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A COMPUTATIONAL SIMULATION OF CONTINUOUS SLAB AND STRIP CASTING.

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ABSTRACT

To study the conventional continuous slab casting process, 3 major zones can be considered. These are; the water cooled copper mould, the spray cooling section, and the radiation cooling section. All parts constitute a complex model of fluid flow, and heat transfer including convection, conduction, radiation and solidification. Another more recent casting process which requires study is the Twin roll continuous strip caster.

This paper considers the copper mould of the conventional caster as a means to validate computational procedure against other previous papers written in this area. Further effort is then directed at studying the flow patterns and heat transfer characteristics of the Twin roll process.

THE COPPER MOULD (CONVENTIONAL CASTER)

The copper mould receives molten steel from a tundish at a temperature of around 1550^{0}C through a tubular nozzle or SEN (Submerged Entry Nozzle). The SEN generally has two opposite exits from which the steel enters the mould. Heat is removed from the molten metal by convection and conduction through the mould. The heat then travels through the mould copper and is finally removed from the system by water through coolant ducts. Once again, conduction and convection are significant. A thin solid shell (6mm) has formed as the slab reaches the mould exit. The flow pattern inside the copper mould is essentially governed by the shape and position of the SEN. Figure 1 shows the shape and position of the SEN with respect to the solution feild.

THE TWIN ROLL STRIP PROCESS

The Twin roll continuous casting process is similar in principal to the conventional process, however the geometry of the melt pool differs greatly. The Twin roll process basically involves an arc furnace feeding molten steel into a tundish which in turn feeds into the space between two rotating water cooled copper or steel wheels of diameter approximately 1000mm. The roll speed ultimately determines the casting speed as total solidification of the strip occurs at a point directly between the roll centres which is where the strip exits the melt pool.

PHEONICS

The C.F.D computer package currently being utilised is PHEONICS version 2.1 with the solidification/melting and particle tracking extension, GENTRA. This package offers a fairly unlimited scope in regard to accuracy of geometry, boundary conditions, and fluid (steel) properties. Programming can be achieved on two levels; the Satellite menu system or the PIL (PHEONICS input language). Material properties which vary with temperature in reality, such as 'C' (specific heat) and 'k' (thermal conductivity) can be considered as constants or vary with temperature. Model construction is simplified by considering these properties as constants. Varying 'C' and 'k' in the model is achieved by the PHEONICS components, Satellite and Earth, communicating during the solution process. After the solution process, the results were viewed through 'Photon' which gives a graphical representation of result variables.

MODEL CONSTRUCTION (SLAB CASTER)

The simulation domain was 0.3m (x) by 2m (y) by 1m (z) and represents a slab of similar size. The computational grid dimension was Nx=15, Ny=70, Nz=36. A nozzle containing the inlet conditions was centrally located at Ny=70 and projected 0.3m down into the solution space. Cast speed was 0.0167m/s or 1m/min and the molten steel inlet temperature was 1550^{0}C, the steel having a liquidus and solidus temperatures of 1525^{0}C and 1518^{0}C respectively. For this simulation 'C' and 'k' were considered constants as the temperature range in the simulation is relatively small. For example, C(liq) = 680 J/KgK and C(sol) = 690 J/KgK do not vary greatly.

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MODEL CONSTRUCTION (TWIN ROLL)

The simulation domain had a 3D grid dimension of Nx=16, Ny=26, Nz=42, and represents a twin roll caster with a roll radius of 1m producing strip of 5mm thickness and 0.8m in width. The curve of the rolls was created using the PHEONICS B.F.C system (body fitted coordinates). Preliminary simulations were carried out to determine the operating conditions that are required for the strip to totally solidify at the narrow gap between the rolls. For strip thickness of 5mm these conditions are; cast speed = 0.08m/s or 4.8m/min, wall temperature = 1500^{0}C (between flux and solidifying shell). The simulation ran at 15 iterations per slab for 120 sweeps.

