A REVIEW OF TECHNOLOGY ISSUES CONFRONTING THE PROCESS & MANUFACTURING INDUSTRY

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SUMMARY

This document summarises the issues confronting the process and manufacturing industry in making effective use of FE technology. The content of this document is based on presentations and discussions held during the FE-Net meetings, more in particular:

- first Industry Workshop, 13-14 November 2001 Wiesbaden, Germany
- second Industry Workshop, 12-13 December 2002, Prague, Czech Republic
- third Industry Workshop, 3-5 December 2003, Hamburg, Germany
- fourth Industry Workshop, 2-3 December 2004, Lisbon, Portugal
- FE-Net Industry Needs Survey, conducted on-line during 2002

Maturity levels are presented for important issues in forming process analysis. Ways forward to address issues that are currently perceived as the most important deficiencies are proposed.

1: INTRODUCTION

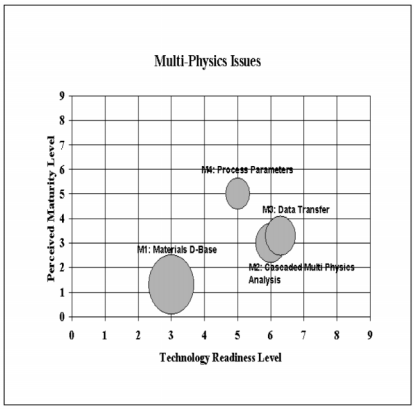
The objective of the industrial working group 'Process and Manufacturing' has been to provide an industry specific opinion to the generic FE-Net themes. This document will review the usage of numerical methods by industry and draw conclusions as to the "effective ability of industrial users to exploit simulation methods".

The Process and Manufacturing Industry Sector is a wide area, both in terms of variety in processes, materials, as well as being regarded a supplier to a multitude of branches of industry. Process and Manufacturing is mostly regarded "an activity relatively deep down the supply chain in a vertical segment of industry".

2: TECHNOLOGY READINESS LEVELS

Generic themes have been derived from information about specific processes. These themes have been grouped in order to link them to one particular Research and Technology Development (RTD) area.

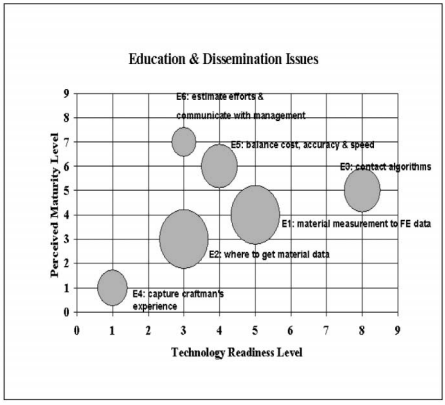
MULTI-PHYSICS ISSUES AND REQUIREMENTS



M1	Databases with material properties for various physical domains and under extreme circumstances
M2	Cascades of multi-physics analysis (for example: coupled Electro-Magnetic analysis followed by Thermo-Mechanical analysis)
M3	Share data across various types of analysis: neutral results format, mapping procedures, direct interfacing
M4	Determination of process parameters I.e. determine friction coefficients, heat transfer coefficients etc.

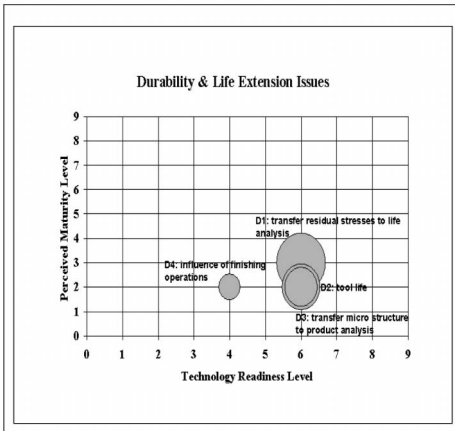
Figure 1:
TRL's of Multi-Physics issues (size of the circle indicates Priority Level)

EDUCATION AND DISSEMINATION ISSUES AND REQUIREMENTS



E1	How to convert material property measurement results to analysis program parameters
E2	Where to obtain reliable material parameters
E3	Contact algorithms in manufacturing analysis
E4	How to capture craftsman's experience in analytical models
E5	How to balance analysis costs, accuracy, computational speed
E6	How to realistically estimate efforts needed for analysis and communicate with management

