CFD and the Real Needs of the Minerals and Metals Processing Industry

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ABSTRACT

Minerals and metals processing have long benefited from the application of leading-edge technology, despite the somewhat drab "smokestack" image of the industry. Recent trends in industry include globalisation of companies and technology and ever-increasing competition.

The real price of most commodities is being driven down steadily due to the intense competition within specific industries or as a result of the contest for market share between rival products. The trend indicates that companies must maintain a reduction in cost of 2% to 4% per year to remain competitive.

The response to this challenge has been varied, but the scale and ferocity of the attack should not be underestimated. The marshalling of entire national industries through organisations like MITI in Japan and the DOE in the USA with their billion-dollar budgets and significant influence over the industries they seek to support, provides some form of benchmark for existing producers and any new players. The consequences for industry are quite clear; introduce improvements that achieve or better the global industry cost reduction performance or go out of business.

Process improvement and innovation offer two potential means to achieve this target.

The implications for Computational Fluid Dynamics (CFD) are profound. CFD has been central to many past developments but now it can be seen as an essential tool in reducing risk, improving process understanding and triggering the innovation process. This paper discusses what this means by focusing on process understanding and on scale-up of new processes.

1. INTRODUCTION

This paper examines the real needs of Minerals and Processing Industries that intend to, or are currently applying CFD techniques to process assessment, control, development, and innovation initiatives. The needs are addressed from both a management and technical perspective as both elements must be handled correctly to achieve the desired result.

The needs can only be addressed when there is clear understanding by the customer of the services provided by the modellers. This only comes through understanding the objectives of the modelling exercise and the nature of the modelling process. Lack of customer understanding of the process by which successful models are established and maintained can easily lead to misconceptions about the potential benefits and can damage the reputation and credibility of technologists working in the industry.

Innovation drives the improvement process. With existing processes there is a pressing need to implement improvements. In new process development, the driver is the reduction of risk. In both areas CFD modelling has a strong track record of supporting process improvements and also reducing risk.

The magnitude of such risk can be seen in the recent difficulties associated with bringing new processes on line at the Kennecott Copper Smelter in Utah and the Escondida solvent extraction plant in Chile. Processing difficulties and reduced throughputs have cut potential earnings by more than $100M per year.
The principles discussed in this paper have been known for a long time[(1)] and do not seem to have changed much in content or relevance[(2)]. The principles were developed through the course of

a number of major process developments such as the HIsmelt™ Direct Ironmaking Process[3] and the Comalco Drained Cathode Cell.

The impact of CFD modelling on these developments has been of substantial benefit [4-5] and can also be shown to have a profound impact on the ability to develop innovative solutions once all elements of an effective strategy are put into place. The down-side to developing such a capability is the effort and cost required to maintain the approach through the lean times. If essential elements are not kept in balance, process modelling can fail and the technologists involved can be seen as unnecessary.

1.1 The Real Needs

As risk is the factor common to all initiatives, a business strategy must be put in place to accurately define, assess and reduce risk.

To accomplish this task, an understanding of the process being improved, developed or superseded is ***essential.*** Process modelling then becomes a fundamental element of the business strategy and the following elements of a productive modelling strategy can be developed:-

1) Long-term commitment to building and improving the capability of the models and modellers.
2) Need to establish and maintain a functional development environment.
3) Adequate support from and frequent interaction with laboratory, pilot plant and plant personnel.
4) Opportunity to test the models over a wide range of operating conditions and to verify this against laboratory, large scale physical model and pilot plant results.
5) Regular reviews with all development personnel involved. Deliberate customer and supplier self education.
6) External scrutiny from experts in the field.
7) Opportunity to benchmark development capabilities through limited interaction with competitors.
8) A mechanism to avoid misuse of models; 'license' capable users.

2. DISCUSSION

2.1 Key Component of a Development Strategy

Aside from the essential role mathematical modelling plays in improving process understanding and thus reducing risk, the new knowledge and capability to explore existing or new process potential acts as a catalyst for the innovation process. Thus the ability to deliver successful improvements or more demanding innovations is greatly enhanced by the application of process models.