RESULTS (CONVENTIONAL)

At this stage in the research, a number of computational models of the copper mould have been constructed and solved using PHEONICS. In the interest of validity, these models were based on work of M. B. Harris and G. D. Mallinson from the university of Auckland, and X. Huang et al. These models are three dimensional- steady state- determinations of the fluid flow field and the temperature field covering the mould and a section approximately 1m below the mould. The results obtained were similar to those of Harris and Mallinson, from their water and numerical models. The shape and positions of the vortices around the SEN, and the flow towards the base of the mould were both consistent. The temperature fields within the mould reported by Huang et al are also very similar in position and magnitude. Figure 2(a) gives a graphical representation of the fluid flow field and the temperature distribution for a plane midway across the solution space. Figure 2(b) is the temperature distribution calculated by Huang et al. Figure 2(c) gives the velocity vectors calculated by Huang et al.

RESULTS (TWIN ROLL)

Preliminary computational models of the Twin Roll Continuous Casting process have also been constructed. A finer computational mesh is more easily obtainable when modelling this system because the molten core length is relatively short (at least ten times shorter than that of conventional continuous casting), however due to the narrow gap (5mm) at the exit of the melt pool, the simulation becomes sensitive and can diverge if variable relaxations are not correctly programmed. It is also important that the number of iterations are sufficient for convergence. The fluid flow variables tend to require more iterations than the temperature field. The results obtained show promising trends with respect to vortices in the flow field and temperature distribution. It is evident from the vector field that turbulence in the twin roll process is low compared to the conventional process. A greater range of models will help to determine the relationships between pool depth, roll spacing, roll speed, strip width, and the temperatures of various surfaces. Figures 3 and 4 show the temperature and flow fields respectively, between the rolls. The temperature profile in Figure 3 gives a vertical temperature plane which represents the slab core as it approaches the narrow gap. It can be seen that the core temperature approaches the solidus temperature at this point. Figure 4 demonstrates the predictable nature of the flow field, as most of the vectors are facing the same direction (towards the exit) with the exception of very weak vortices in the upper corners of the solution space. This condition may change with the introduction of a different nozzle geometry.

CONCLUSION

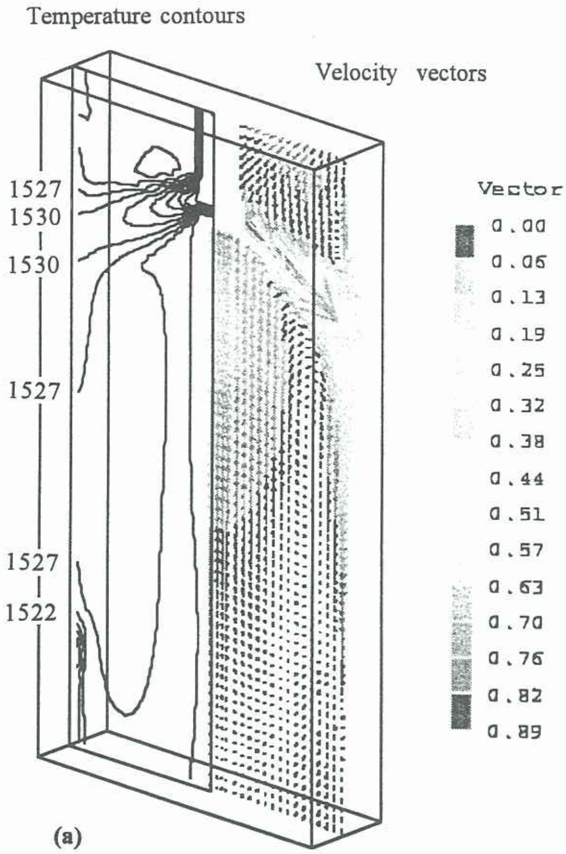
The results obtained for the conventional slab caster have successfully been validated against a number of previous relevant technical reports based on industrial systems. Given that a similar procedure was undertaken for the Twin Roll Continuous Strip Caster, it seems that computational results obtained from this system would also relate to industrial Strip Caster.

