VIRTUAL EXPERIMENTATION WITH THE FOSECO PRO MODULE

New Sleeve Shapes, recipe formulations, applications and supporting thermophysical data for improved casting quality.

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Foseco is a leading supplier of consumables to the global foundry industry. With sales and technical personnel in all key markets, Foseco application engineers work in partnership with foundry customers to develop customised solutions. This combined effort involves adapting and fine tuning Foseco product and process-control technology to each foundry's unique circumstances.

CONTINUOUS TECHNOLOGICAL EVOLUTION

Continuous technological evolution drives innovation in casting design and foundries must find solutions to the various challenges that these innovations present. When new challenges emerge, Foseco's strength is its ability to combine expertise from global technical networks with local knowledge to help deliver new solutions.

The casting engineering skills to bring high quality castings to market requires an ever-evolving blend of technical knowledge, practical experience, problem-solving skills and "human" intelligence along with an ongoing investment in engineering and production technology. An important part of this know-how is the successful exploitation of computer technology to tackle and address the complexities of making castings commercially. This is also in constant evolution.

Simulation engineering is therefore a key technical element behind efforts to gain competitive advantage. The "method", and choice of consumables used in that method, plays a significant role in final casting quality and production costs. For either new or existing castings, computer modelling with simulation tools such as MAGMASOFT® provide invaluable insights to help manage these factors before committing to making pattern or process changes. This visual analysis tool helps reach a common understanding of a problem or opportunity and then how best to address it.

FOSECO and MAGMA work in close cooperation to create real value for the foundryman through their joint activities in areas of technology development and know-how. Together both partners seek to advance foundry knowledge in the areas of improved gating and risering design, robust production practices and improved consciousness of cost and quality trade-offs, thus helping to deliver enhanced solutions and even more competitive cast-parts.

The basis for this approach is the ability to quantify and effectively model FOSECO products. This requires the determination of key material properties using advanced measurement techniques and then validating it in MAGMA. The resultant information is provided to the foundryman via the FOSECO Pro Module for MAGMASOFT®.

Foseco works continuously to develop new product technology and application techniques to meet the ever-changing needs of customers. Simulation with MAGMA plays an important role in virtual experimentation and new sleeve development. New additions to the Foseco sleeve product range are made available in the Pro Module database so that MAGMA simulation engineers can integrate them for their daily methoding analysis and optimisation work.

The Foseco Pro Module is a parametric 3D library of sleeve and filter products, combined with proprietary thermo-physical data, which has been integrated directly into MAGMASOFT®.

The key benefit is that it reduces the time to set up, model and simulate the performance of Foseco products. The consequence for the foundry is enhanced casting quality and more robust production processes through better correlation between real and simulated casting results.

Figure 1: Foseco's collective competence in methoding is a complex mixture of foundry engineering, product and recipe development, gating and risering design and casting process simulation expertise

EXAMPLES

Examples of such recent developments include the FEEDEX VAK and the FEEDEX SCK (Sleeve Construction Kit) product ranges shown below as they will appear in the latest release of MAGMASOFT® 5.4 autonomous engineering.

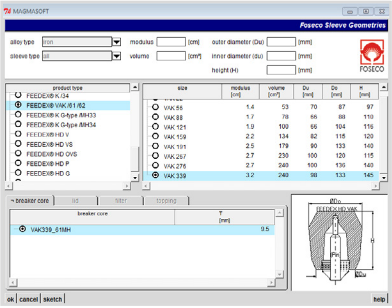


Figure 2a. FEEDEX VAK in the Foseco Pro Module interface

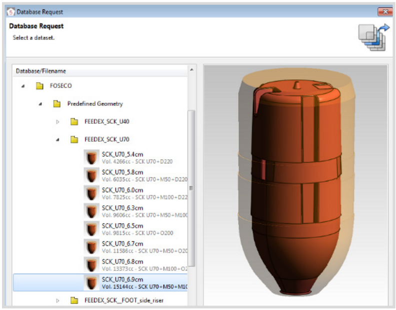


Figure 2b. FEEDEX SCK ranges in the Geometry Database

FEEDEX VAK is a further development of the well-proven Kompressor spot feeder technology for grey, ductile and CGI castings. FEEDEX VAK sleeves are fitted with a patented collapsible metal core, which allows precise spot feeding on the smallest casting section. The VAK /61 series is designed for moulding machines with standard moulding pressure and the VAK /62 series for extreme moulding pressures. The cores are designed to ensure a reliable feeder neck pass-through and an optimum feeder knock-off after casting

The FEEDEX SCK Sleeve system is an innovative, hybrid insulating/exothermic, modular sleeve construction kit for Iron and Steel jobbing foundries. The glue-free, interlocking and easy-to-assemble range of 8 elements provides 31 options (23 iron and 8 steel) with modulus values between 5.4cm to 6.9 cm for precision feeding in large castings. SCK provides flexibility, feeding efficiency and small contact areas, thereby optimising yield and casting cleaning costs.

