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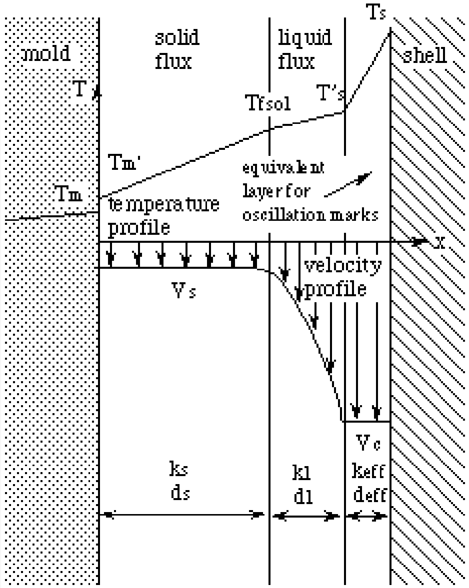
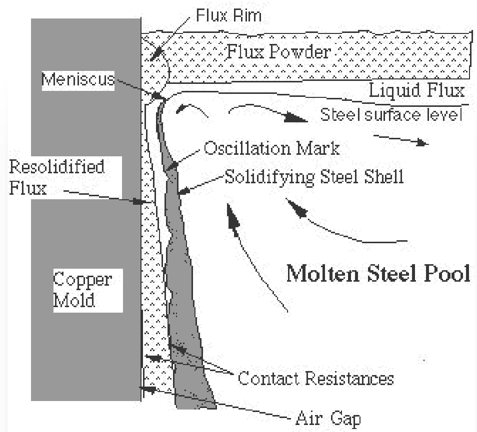
PRIVATE LIMITED
Bengaluru 560076, INDIA www.thermetsolutions.com

InverseSOLVER Case Studies

Solutions to complex structure-fluid interaction problems by InverseSOLVER





Heat transfer in the Continuous Casting Mold

- The problem is to estimate the heat transfer during continuous casting from the solidifying shell to the copper mold.
- The gap is filled with liquid and solid fluxing agents of varying thickness
- InverseSOLVER provides a solution

T.S.Prasanna Kumar, **"Estimation of Heat Flux in a Thin Slab Continuous Casting Mold by Inverse Thermal Analysis"** International Conference on Continuous Casting Past, Present & Future, Jamshedpur, 24th & 25th October 2005, IIM and TATA STEEL

Surface cracks in Induction Hardening

- During Induction Hardening, a spray of the quenchant follows closely the heated part
- The spray induces rapid cooling in the steel resulting in a hard surface
- If the cooling intensity of the spray is too high, the surface may crack due to thermal stresses.
- If it is too low, it may result in insufficient hardness
- How to compute the spray heat transfer coefficient for the selection of proper quenchant and proper intensity?

Sponsored Research from Caterpillar India Pvt., Ltd, Hosur, Bangalore, India, 2011

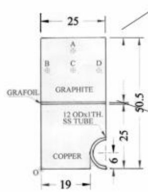
Heat flux on the Plasma Facing Component in Nuclear Reactors

- The problem is to design the cooling capacity required for dissipating the plasma heat through layers of graphite, stainless steel and copper tubing.
- How much heat must be dissipated?

TABLE 3
Input Parameters used in ANSYS

Properties	Input
Heat Flux (MW/m^2)	0.6
HTC (W/m^2-K)	22,000
Water Bulk Temp: T_b (° C)	50

Fig. 3. Model used in ANSYS

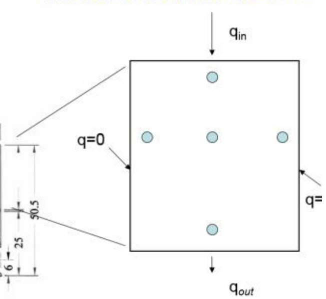


ORIGIN	CO-ORDINATES OF THERMOCOUPLES			
O (mm)	A (mm)	B (mm)	C (mm)	D (mm)
0,0	12.5,45.5	2.5,38	12.5,38	22.5,38
Temp (oC)	455.43	394.82	394.41	394.16

DIM IN 'mm'
TILE TC DETAILS

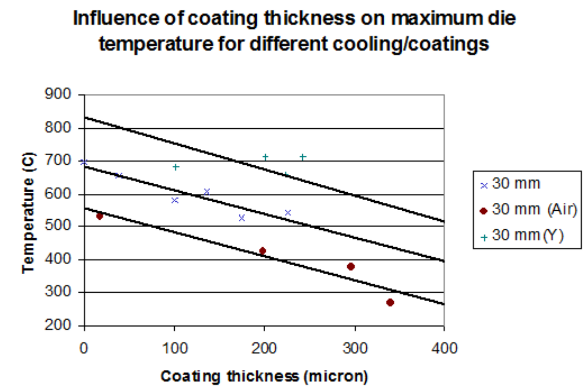
Fig. 4. Dimensional details of the model

Model domain of the PFC

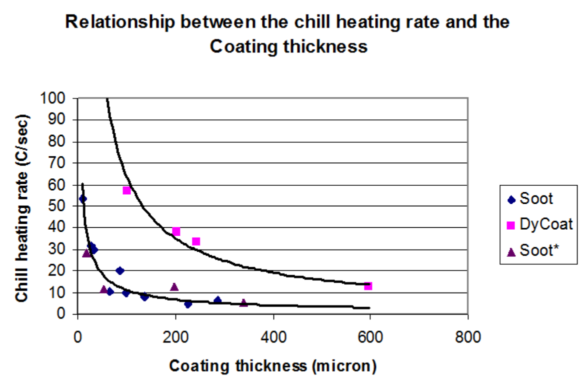


Sponsored Research: "Estimation of Heat Flux on PFC form Temperature Measurements by Inverse Conduction Method", Institute of Plasma Research, Bhat, Gandhinagar, India

Improving service life of dies for casting grey iron auto components



Industrial Project Sponsored by Brakes India Pvt. Ltd., Sholinganallur, India, 2004



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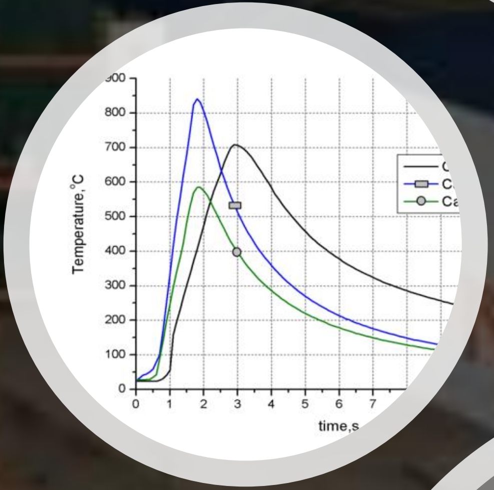
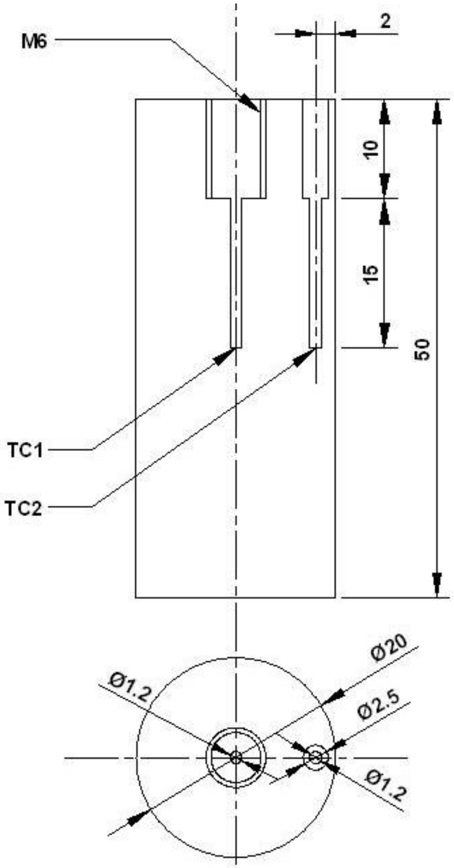
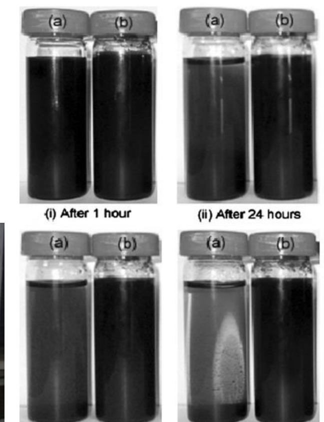
Heat flux due to the arc in Gas Tungsten Arc Welding

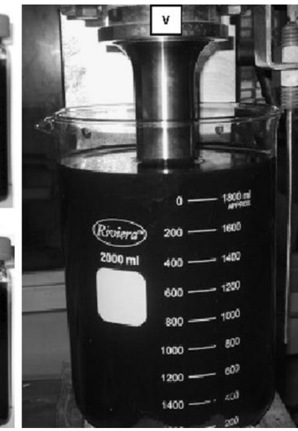
- Modeling fusion zone in welding requires estimation of heat flux as an input to the weld zone.
- Can CFD offer a simple solution to the heat distribution due to the arc?