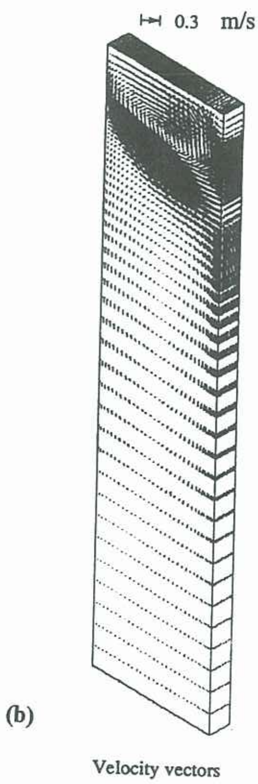
The Twin Roll Strip Caster simulations already conducted have paved the way for more varied, and more accurate, simulations in the hope of further understanding this complicated heat transfer process.

REFERENCES

Harris, M. B., and Mallinson. G. D., 1992, "Mould flow considerations during the conventional casting of steel", *Eleventh Austrtralasian fluid mechanics conference*, pp 587 - 590.

Huang. X., Thomas. B. G., Naggar. F. M., 1990, "Modelling Superheat Removal during Continuous Casting of Steel Slabs", *Metallurgical Transactions B*, pp 340-346.





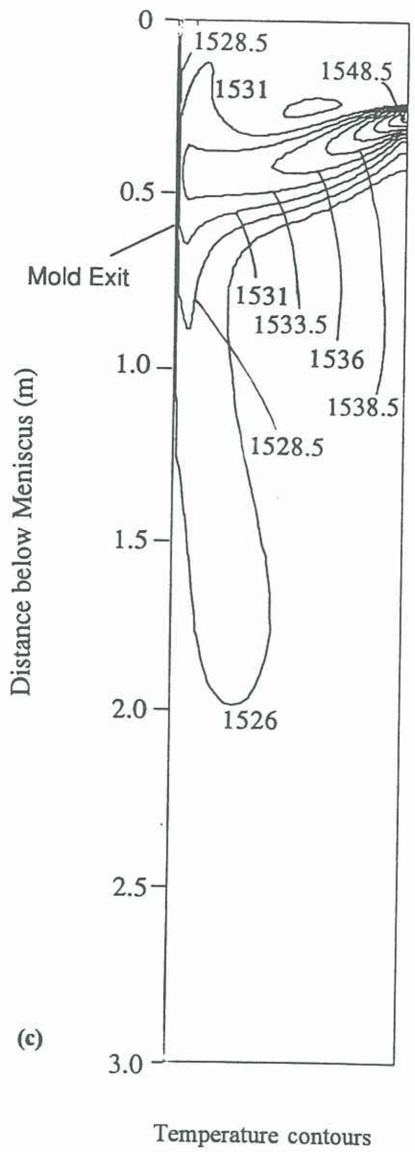


Figure 2: (a) Calculated Vector and Temperature fields of the Continuous Caster simulation. **(b)** Calculated Vector Field from Huang et al. **(c)** Temperature fields from Huang et al.