In order to include the SCK range in the Pro Module, a material dataset which describes the thermal properties of the C6_SCK insulating neck material had to be developed. Using a procedure previously described in the joint Foseco-MAGMA technical paper "Advanced thermo-physical data for casting process simulation – the importance of accurate sleeve properties", the process to develop a material dataset began at Foseco's global Foundry R&D centre located in Enschede, Holland. The material properties were first measured in the analytics laboratory thereby giving a base dataset.

A pattern was specially designed to allow measurement of the temperatures in the casting and sleeve material inside the mould. The mould was subsequently poured, and the temperature history was recorded. The real-life physical setup was modelled, and the actual boundary conditions were applied to the virtual twin modelled in MAGMA. Using the Inverse functionality to match measured and calculated curves, a series of simulation experiments were run, allowing the refinement of the final material properties for use in MAGMA.

MAGMA is a world leader in the development of casting process simulation software who first introduced fully integrated Optimisation and virtual **Design of Experiments (D.O.E.)** methodology into MAGMASOFT® v5.3 in 2015.

The current release MAGMASOFT® 5.4 further advances the ability to comprehensively model and simulate all stages of a wide range of casting making and foundry related processes.

Figure 3. Sleeve Thermo-physical data development at Foseco's Global R&D centre in Enschede

This new generation of tools gives the user the ability to both visually analyse and statistically evaluate the simulation results. The statistical evaluation tools give a relative numerical value for the specific chosen criteria which allows the user to quantifiably compare competing methods that would be otherwise very difficult or impossible to do. An example of such would be to quantify the relative quality differences between multiple gating system or Feeding system proposals.

In the example pictured, a 1700 kg roller casting, the challenge is to feed the chunky centre of the casting when there is very limited space on which to place sleeves. Similar casting are extensively chilled to help with the directional solidification of the casting towards the risers. The aim of the study was to see if it was possible to reduce casting costs either through use of fewer chills, smaller risers, or less padding (machining) in the centre of the casting whilst still maintaining casting quality.

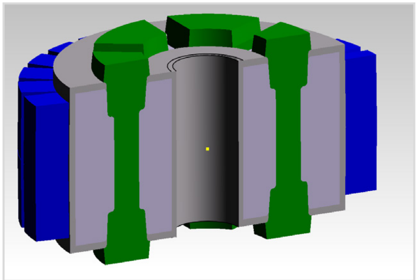


Figure 4: 1700 kg roller casting

The goal of all simulation modelling is to correctly predict the final casting properties. In all cases, having accurate thermo-physical properties are critical to the final quality of the simulation results. With the new generation of modern simulation software and computer hardware, the foundryman can leverage these new sleeve, recipe and simulation technologies to optimise their casting production method.

Figures 5a and 5b illustrate the competing trade offs between increasing padding at the cost of increasing thermal modulus and feeding requirements, combined with influence of whether chills are used in the top/bottom rings. The Chills do not remove shrinkage but help move it into another location.