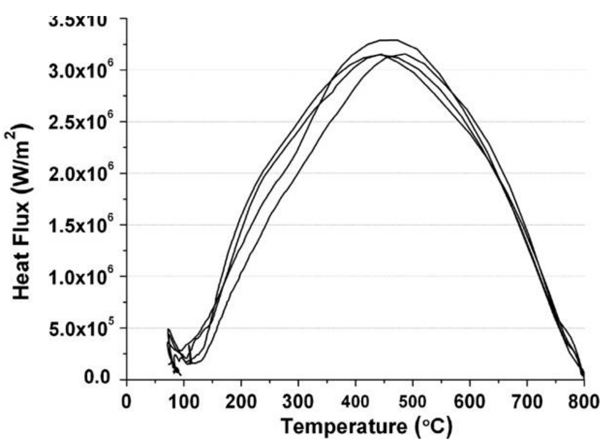


T. S. Prasanna Kumar, P. V. D. Ramesh, D. R. G. Achar, ESTIMATION OF HEAT FLUX IN GTAW PROCESS USING INVERSE HEAT CONDUCTION METHOD, IIW IC 08, Jan 2008, Chennai







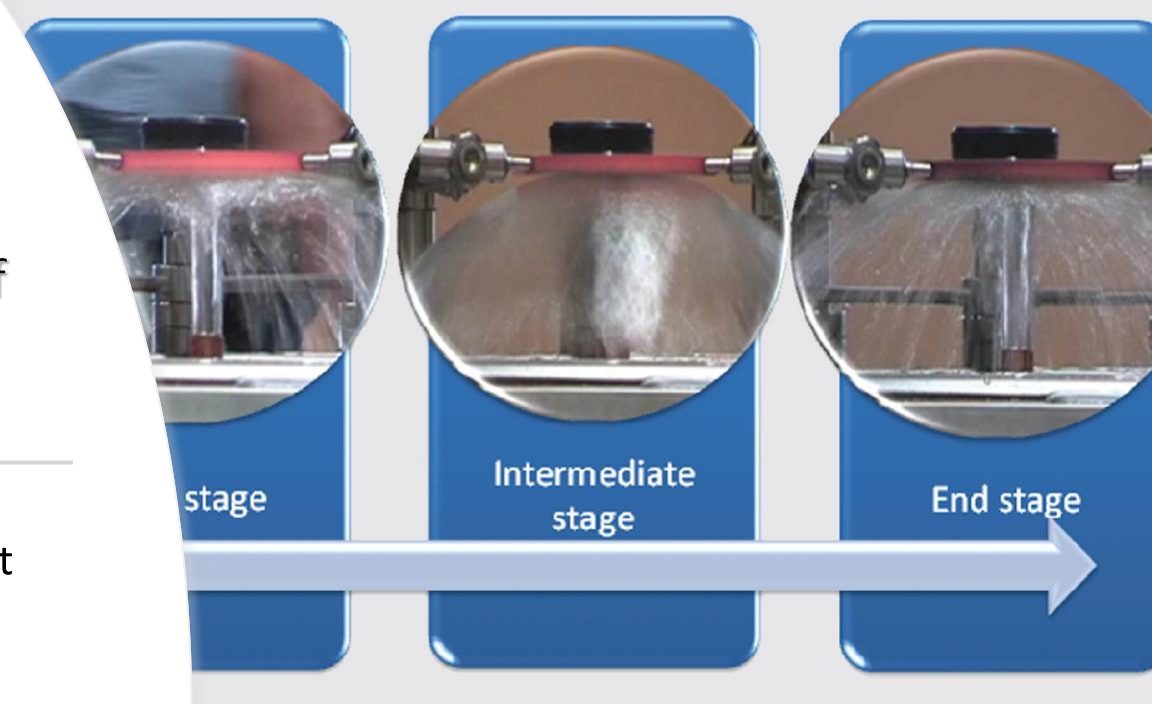


Cooling Efficiency of Nano Fluids

K. Babu, T.S. Prasanna Kumar, Effect of Bath Temperature on Surface Heat Flux during Quenching in CNT Nanofluids, Proceedings of the 26th ASM Heat Treating Society Conference Oct 31 – Nov 3, 2011, Cincinnati, Ohio, USA.; Eds: B.L. Ferguson, R. Jones, D.S. MacKenzie, and D. Weires

Heat transfer during cooling of a steel plate from a water jet

- Use of water spray, water jets, mist cooling are routinely practiced in the manufacturing industry.
- How to effectively design the cooling system for optimum results?
- As the systems deteriorate over time, is there a way to monitor their performance?



Análisis Multidimensional para la Estimación de Historias de Flux de Calor en las Fronteras de un Disco de Acero Inoxidable Enfriado Horizontalmente por el Impacto de una Columna de Agua, J.S. Tellez-Martinez, B. Hernandez-Morales, T.S. Prasanna-Kumar (In Spanish)

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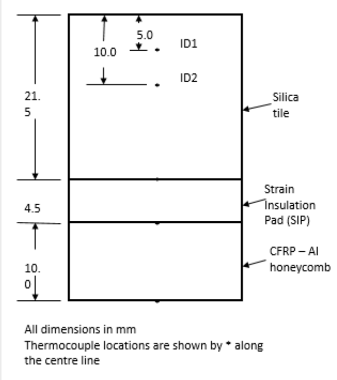
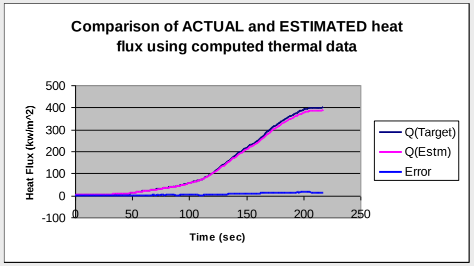
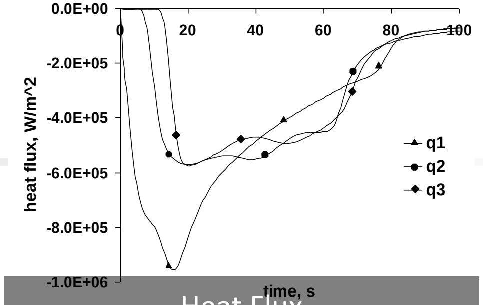
Design of Heat Shields for Re-entry Space Vehicles

- Aerodynamic heating during re-entry of space vehicles: A crucial issue for safety in space technology
- What parameters to consider during the design of Heat Shields
- New insulating materials will have to be assessed for their thermal properties
- What are the tools we have, apart from CFD Techniques?