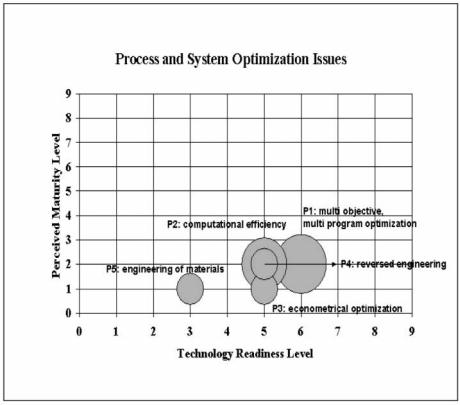
Figure 2:
TRL's of Education & Dissemination issues (size of the circle indicates Priority Level)



D1	Transfer residual stresses from P&M analysis to component life analysis, including mapping of results to new mesh
D2	Tool life and fatigue
D3	Transfer material structure from P&M analysis to subsequent product performance analysis for life evaluation
D4	Influence of finishing operations (for example shot peening after forging)

Figure 3: TRL's of Durability & Life Extension issues (size of the circle indicates Priority Level)

PROCESS AND SYSTEM OPTIMIZATION ISSUES AND REQUIREMENTS



P1	Optimization using the results of multiple non-linear analysis (for example a forging analysis and the component fatigue analysis)
P2	Efficient execution of large multi physics analysis
P3	Include economical/environmental parameters in optimization loop
P4	Reversed engineering (component life requirements determine product shape, how should the blank look in order to forge the product)
P5	Material engineering (can a material be composed that suits all needs of the product and can be used in manufacturing)

Figure 4: TRL's of Process and system optimization issues (size of the circle indicates Priority Level)

3: BUSINESS DRIVERS

The main drivers are:

- cost reduction
- minimize time to market
- first time right (avoid extensive trial and error on tool & process design)

These key drivers can be further detailed to:

- ✓ research on new materials in production (part of cost efficiency)
- ✓ concurrent engineering (part of time to market)
- ✓ reduction of waste material and weight reduction of final product
- ✓ replace the empirical knowledge of 'old craftsmen' on the factories (many of whom are about to retire), by knowledge based systems fed by analytical results
- ✓ reduce the pressure on the eco-system, i.e. optimise production processes with respect to environmental issues
- ✓ communication between customers and suppliers at different tier levels in the supply chain

One particular factor puts Process and Manufacturing Industry in a special position:

In a vertical market segment, profits are often accumulated at the highest level in the chain of suppliers. Production of single components is often regarded a "low value added activity" and therefore pushed down to a lower level supplier.

4: STATE OF PRACTICE AND LEVEL OF MATURITY

Process and Manufacturing analysis are mostly performed subsequent to design analysis, and the results are only occasionally used in the evaluation of the design analyses. Mostly the production process is analysed at a lower tier in the supply chain than the product analysis.

Analytical methods are almost uniquely applied to core processes in the manufacturing stream. Deploying simulation techniques as a concurrent engineering activity in a product design process is seldom used. Industry is heavily relying on consultants to guide them around the pitfalls that are inherent to these complex analyses. With some positive exceptions, the software is 'not fit for use by process design engineers'. The success rate of implementing simulation techniques in the factories mainstream processes varies through industry. Some companies have managed to integrate analysis in the mainstream development, some other early adapters of the method have abandoned simulation after a disappointing experience.

