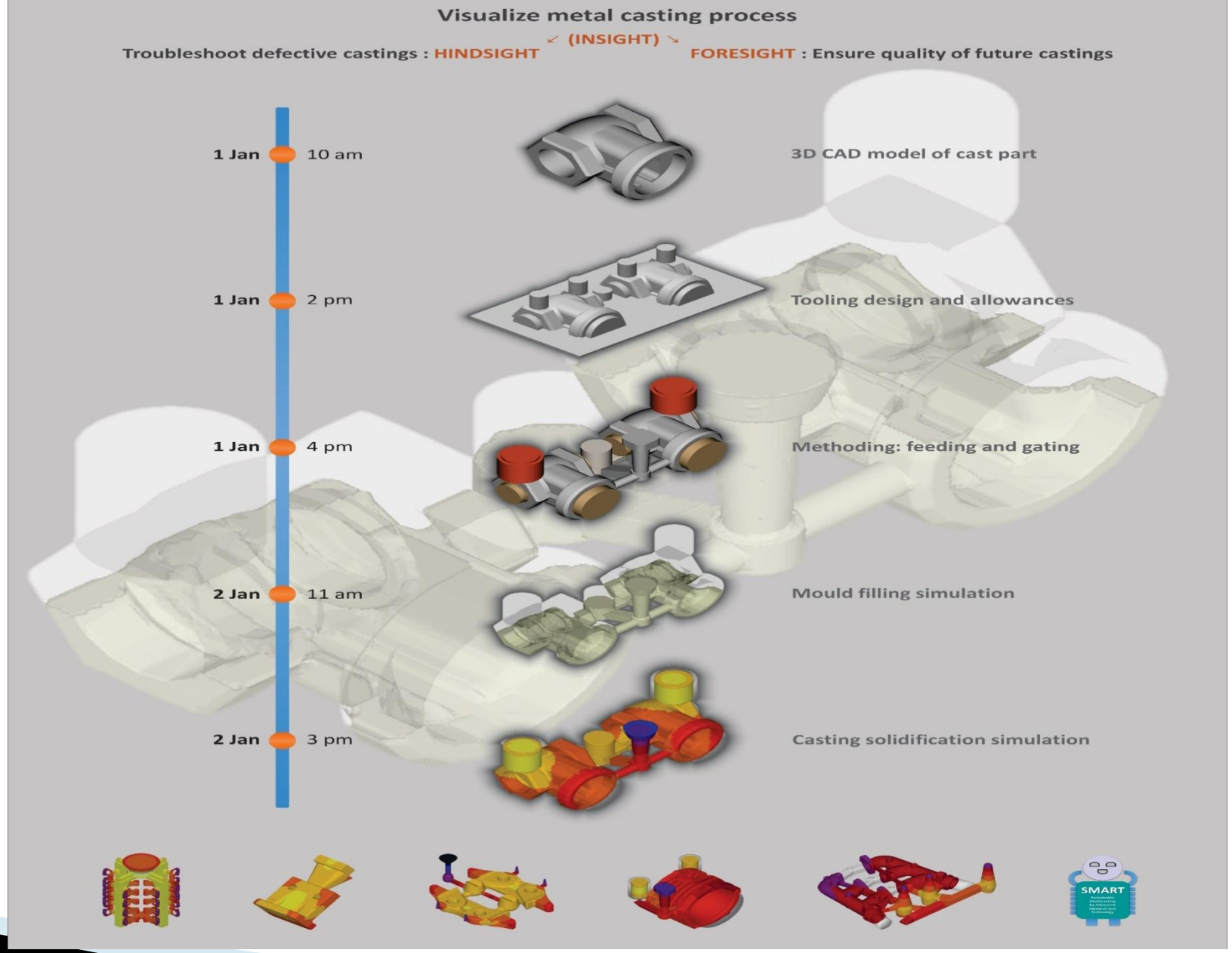


Fig. Proposed SMART Foundry

hsingha01@hotmail.com

Casting Design and Simulation



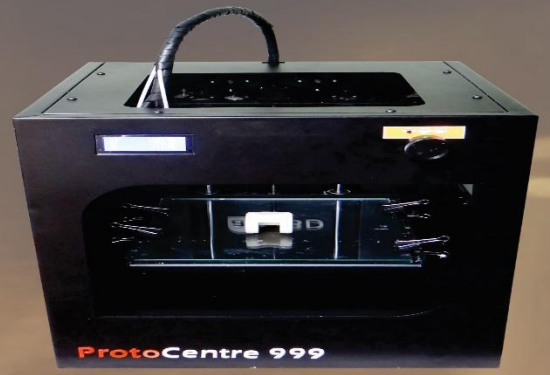
hsingha01@hotmail.com

SMART
Sustainable Metalcasting by Advanced Research and Technology

3D Printing of Casting Patterns

Automatic manufacture of tooling for short production runs

3D CAD model



3D Plastic Printer

Tooling (pattern / die / mold) can be manufactured by any of these routes:

+ Additive (3D Printing): *fast*
– Subtractive (Machining): *accurate*
~ Formative (Casting): *economical*

Hybrid route combining all three, is useful for rapid manufacture of plastic or metal patterns with high accuracy yet low cost.