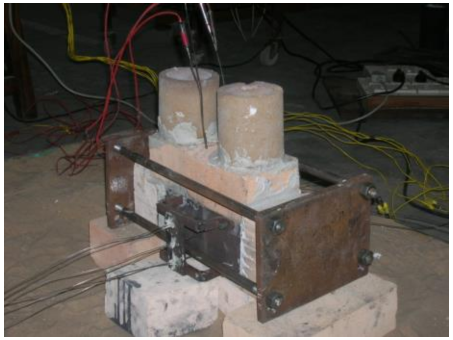


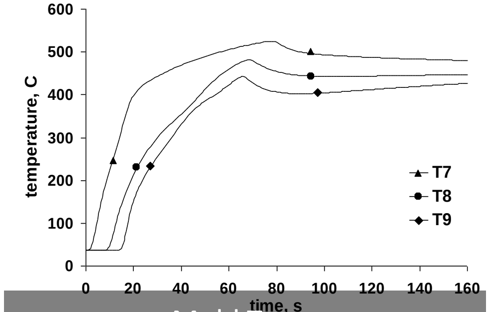


Sponsored Project; "Parameter Estimation and Inverse Solution of Non-Linear Heat Conduction Problems" Vikram Sarabhai Space Center, Trivandrum, 2005-2008,



Heat Flux



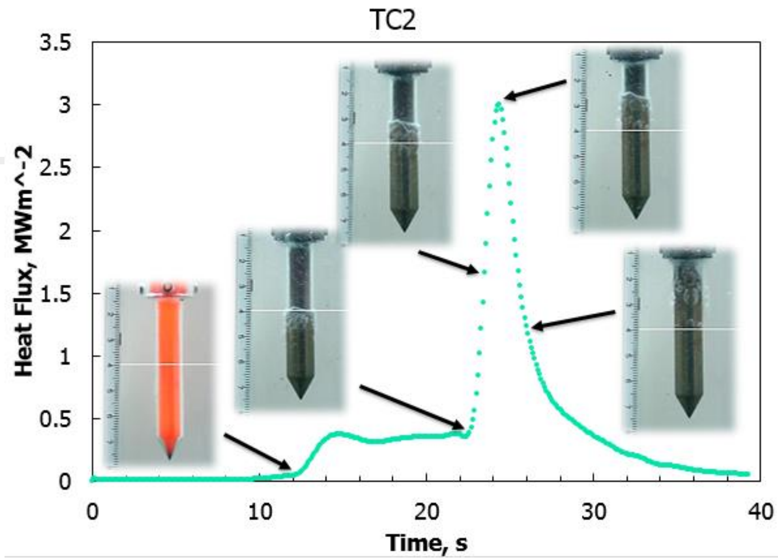


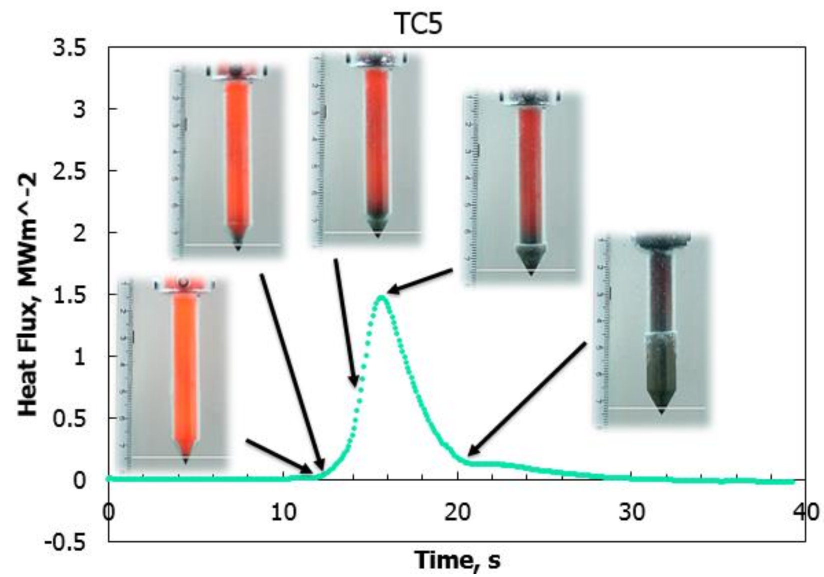
Mold Temp

Heat flux at the metal/mold interface during Metal Casting

S. Arunkumar, K. V. Sreenivas Rao, T. S. Prasanna Kumar, "Spatial Variation of Heat Flux at the Metal-Mold Interface due to Mold Filling Effects in Gravity Die-Casting", International Journal of Heat and Mass Transfer

Tracking the wetting front during quenching





Collaborative Project with Prof Bernardo, University of Mexico

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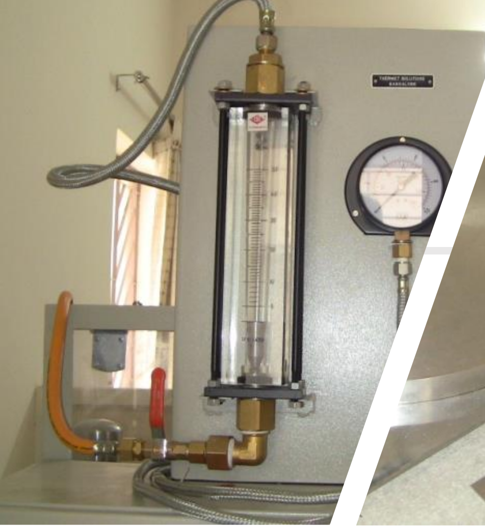

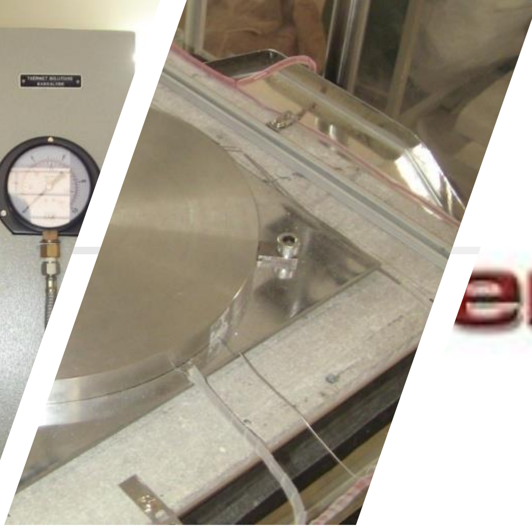

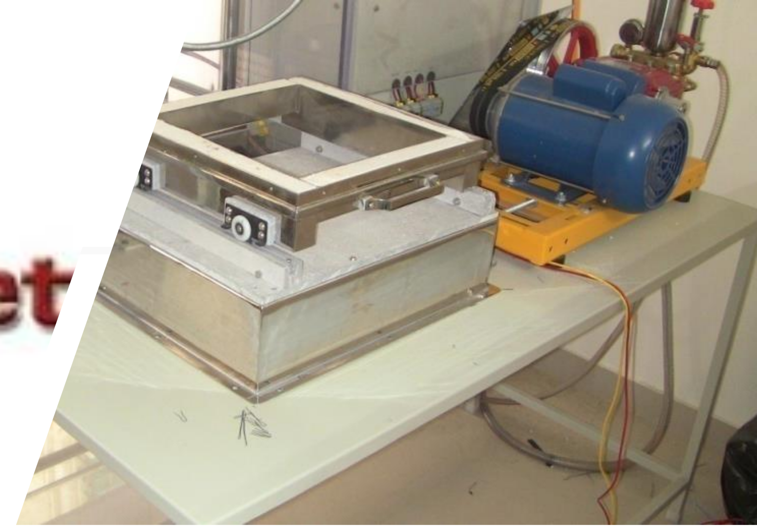

Heat Transfer during Spray Quenching- Equipment Designed and Fabricated by TherMet Solutions