Process mathematical models embody the condensed understanding of an operation reduced to a series of formulations that best represent the physical and chemical process occurring. Improved understanding of these processes, when confirmed by model verification, coupled with the ability to test ideas at low cost make the model an extremely powerful tool.

Ranking of the importance of various sub-processes provides the insight necessary to clearly define the problem or opportunity that may exist. A better-defined task then permits a number of directed solutions to be formulated which may contain genuine innovation/s.

Competition also dictates that such powerful tools must be applied to achieve optimum outcomes. With the push to take advantage of industry globalisation and the economies of scale, the risk associated with implementing change has increased disproportionately and should only be undertaken when the implications of such change have been thoroughly investigated. Informed changes reduce the requirements for expensive plant trials. Application of models to such tasks is a key element in testing the strategy.

With the capability of the modelling platforms available today and the range of expertise that can be tapped through universities, research organisations, modelling consultancies and to some extent in-house expertise, there is no longer an excuse that an individual process is too complex to model. Inability to formulate a model probably indicates a poorly controlled or out of control process, a lack of understanding of the state of the process or a deficiency in the capabilities of the development group - none of which would engender confidence in the groups ability to undertake significant process improvement.

Companies engaged in secondary processing of minerals that have avoided in-house research and development generally reach a certain size or maturity and then find it necessary to undertake both elements of the improvement strategy. NUCOR's rise to fortune in the steel industry came from their ability to identify and implement emerging technologies developed by others ahead of the competition, but NUCOR has recently undertaken the development of their own processes tailored to their specific needs.

The application of models to achieve the optimum technical and economic outcome is a component of a successful business strategy. This implies that management should be sufficiently accomplished in interpreting modelling outcomes to make informed decisions when reviewing development proposals.

2.2 Long-Term Commitment

Process models applying CFD modelling techniques have a key role to play in both elements of the process and plant improvement initiatives. The process of innovation represents a higher order of complexity as models are more likely to be used to extrapolate outside the boundaries for which they were initially created and subsequently verified. In these critical applications the understanding of the processes, the capacity of the models and the ability to recognise weaknesses is essential. The skills and experience necessary to undertake this complex task take time.

Successful modelling represents a considerable investment in technology and personnel. To sustain the value of this investment there is a real need for continuity of personnel and a long-term approach to model development and assessment of the value of information coming from models.

In almost all instances the most valuable assets generated in this activity are the skills and experience gained by the modeller or modelling group rather than the improved capability of the actual model. The experience cannot be easily passed on or documented and should therefore be protected. Models used for process development and improvement must remain dynamic and therefore require personnel with the capability to sustain improvement.

This requirement also applies to those who play the key role of generating the necessary data for model validation. Without validation the whole exercise lacks credibility as it is not possible to choose between competing mechanisms without returning to experiment. The skills required to undertake laboratory, pilot and full-scale experiments to continue this iterative process must also be maintained.

In many circumstances the correct interpretation of model information may not be possible until suitable plant data is forthcoming. A realistic time frame for assessment of model results for large scale and/or complex developments may approach several years.

2.3 Functional Development Environment

As industry pursues constant improvement, the same elements of improvement must apply to process model development. Properly managed, this becomes a self-sustaining, symbiotic environment that ensures the growth of capabilities and knowledge of all parties by feeding off the information generated from plant, laboratory and model experiments. When suitable resources are applied to this task, development can continue to flourish even where strict confidentiality must be maintained and exposure to competitor activities is limited.

It is a key role of management to support and sustain this cooperative environment if successful innovation is to be realised.

The foundation of a functional development environment involves maintaining a sufficiently large group of modellers as a close working team. The CFD field is sufficiently complex and dynamic that individuals are rarely able to cope with all the demands of maintaining best practice and solving the wide range of problems confronting the modeller. In small organisations this can only be accomplished by working, perhaps collaboratively, with external groups that are sufficiently experienced to fill the gaps.

Providing modelling staff with challenging tasks and the opportunity to expand their capabilities is an important consideration in maintaining work satisfaction and thus promoting key staff retention. Such opportunities are necessary to ensure the modelling remains current, vibrant and highly productive.

If the entire development infrastructure is not being continuously improved and becomes superseded, stagnation can erode business profitability.