Plastic pattern

Sand casting

Investment casting
Ceramic shell

Metal part or pattern

hsingha01@hotmail.com

SMART
Sustainable Metalcasting by Advanced Research and Technology

Rapid (No-bake) Sand Moulding

Chemical resin bonded sand moulds
manual or automatic | clean and easy process

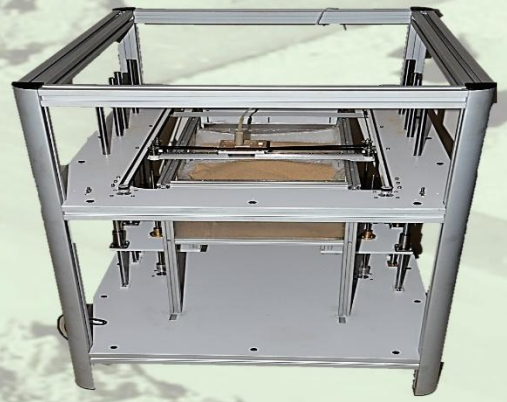
Silica Sand

Chemicals

Sand Mixer

Plastic pattern fabricated by 3D Printing

Manual mould making



3D Printer for automatic fabrication of sand moulds

Resin based moulding:

- ✓ Clean (unlike clay based)
- ✓ Less ramming pressure
- ✓ No baking (energy saving)
- ✓ Quick hardening & strength
- ✓ Good dimensional quality
- ✓ Easy to shake-out

Mould ready for pouring (within one hour)

Al-alloy casting

hsingha01@hotmail.com

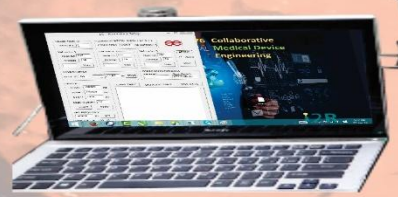
SMART
Sustainable Metalcasting by Advanced Research and Technology

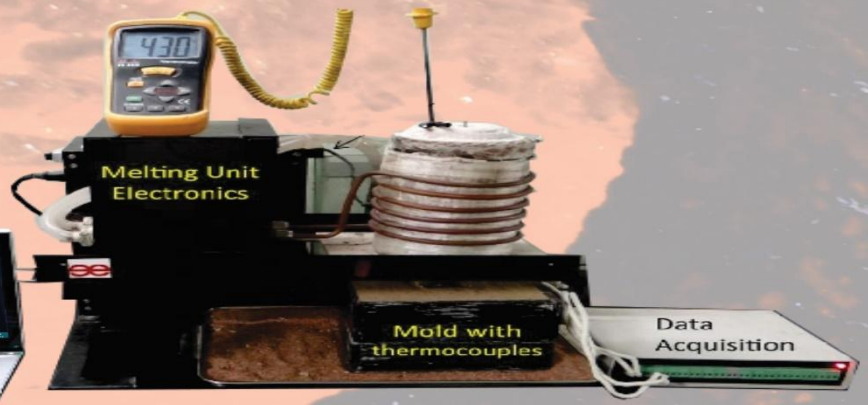
Tabletop Casting (Melting + Pouring)

Induction melting and direct pouring into mould:
Compact, energy-efficient, safe

Sand Mold

Computer-controlled tabletop casting unit with temperature data acquisition



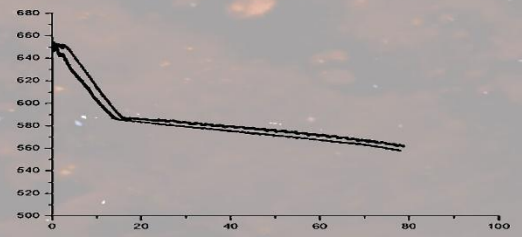


Speed: CAD to First Part in 8 hours
Subsequently, 1 part/ hour/ mould

Cost: 2-5% of Metal 3D Printing

Quality: Direct pouring minimizes
- *Air contact:*
  - Less gas pickup (gas porosity)
  - Less oxidation (slag inclusion)
- *Temperature drop*
  - Less fluidity issues (cold shut)