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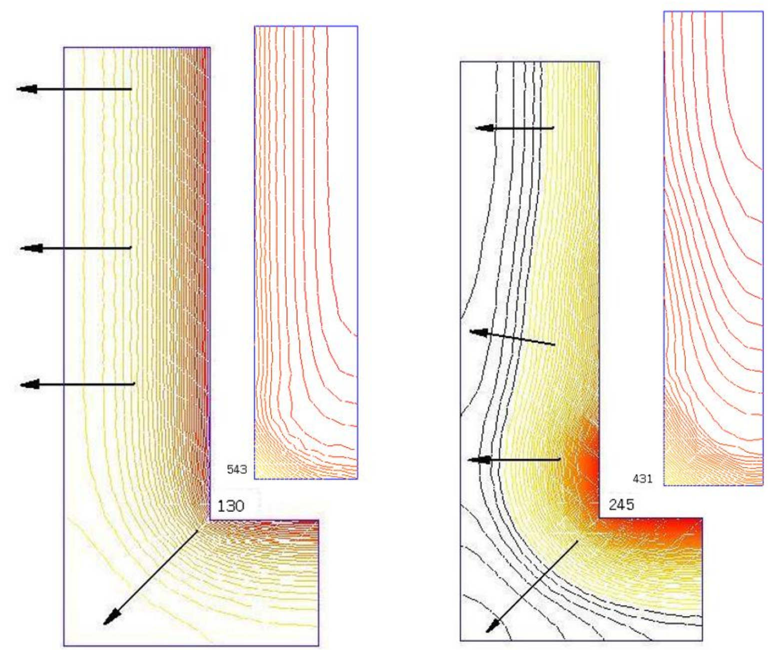
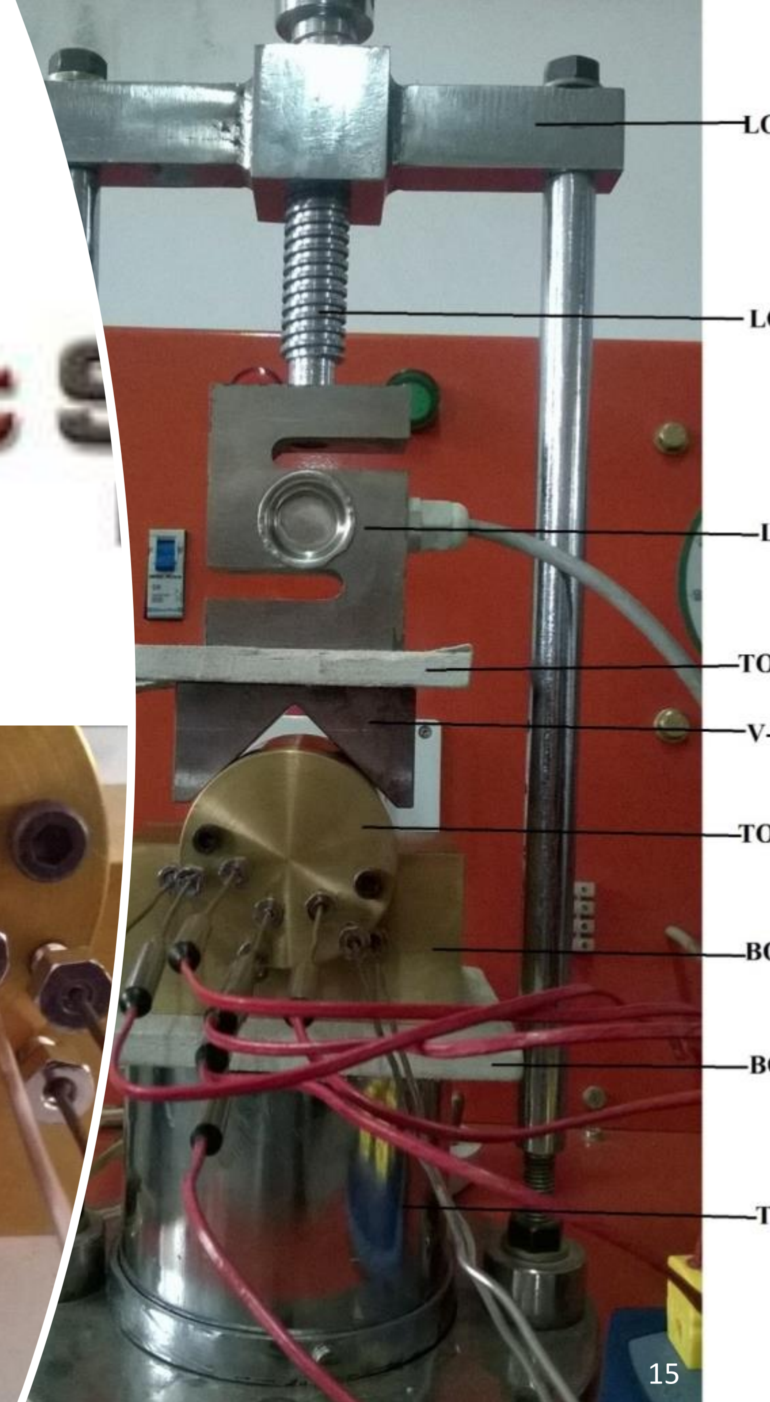
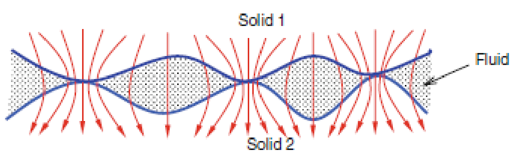
Modeling Multiple Heat Flux Components at the Metal/Mold Interface

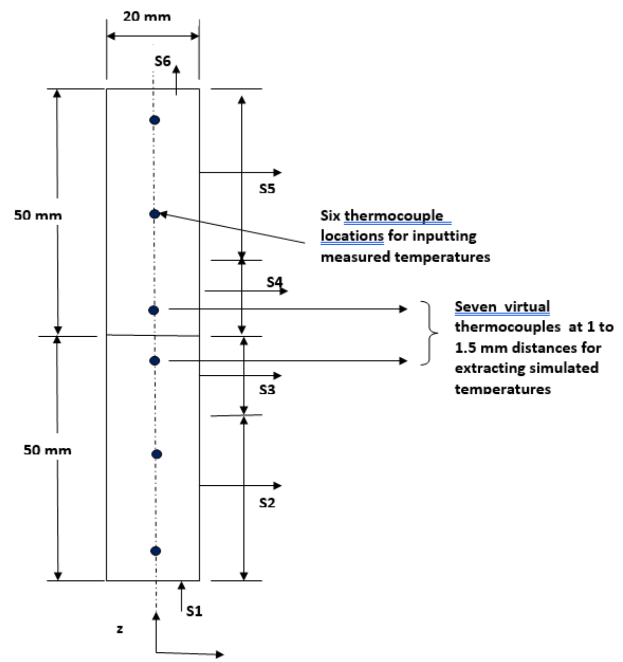


H.C.Kamath and T.S.Prasanna Kumar: “Multidimensional Analysis of Interface Heat Flux in Metallic Molds during Solidification of Aluminum Alloy Plate Castings” 108th Casting Congress of American Foundrymen’s Society at Rosemont, IL, USA in June 2004, pp 359-371

Contact Conductance Measurement (Curved surfaces) - Equipment Designed and Fabricated by TherMet Solutions





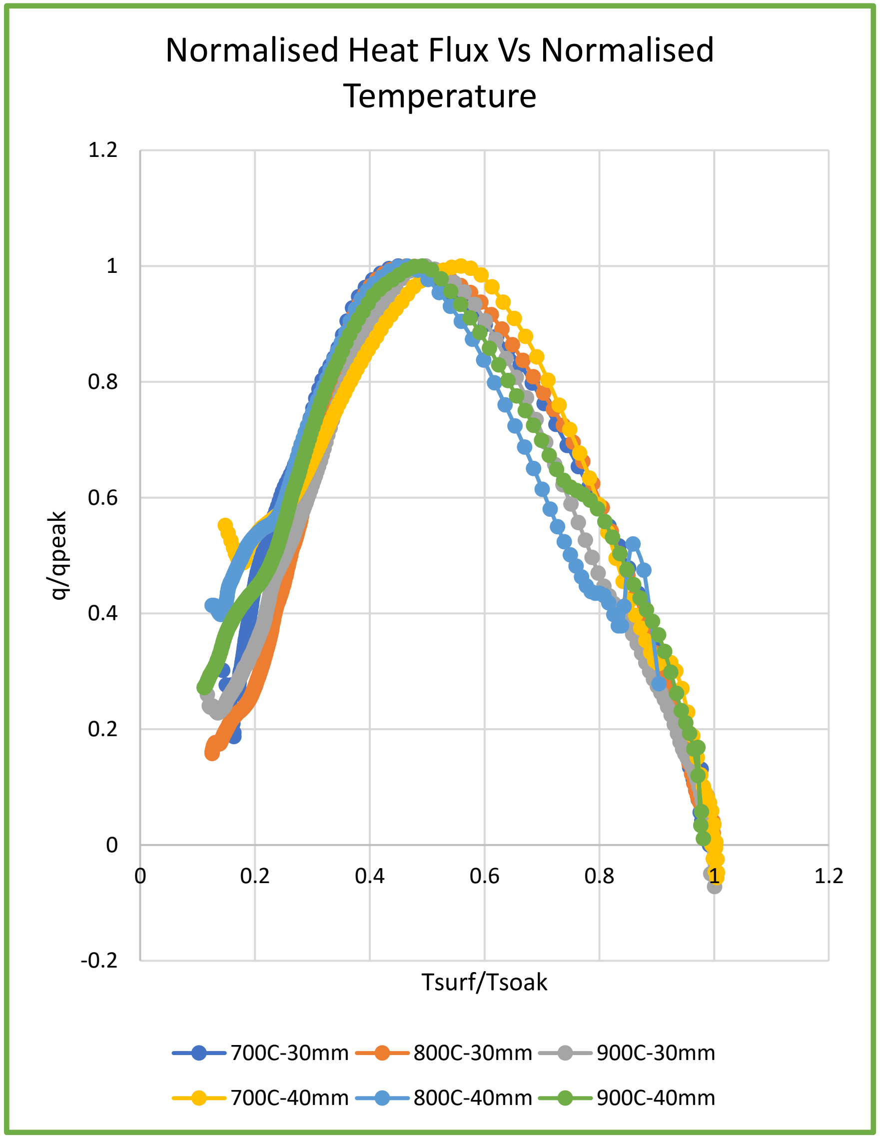


Contact Conductance Measurement (Flat surfaces) - Equipment Designed and Fabricated by TherMet Solutions