Access to software and adequate computing facilities must be matched to the scale and complexity of the task. Computing power and adequate modelling platforms do not have the limitations of even 5 years ago and competition amongst hardware and software suppliers has dramatically reduced the real cost of undertaking modelling tasks.

The issue for the process developers is the allocation of resources as there are always more potential improvements than resources permit.

2.4 Support and Interaction

The commitment to undertake process modelling requires an equivalent commitment to providing quality data for model verification. The capability of the model is a direct consequence of the degree to which verification has been sought.

Those engaged in the development must actively seek to determine the deficiencies of the models and verification data and adequately support both modelling and experimental activities to close gaps and eliminate weaknesses.

It is difficult to proportion the effort required for modelling or experimental activity as it depends to a large extent on the scale of operation being investigated. Experience suggests the expenditure ratio should never go outside 3:1 in either direction.

Clearly those engaged in these activities must communicate effectively. This can only be accomplished by direct contact between the specialist modellers, researchers and plant operations staff. Frequent contact must be fostered even when the groups are separated by large distances.

2.5 Test the Boundaries

The process should be investigated over the widest practical range of operating conditions so that the applicability of the model is firmly established. This usually results in more readily quantifiable change in process performance and defines genuine limitations. Many pyrometallurgical processes operate close to the conditions of process collapse (which can be disastrous). This then defines the maximum capability and key rate-determining processes. This information is invaluable in defining key processes and setting model parameters and boundary conditions. The nature of this type of approach dictates that only those who can safely afford to fail should attempt such a strategy.

In some cases this may require operating at conditions that could result in damage to pilot plant components or reduced plant life. As long as the safe operation can be guaranteed, it is extremely effective to complete pilot scale tests under conditions that have not been previously possible. New insight, understanding and improved model formulation generally result.

Where scale-up is a key task for model predictions, the effect of scale must be verified for some key elements of the simulation. The best approach involves laboratory, pilot and full scale testing of tightly controlled conditions, sometimes employing special measurements and additional data collection.

2.6 Regular Reviews

The opportunity to bring all parties together to review progress and set tasks is essential in maintaining effective communication. For large scale developments this may involve meetings with wide ranging agendas and diverse people; the type of meeting that is often difficult to manage. The benefits of bringing a wide range of different disciplines to bear however can often be substantial. This type of larger scale activity can only be justified on a longer-term basis.

2.7 External Scrutiny

In development activities where strict confidentiality must be maintained, there is a need for external experts to scrutinise modelling development activities to ensure that the development has not become too narrowly focused or has missed an opportunity or become bogged down in detail.

Finding the appropriate expertise is a key task for management.

2.8 Limited Benchmarking

As resources are always limited, it is necessary to provide an opportunity for development groups to benchmark their capabilities against those of others engaged in similar work. Whilst this type of comparison must be carefully managed to limit exposure of confidential material, cooperation on research into common process fundamentals, modelling approaches and bench scale research etc. can still provide a powerful basis for comparison and generally results in a wide range of improvement initiatives.

There is therefore a need for some opportunity to compare capabilities if world class developments are to be successfully undertaken.

2.9 Avoid Misuse

Once a model establishes credibility, it becomes a technical and political tool that must be used with discretion. If misused, there will be considerable damage to credibility. Such an enabling technology must always have checks and controls.

The tool can also stifle creativity if the development becomes too reliant on models. This may also occur if the model, modellers or customer reaches the limits of their capability and/or courage.

There is almost a need to 'license' users working on models that have a long history of development. Obtaining a licence may involve demonstrating an adequate understanding of the history and capabilities of the model. The final test should require a demonstration of the ability to improve simulation capability. A licensed user should only then be permitted to use the model on simulations outside current verification.

3. CONCLUSION

Global competition dictates that a competitive position can only be maintained if cost reduction initiatives meet or better industry trends. This condition requires that an overall business strategy must involve innovation and an adequate assessment of risk.

Mathematical models using CFD techniques are a proven way of focusing innovation and assisting in risk assessment; however, such an enabling technology must be used cautiously and by experienced staff committed to model validation at all levels.

To achieve these ends there is a need for:-

- management with an understanding of the modelling process
- a long term commitment to the endeavour and to the individuals involved
- considerable tolerance

all of which are becoming increasingly harder to find.

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