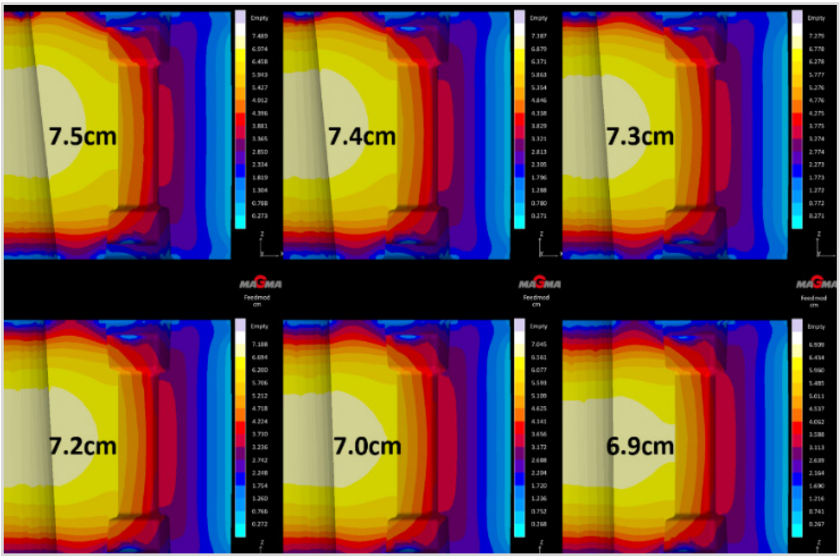


Figure 5a: Influence of Feeding Taper on peak FEEDMOD result (Casting without Feeder, all chills active)

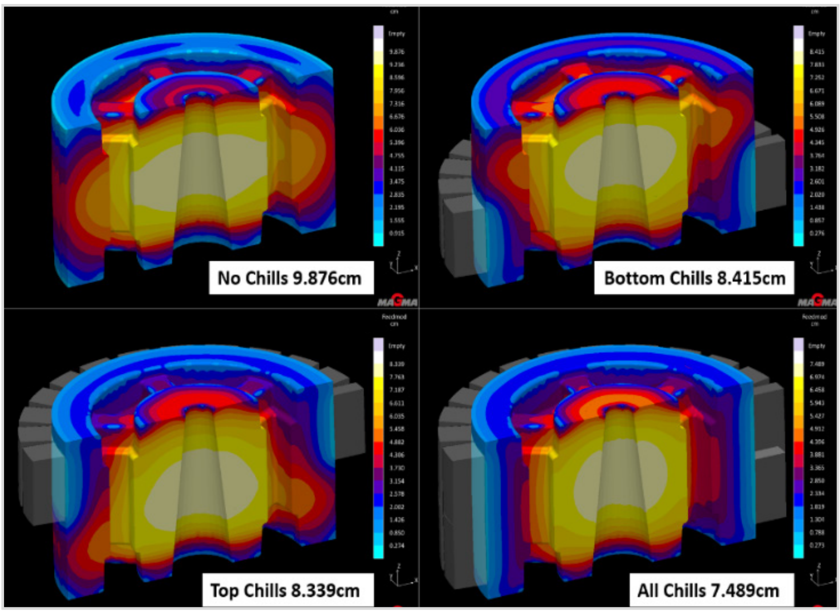


Figure 5b: Influence of Chill activation on peak FEEDMOD result

CASTING OPTIMISATION STUDY OF A DUCTILE IRON ROLLER CASTING

The following analysis is a typical example on how the Foseco Pro Module and MAGMASOFT® 5.4 Autonomous Engineering can be used to study and optimise a casting method. The simulation analysis provides essential input for decision making processes in the foundry and provides insights that may be pertinent to future casting simulation analyses.

Using this new generation of simulation technology tools, specifically the methodology of virtual Design of Experiments, requires a slightly different approach in how a casting is to be studied. Having the ability to vary and analyse a potentially infinite number of potential variables, simulation engineers have to take a efficient approach to setting up and running Optimisation and virtual Design of Experiment studies. Having first considered and defined the objectives and variables, the model has to be correctly prepared and the D.O.E. defined.

VARIABLES

A DOE was setup to try to identify the best possible compromise between the competing factors. These are illustrated in figure 5. The total number of designs was 96.

For efficiency, this D.O.E. with 96 designs was run with a relatively coarse MESH, without a gating system, and therefore solidification only. It was simulated overnight on an 8-core workstation.