T.S.Prasanna Kumar et.al., ESTIMATION OF SOLID-SOLID CONTACT CONDUCTANCE BASED ON INVERSE SOLUTION, Proceedings of the 24th National and 2nd IHMTC-2017,December 27-30, 2017, BITS Pilani, Hyderabad, India.

Modeling Boiling Heat Transfer as a function of surface Temperature and Thickness

Student Project, PES University, Bangalore, 2017



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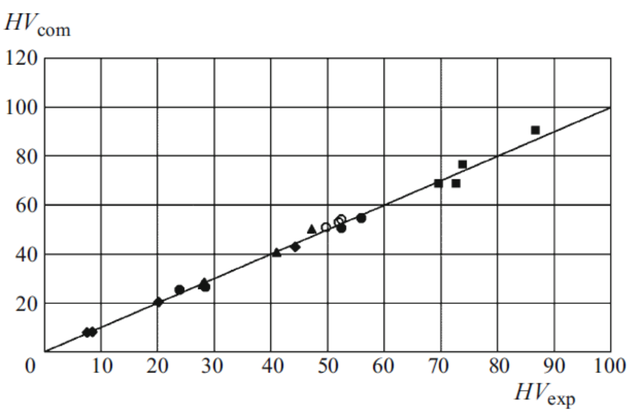
Equipment Designed and Fabricated by TherMet Solutions



As-Quenched Hardness Modeling in Steels

N. R. Abhaya Simha, M. P. Sushanth, V. Bagali Sachin, K.Maruti, T. S. Prasanna Kumar and V. Krishna, ESTIMATION OF HARDNESS DURING HEAT TREATMENT OF STEELS, *Metal Science and Heat Treatment*, Vol. 61, Nos. 7 – 8, November, 2019 (Russian Original Nos. 7 – 8, July – August, 2019) A

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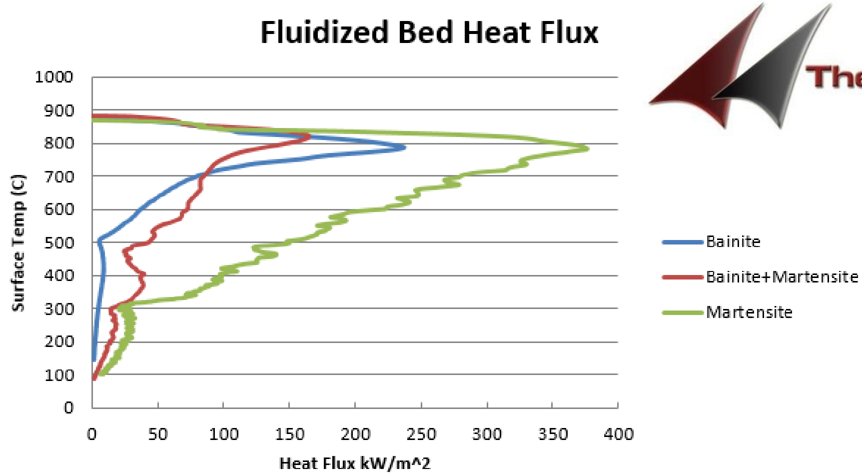
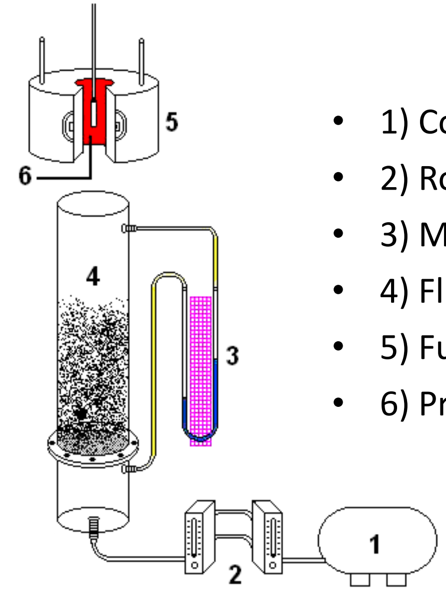
Quenching of a steel probe in a fluidized bed reactor

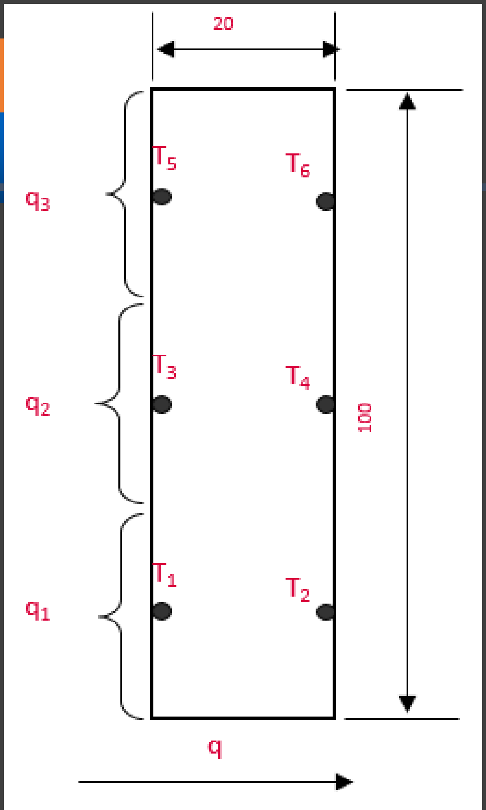


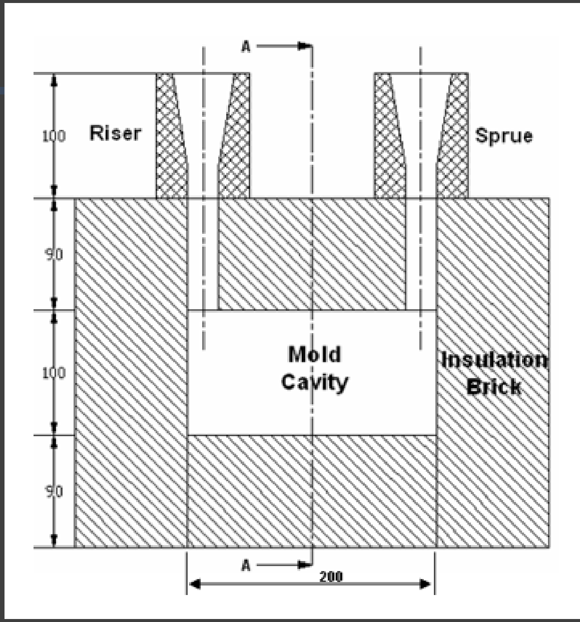
Alumina + air at room temperature



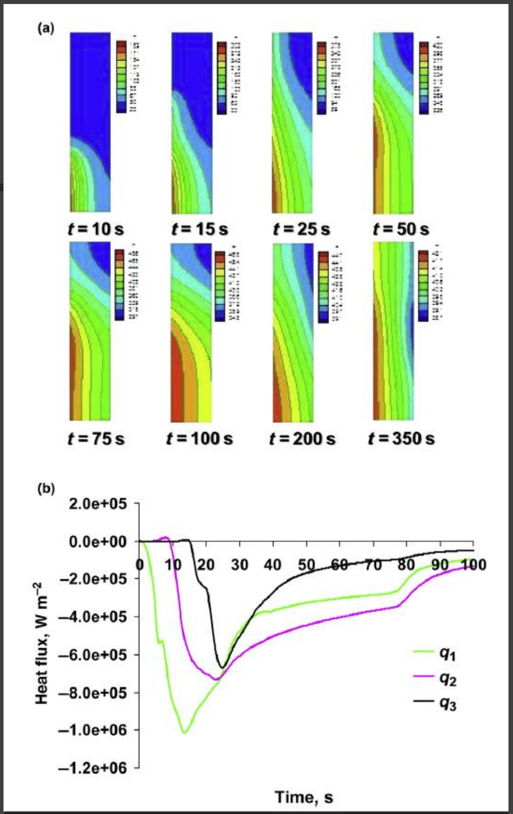
- 1) Compressor
- 2) Rotameters
- 3) Manometer
- 4) Fluidized bed reactor
- 5) Furnace
- 6) Probe