Casting with thermocouples



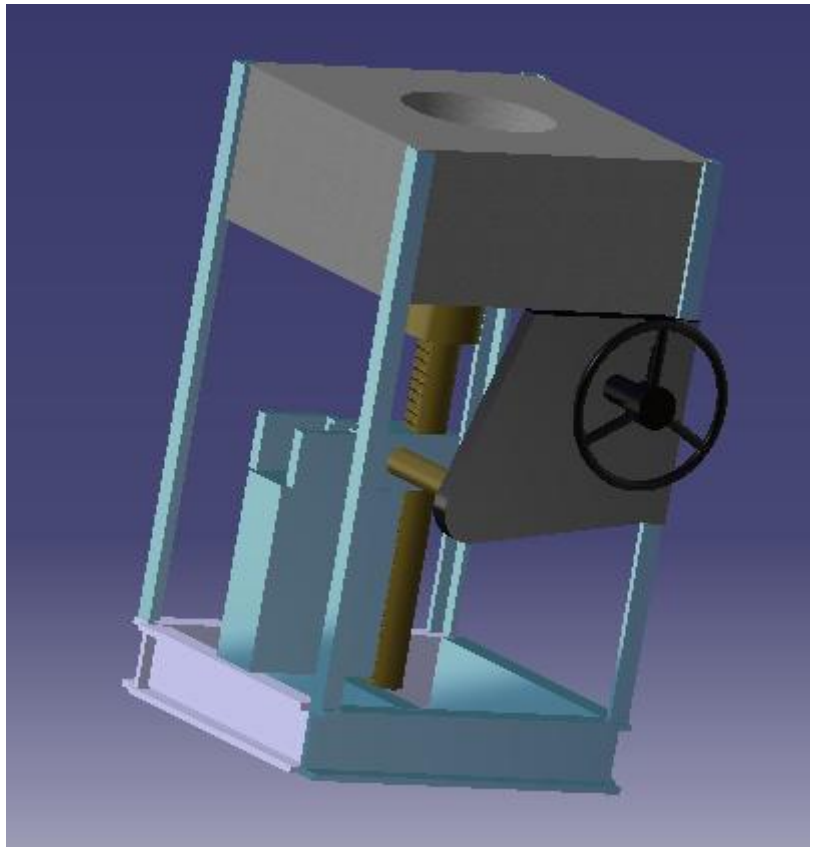
Cooling curves

Cooling curve is a signature of the alloy composition and processing. It helps predict the mechanical properties of casting.

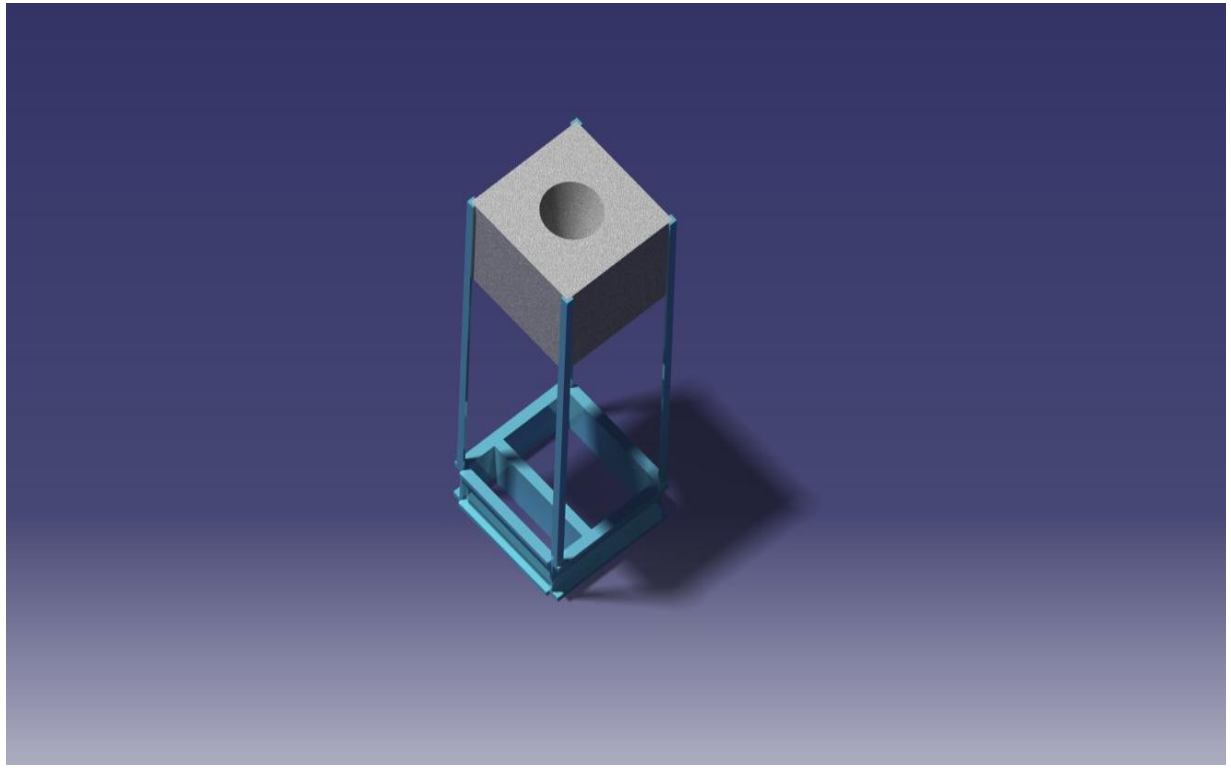
hsingha01@hotmail.com

THANK YOU

hsingha01@hotmail.com



hsingha01@hotmail.com



hsingha01@hotmail.com