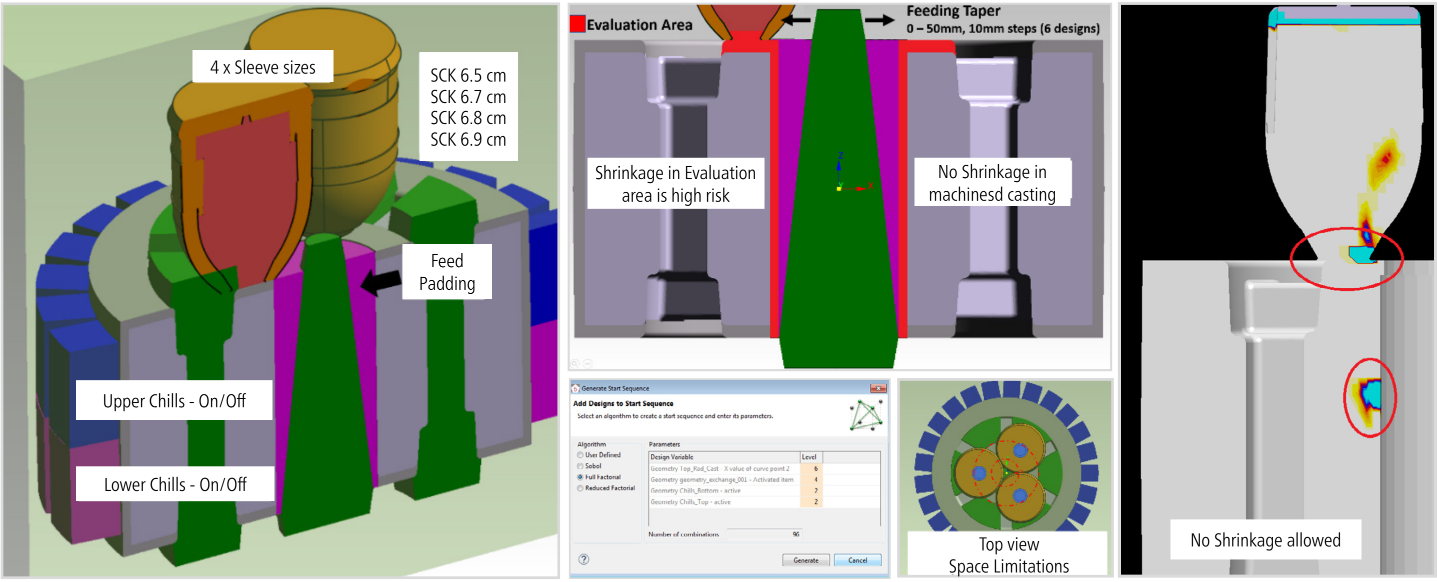
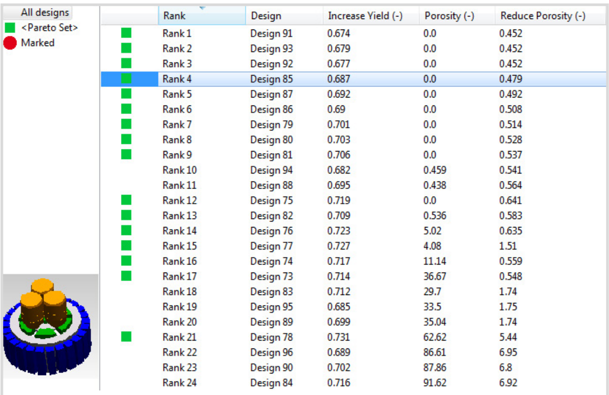


Figure 6: Overview of variables, sleeve positioning constraints and the size of the D.O.E.

SUMMARY OF RESULTS AND ANALYSIS



	Rank	Design	Increase Yield (-)	Porosity (-)	Reduce Porosity (-)
	Rank 1	Design 91	0.674	0.0	0.452
	Rank 2	Design 93	0.679	0.0	0.452
	Rank 3	Design 92	0.677	0.0	0.452
	Rank 4	Design 85	0.687	0.0	0.479
	Rank 5	Design 87	0.692	0.0	0.492
	Rank 6	Design 86	0.69	0.0	0.508
	Rank 7	Design 79	0.701	0.0	0.514
	Rank 8	Design 80	0.703	0.0	0.528
	Rank 9	Design 81	0.706	0.0	0.537
	Rank 10	Design 94	0.682	0.459	0.541
	Rank 11	Design 88	0.695	0.438	0.564
	Rank 12	Design 75	0.719	0.0	0.641
	Rank 13	Design 82	0.709	0.536	0.583
	Rank 14	Design 76	0.723	5.02	0.635
	Rank 15	Design 77	0.727	4.08	1.51
	Rank 16	Design 74	0.717	11.14	0.559
	Rank 17	Design 73	0.714	36.67	0.548
	Rank 18	Design 83	0.712	29.7	1.74
	Rank 19	Design 95	0.685	33.5	1.75
	Rank 20	Design 89	0.699	35.04	1.74
	Rank 21	Design 78	0.731	62.62	5.44
	Rank 22	Design 96	0.689	86.61	6.95
	Rank 23	Design 90	0.702	87.86	6.8
	Rank 24	Design 84	0.716	91.62	6.92