Collaborative Project with Prof. Bernardo, University of Mexico





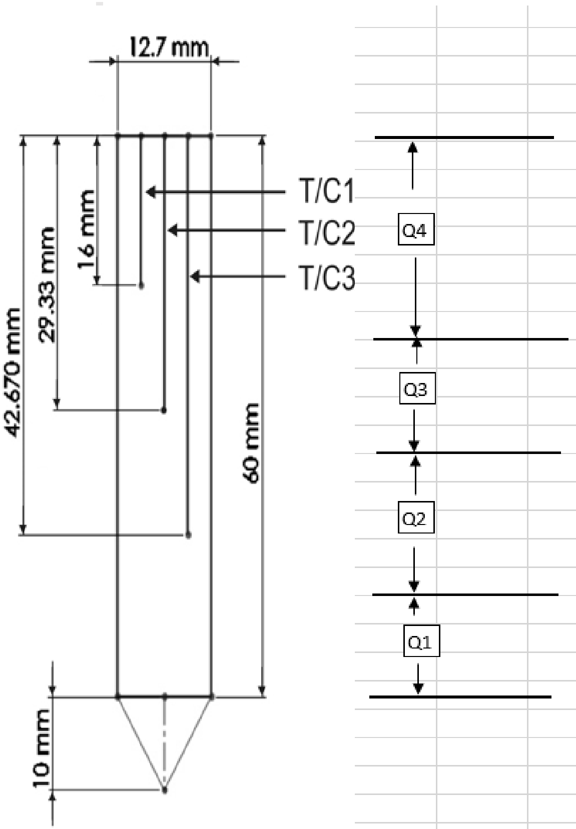
Casting setup

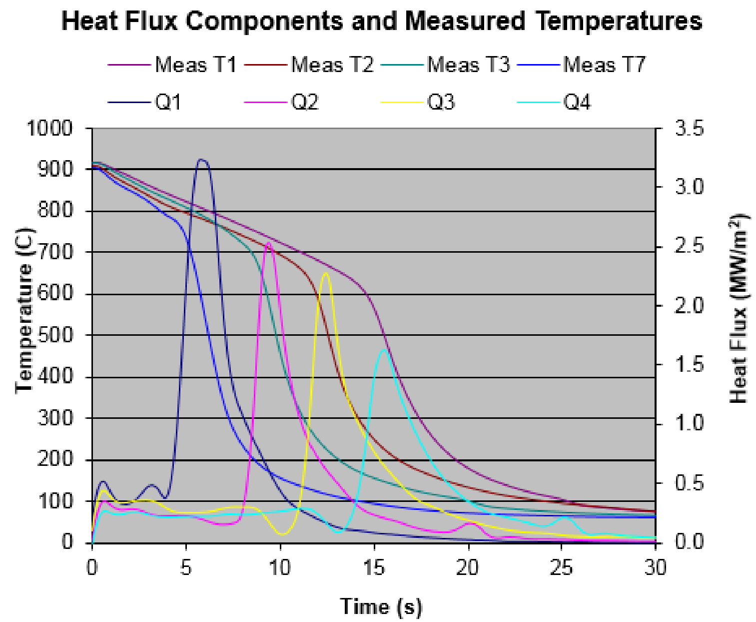


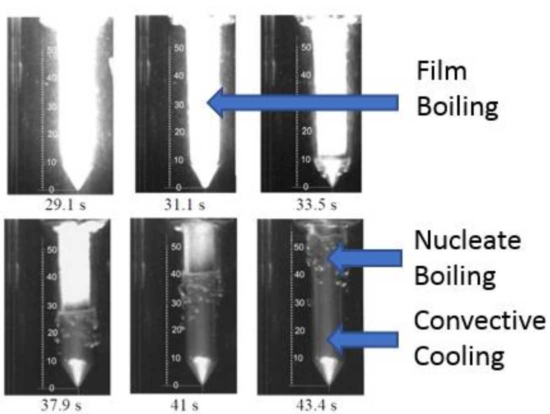
Heat Flux across the interface

Heat flux at the metal/mold interface during Metal Casting

Sreenivas Rao, K. V., Phanikumar, G., Prasanna Kumar, T. S., "Effect of Mold Material on Boundary Heat Flux Transients, Macro Segregation and Microstructure Evolution during Gravity Die Casting", The 10th Asian Foundry Congress (AFC-10), 21-24 May 2008, Nagoya, Japan,

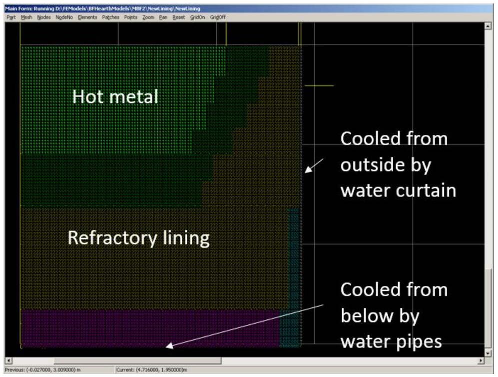


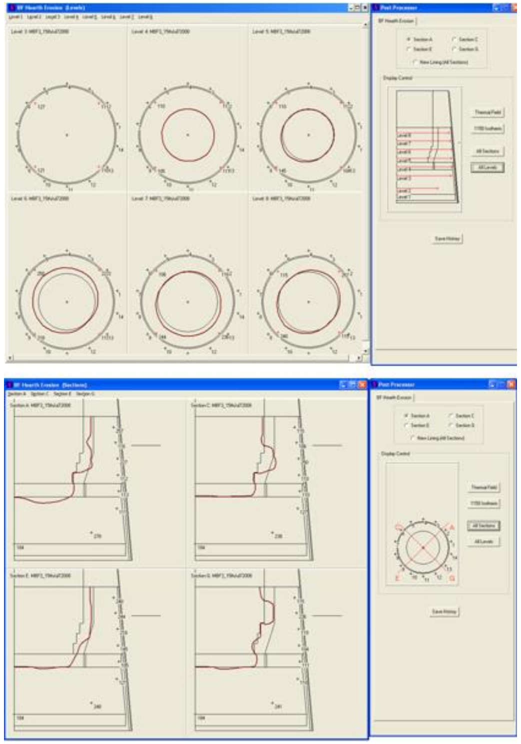


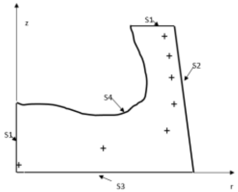


Heat Flux during Boiling of Water (Transient Condition)

Joint Project with Prof Bernardo Hernández-Morales, University of Mexico, 2012







$$\frac{\partial}{\partial r}\left(k(T)\frac{\partial T}{\partial r}\right)+\frac{\partial}{\partial z}\left(k(T)\frac{\partial T}{\partial z}\right)=0$$

With the boundary conditions

$$T=T_{tap} \text{ on S4}$$

$$-k\left(\frac{\partial T}{\partial r}\right)n_r-k\left(\frac{\partial T}{\partial z}\right)n_z=0 \quad \text{on S1}$$

$$-k\left(\frac{\partial T}{\partial r}\right)n_r-k\left(\frac{\partial T}{\partial z}\right)n_z=q_m \quad \text{on S3}$$

$$-k\left(\frac{\partial T}{\partial r}\right)n_r-k\left(\frac{\partial T}{\partial z}\right)n_z=h_c(T_{wall}-T_{water}) \quad \text{on S2}$$