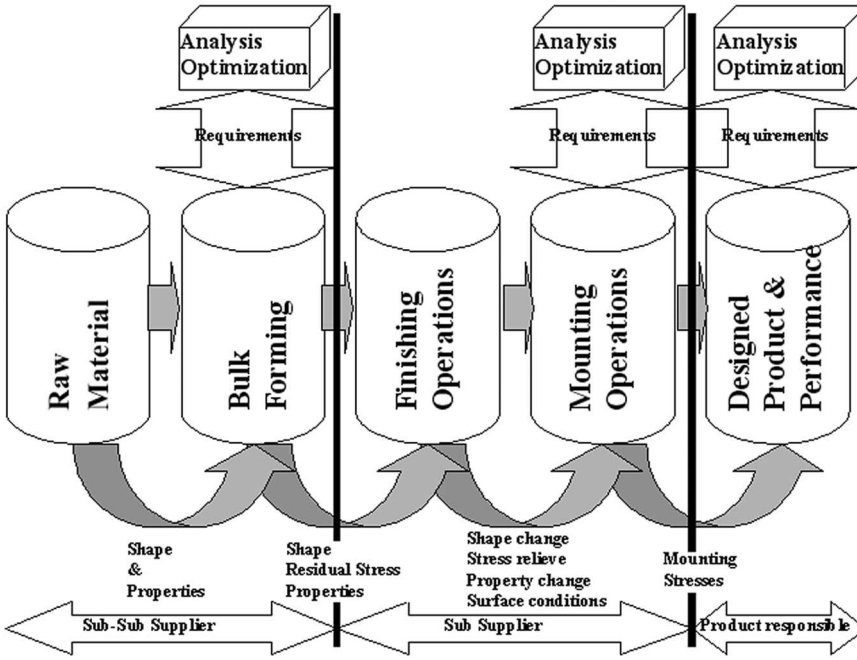


Figure 5: State of practice in Process & Manufacturing analysis

Especially Medium and Small Enterprises find it difficult to retain skilled analytical resources. Furthermore MSE often hesitate to implement simulation techniques because of the high investment.

One of the consequences of the "many different processes" is that there is a market for the software vendors to sell dedicated solutions. Alternatively, general purpose software can be used for simulating specialized processes. The drawback of using general purpose software is that a FEA specialist is needed to perform the modelling. Dedicated solutions are often considered more attractive since it is possible to use 'forging terms' in the menus of 'forging simulation software'. This makes it possible that the process design, rather than the FEA specialist, engineer uses the software.

Special purpose software is more often appreciated through a high Perceived Maturity Level than general purpose software. The software needs to address the matter in terms of the design engineer, should be user friendly, robust, and should offer a database of material properties in order to be successful. In other words: the flaws and shortcomings of the underlying methods are hidden by user-friendly shell on top of it.

5: STATE OF THE ART

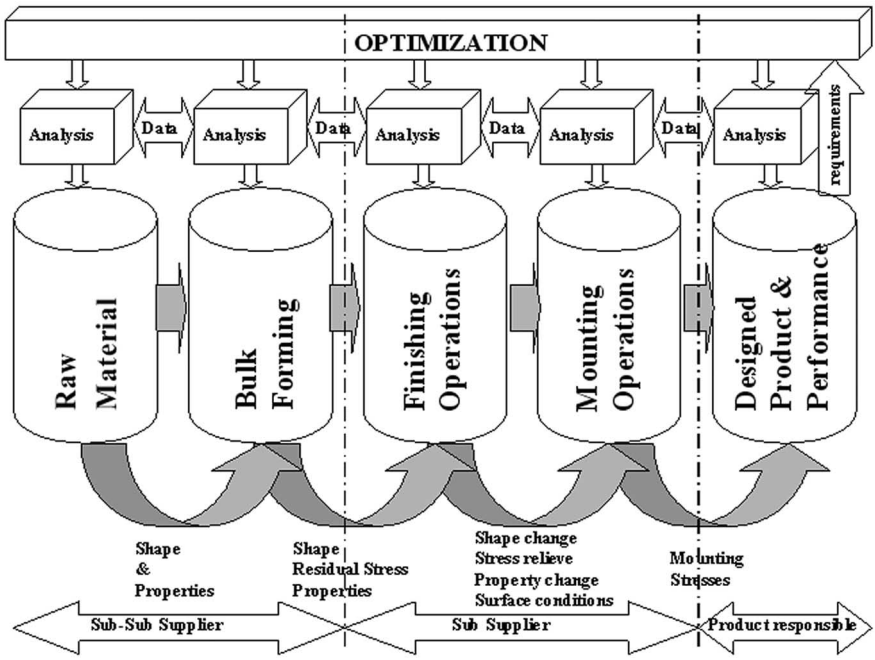


Figure 6: State of art and future in Process & Manufacturing analysis 0

Current state of the art activities in process and manufacturing simulation are projects in which:

1 determination of the material properties has been made an integral part of the project;

2 analysis data (both results and geometry) are shared through a sequence of analysis. Various analytical codes, originating from different suppliers, may be needed to analyse the production steps that are used to create a product;

3 each of analysis steps may use a different discretisation of the part;

4 it is recognized that he production processes will determine the material properties that should be taken into account in the operation performance analysis of the final product;

6: MARKET TRENDS

The current Technology Trends in P&M software development are:

- growing analytical possibilities;

- many niche programs (because it is too difficult to program all physics for all processes into one code) are introduced on the market. They all have their own, unique, user interface. The specialized programs often address the matters in terms of the factory process engineer rather than in terms of a FEA specialist. General purpose programs offer an increasing number of modelling possibilities. These programs are getting increasingly complex. The makers of the general purpose programs recognize the need to offer the non FEA specialist a possibility to use the code. They therefore offer "customisation" possibilities. From a users' perspective the need for one uniform CAE environment (ease of use) exists, so there is no need to learn many different Graphical User Interfaces;
- the optimization programs that can do cross-software, non-linear optimisation force analysis programs to become parameter driven (parameters in, parameters out without the strict need for user interference);
- multi physic analysis offered in one single software platform

7: BARRIERS TO THE UPTAKE AND DISSEMINATION OF SIMULATION METHODS

A significant investment from industry in human resources, training, and education is needed in order to successfully implement numerical simulation methods in the business process. Most successful implementations of process simulation have been preceded by a long term investment in education. Good training is available from:

1 the software vendors (focus on strategy, tips, and tricks to operate the specific software)

2 independent institutes (focus on quality and theoretical background)

The amount of training needed (often two or more weeks) is often a problem in itself to industry since it will take crucial resources out of the daily business for a longer period of time. Depending on the region in Europe, there seems to be an increased interest from industry in training and courses.

The primary barriers to the uptake of modelling and simulation techniques by the process and manufacturing industry are:

1 Lack of material data to adequately describe the material under process circumstances;

2 Little knowledge transfer on "How to translate material test data to analysis program parameters";

3 Making results data from an analysis step available as input to a subsequent analysis is problematic. Especially the coupling of software from various vendors poses problems. In general each analysis step requires a unique mesh. Adequate result field mapping is a general problem in data transfer.

4 Optimisation of non linear analysis, like production process optimisation, poses difficulties. Often optimisation is done on an intuitive bases, as opposed to an analytical, structured approach. Making models at industrial scale parametric is very labour intensive.

8: RESEARCH AND TECHNOLOGY NEEDS

Research and Technology needs can be derived from the predominant barriers to the Uptake of Simulation Methods.

1 **Database with appropriate material data.** Appropriate means: physical correct data for the circumstances at which the process takes place. Usually this means high temperatures, high strain rates etc.(**Multi-Physics issue**)

2 **'Where to obtain material data'**, and **'How to translate material data measurements to parameters for the FE-program'** is the **Education and Dissemination** component of the urgent need for better availability of material data.

3 **The smooth transfer of data from a process simulation to a product performance analysis** is the main issue to be addressed by the **Durability and Life Extension area.** Production processes actually create material properties that should be considered in product analysis. Some possibilities exist to transfer relevant data. However significant efforts are needed to couple any arbitrary process analysis to any arbitrary product analysis.

4 Further development of **multi objective and multi program optimisation** is the main request form the P&M industry sector towards the **Process and System Optimisation** RTD area. To fulfil this requirement it should become possible to run analysis programs in a "parameter in" "parameter out" mode. This will facilitate the designers of processes to link highly specialized codes in their analysis stream, with the need of in depth knowledge of that model. **Further increase of computational efficiency** is the second important issue for **Process and System Optimisation.**

9 CONCLUSIONS

Lifting the indicated barriers will bring Process and Manufacturing analysis closer to the ideal state that has been defined as:

To have access to skilled human resources, a set of verified software, and reliable material data that will allow for the scanning through a variety of possible production processes in order to optimize the production process, production costs, end product performance, and pressure on the eco system.