Figure 7a: Reduced list of ranked solutions

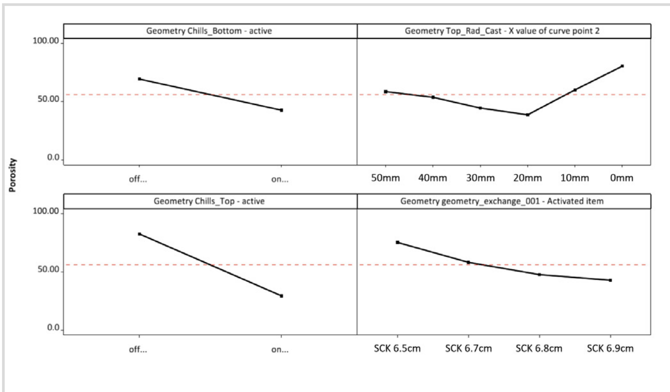


Figure 7b: Result Assessment: Main Effects Diagram

MAGMA produces a list of solutions which are ranked relative to the objectives, (in this case porosity, yield and total porosity), and given a relative numerical score. Figure 7b shows the Main Effects Diagram which summarises the influence of each of the parameters. Turning off top or bottom chills is negatively correlated with increased porosity. There is a distinct step change increase below 20mm padding radius, along with a general trend showing less porosity with bigger sleeves (which is competing with the maximise yield objective).

Individual inspection of the generated results images allows quick and focussed comparison between different versions. Figure 8a shows all results plotted on the Parallel Coordinates Diagram, a tool which allows the user to follow the parameter combination routes to give specific solutions. Clear tendencies were further revealed are summarised below and illustrated on figure 8b.

PARALLEL COORDINATES DIAGRAM

1. When both Top and bottom sets of chills were removed – Shrinkage in final casting.
2. Top Chill ON + Bottom chill OFF – Shrinkage in (high risk) evaluation area.
3. Top Chill OFF + Bottom Chill ON – Shrinkage in Feeder Neck.
4. Minimum taper – 0mm and 10mm – Shrinkage in final casting
5. 20mm and 30mm taper – critical Fraction liquid separation between feeders and casting.
6. Smallest riser – SCK 6.5cm – Isolated Hotspot – all discarded.
7. Largest Feeder SCK 6.9cm –no improvement with smaller tapers, worse yield - discarded.

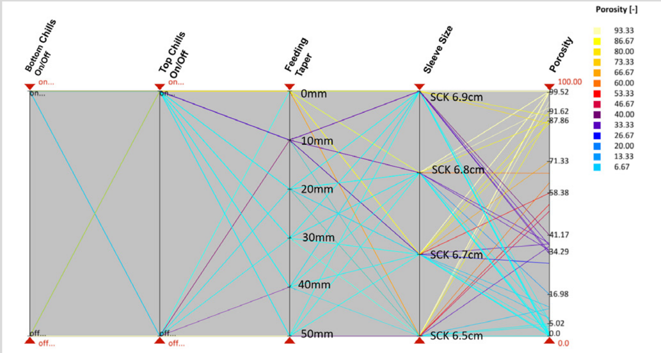


Fig 8a - MAGMA Parallel Coordinates diagram showing all options and porosity results

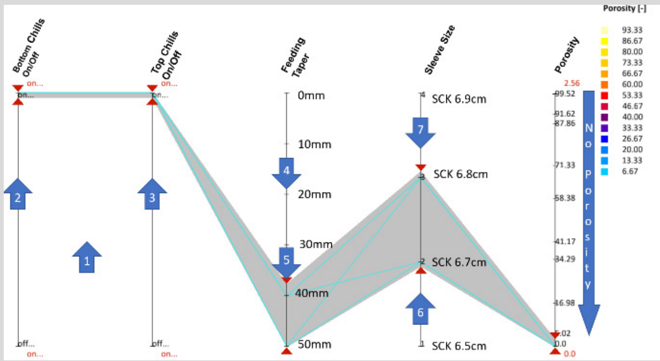


Fig 8b - After analysis, the workable options are narrowed down to 2 sizes and 2 feeding pad radii.