Rules for convergence

If Local Erosion is > 0 then

If (T_{comp}>(T_{meas}+dT)) then

decrease Local Erosion

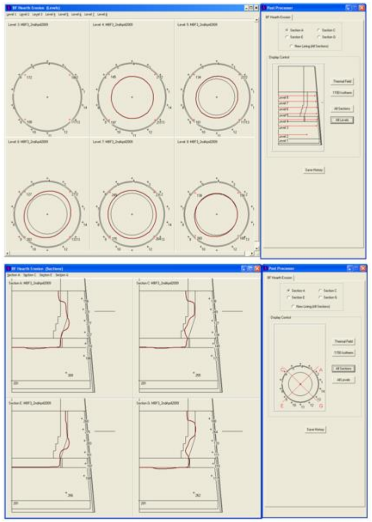
Else if (T_{comp}<(T_{meas}-dT)) then

increase Local Erosion

Convergence criteria

$$\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(T_{meas}-T_{comp}\right)^2}\le e$$ For all *i*s with Erosion>0

Obtained iteratively by Non-linear Finite Element Analysis, Heuristics and Data Structures



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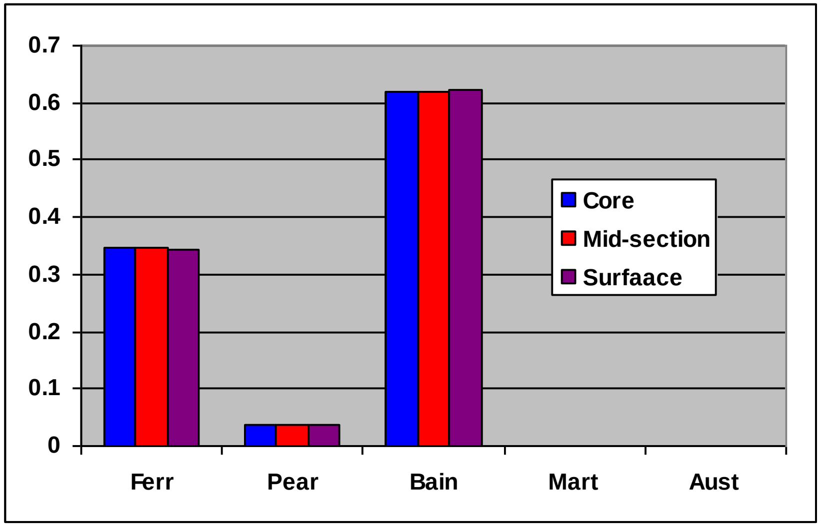
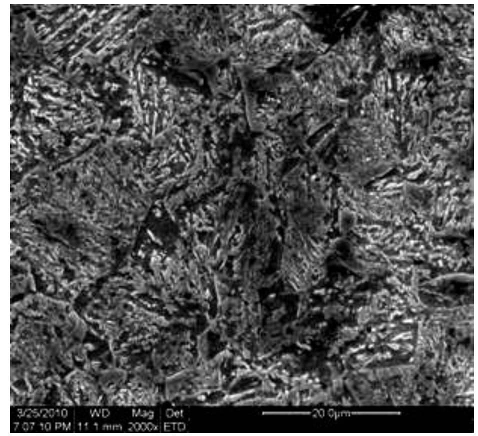
Assessment of Refractory Wear in a Blast Furnace by Inverse Analysis of a Moving Boundary

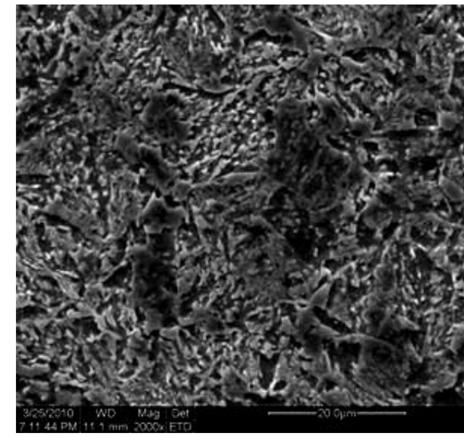
Sponsored Project from
Hospet Steels, Hospet, India

Simulation of Air Cooled AISI 4140 Steel

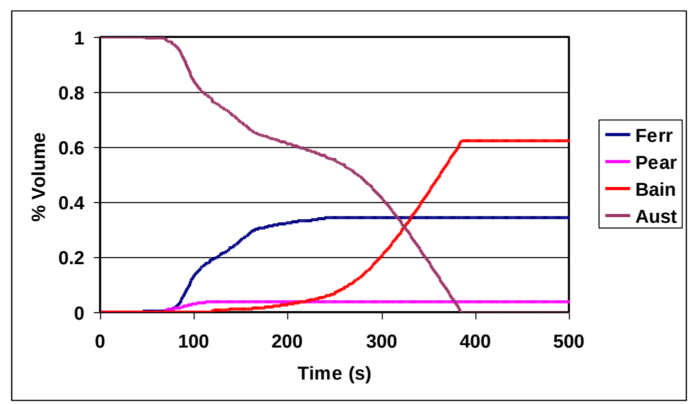




SEM at surface



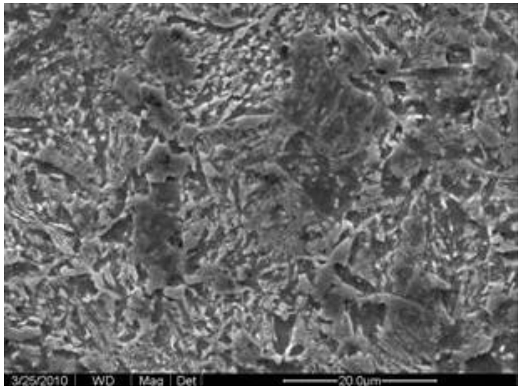
SEM at Core

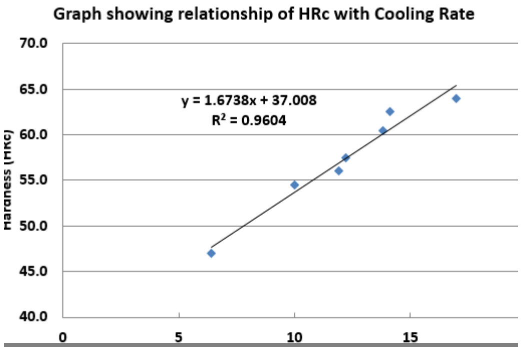


K. Babu and T.S. Prasanna Kumar**,** Finite element modeling of quenching heat treatment of AISI 4140 steel with phase transformation. Proceedings of *4th International Conference on Thermal Process Modeling and Computer Simulation (ICTPMCS 2010),* Shanghai, China, May 31 – Jun 02, 2010

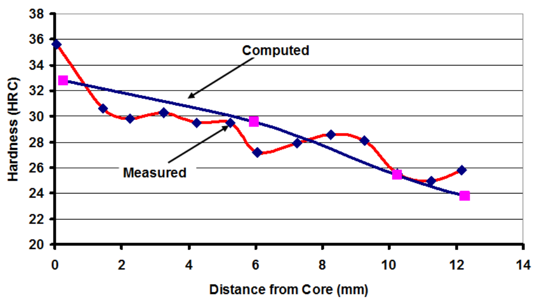
Case Study with Ind Carb; Industrial Heat Treaters, Bangalore, India 2015

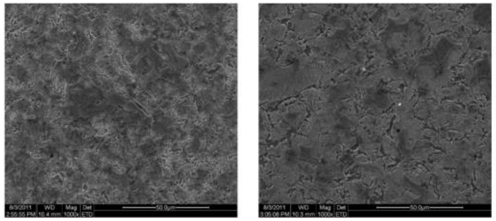
Estimation of Hardness during Quenching of Case Carburized Steels