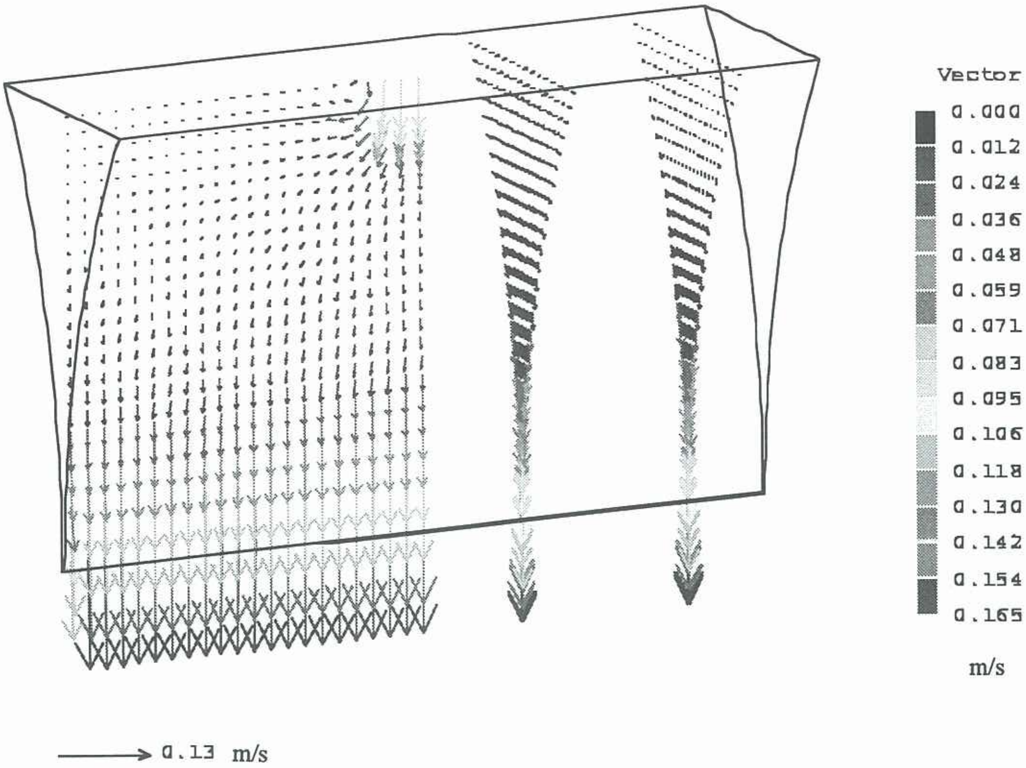


Figure 4: Vector field of the Twin Roll Continuous Caster simulation.

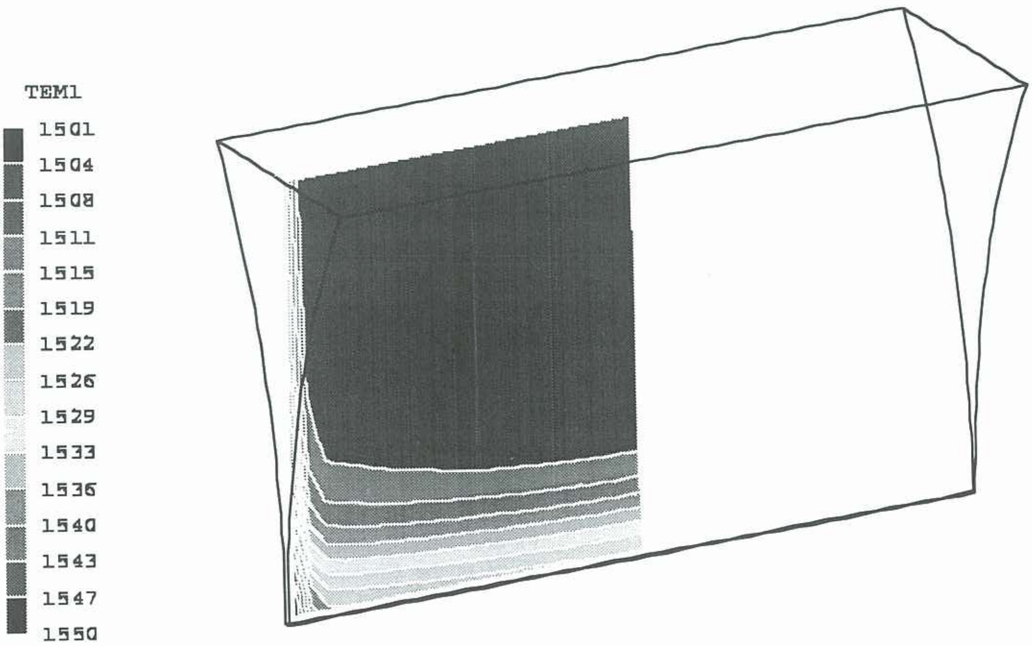


Figure 3: Temperature field of the Twin Roll Continuous Caster simulation.