A second D.O.E. was run on the 4 best candidates. As this casting is bottom gated with a long filling time, it is important to correctly account for temperature distributions at the end of filling. The gating system was added, the mesh was refined, and filling was also calculated. The results of these are shown below in figure 8 and figure 9.

In each of the 4 designs above in figure 8, it can be seen in the fraction liquid results that there is a separation between the liquid metal in the feeder and the hotspot in the casting. There is some final porosity as-cast but this is moved into the machining allowance and the feeding taper, figure 9. There is no shrinkage in the final machined casting in any of the four designs. There is a clear tendency that reducing the taper increases the surface shrinkage (fig. 9b, 9d), and that the feed safety margin is lower with the SCK 6.7cm (fig. 9a, 9b). The relative depth of the hot spot zone is also deeper into the casting for the smaller SCK 6.7 cm (fig. 8a, 8b). In order to have a robust method which can potentially withstand variations in pouring temperature and iron quality, the prudent choice is to select the SCK 6.8 cm sleeve with the 50mm taper (fig. 9 c).

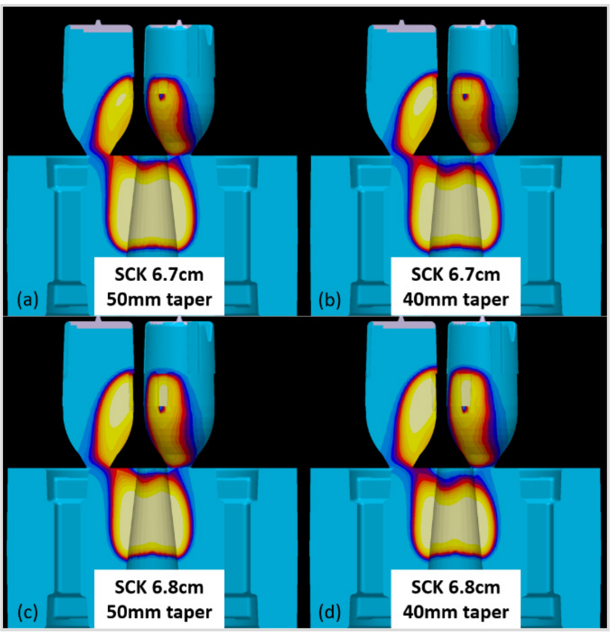


Figure 8: Fraction liquid results

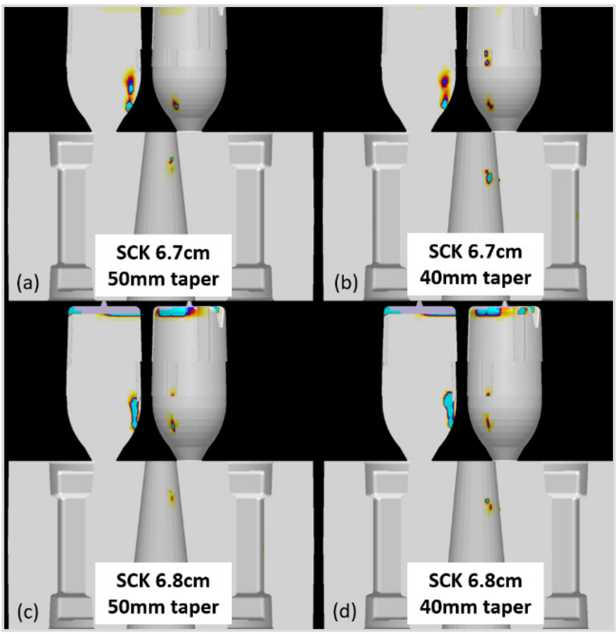


Figure 9: Casting soundness results.

CONCLUSION

In all walks of life, computers and information technology are being used more and more to analyse and make sense of big data. This new generation of autonomous engineering tools developed by MAGMA have greatly simplified the means to simulate and analyse casting projects from multiple viewpoints in parallel. It is very useful for virtual experimentation and learning. The continuous advancement in all foundry related technology requires similar developments by foundries, software companies and consumable suppliers.

Foseco continues to add new sleeve, filter and breaker core size updates to all the available regional databases. It is committed to working on developing new and improving existing thermo-physical datasets to support the technical advancements being made.

The latest Pro Module database, version 2.5.4, is distributed on the MAGMA installation DVD. It is necessary to Install the FosecoDB to update the database. For further information on the Foseco Pro Module for MAGMASOFT®, please contact your local Foseco company.

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