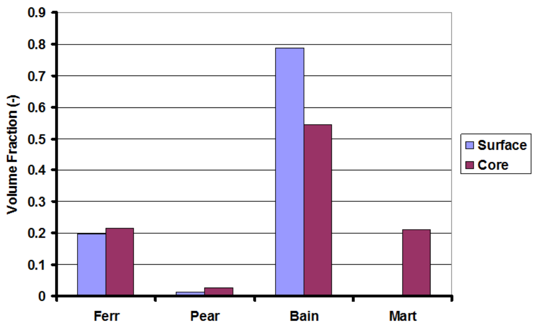


Sponsored Research from Ind Carb; Industrial Heat





SEM micrographs of the specimen surface (left) and the core (right)



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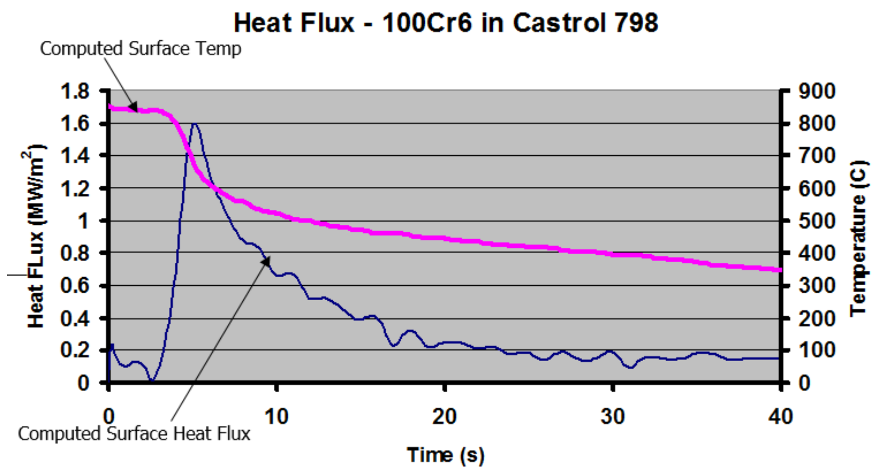
Coupled Analysis of Surface Heat Flux, Microstructure Evolution and Hardness during Immersion Quenching of a Medium Carbon Steel in Plant Conditions

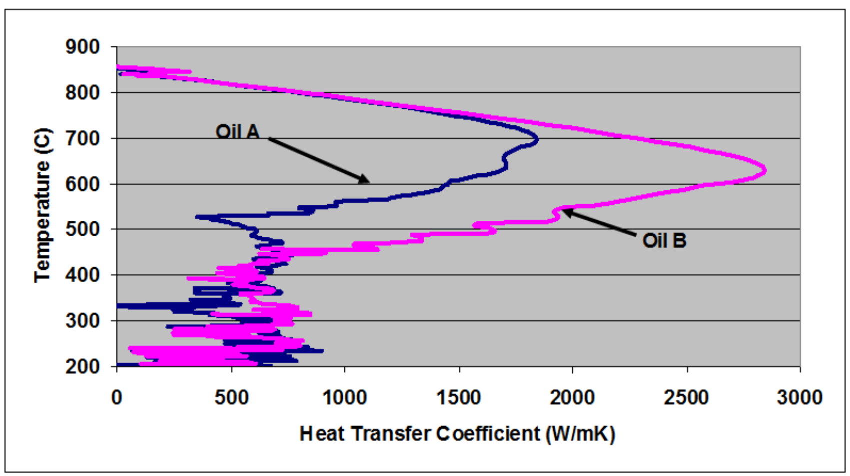
Heat Treat 2011, 26th Conference and Exposition, The American Society of Metals Heat Treating Society, Cincicnnati, OH, USA, 31st October 2011

Determination of Heat Transfer Coefficient during *In-Situ* Quenching of Alloy Steels

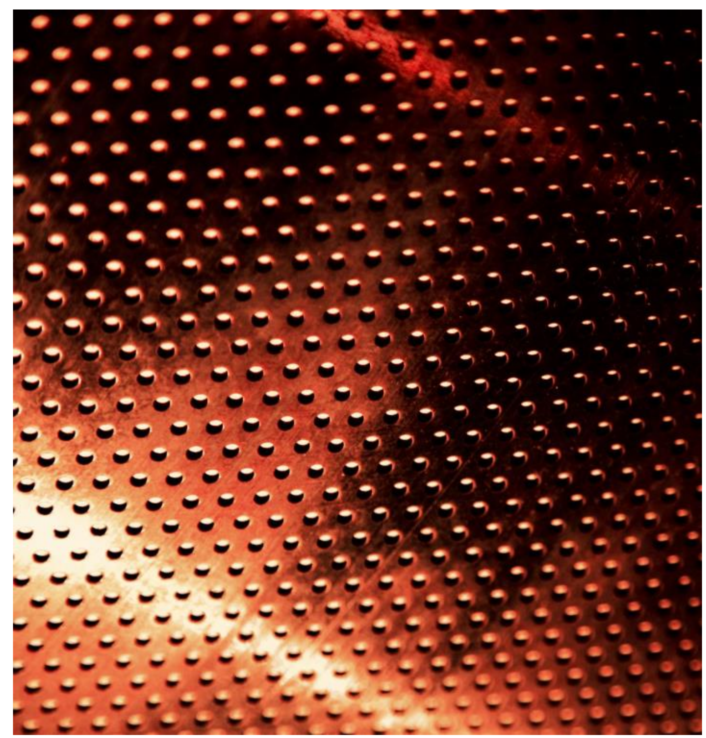
T.S.Prasanna Kumar, Ashok Pareek, N. Arjun

6th Int. Conf. on Quenching and Control of Distortion 2012, The American Society of Metals Heat Treating Society, Chicago, IL, USA, 10-13th Sept 2012





Comparison of heat transfer coefficient as function of surface temperature during immersion quenching of a 25 mm diameter 100Cr6 grade steel in two Oils.



Stacking Efficiency during Quenching of Rods

Location	Ferrite	Pearlite	Bainite	Martensite	Austenite	Hardness(Rc)
Top	0.02	0.00	0.37	0.58	0.03	44.89
Left	0.00	0.00	0.23	0.73	0.04	48.20
Bottom	0.00	0.00	0.42	0.55	0.03	45.14
Right	0.18	0.00	0.13	0.67	0.02	43.33
Core	0.26	0.15	0.59	0.00	0.00	25.21

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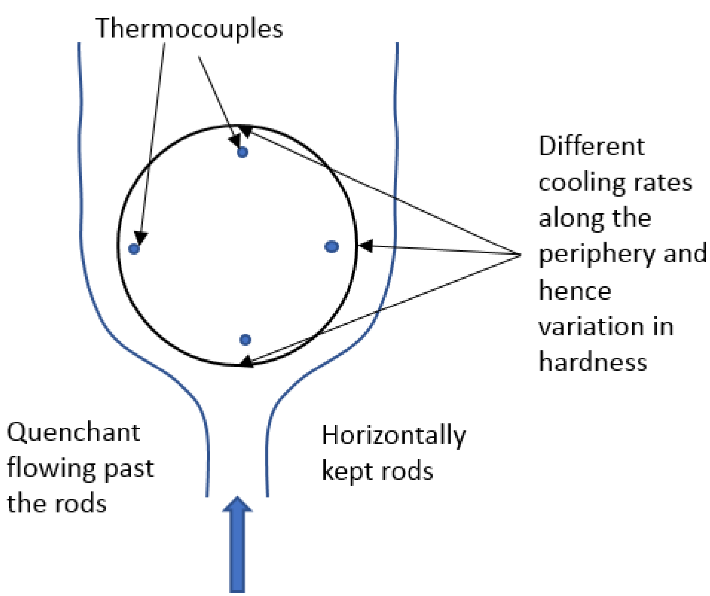

Schematic of the test rod (90 mm diameter) instrumented with four thermocouples

Sl No	Parameter	Top	Left	Bot'm	Right	Core
1	Maximum heat flux (MW/m$^{2)}$	1.50	3.40	2.97	1.84	-
2	Surface temperature at which Maximum heat flux occurs (C)	430.00	570.00	572.00	523.0	-
3	Maximum heat transfer coefficient (W/mK)	-	-	-	-	-
4	Surface temperature at which the maximum heat transfer coefficient occurs (C)	-	-	-	-	-
5	Maximum cooling rate (C/s)	73.00	320.00	269.00	119.00	13.6
6	Surface temperature at which the maximum cooling rate occurs (C)	673.00	569.00	572.00	523.00	680.00

Thank you for your Attention

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