Abstract: The paper is concerned with daily live quality control modelling. It presents a particular enterprise model of process control and its use for integration. The aim of the paper is to understand enterprise activities, their overlaps and related business processes. It also presents how the model helps integration of process control applications in a Computer-Aided Manufacturing system. Applications of the model to case studies in thin film plastic and semiconductor industries are given. Copyright © 2006 IFAC

Keywords: Enterprise Modelling, Computer-Integrated Manufacturing, Statistical Process Control, Integration, Information Systems.

1. INTRODUCTION

This paper deals with process control structures, which form the operational part of quality control. In industrial contexts, these organisations are involved in several levels of controls: from those close to tools regulators like PID controllers (Corriou, 1996) to those close to production control such as SPC (Montgomery, 2001) and organisational process regulation loops (zur Muehlen, 2005). For example, in semiconductor facility, Sach et al. (1991) present a process control framework based on three levels of control: Real time control, Run by Run control and Automatic Recipes generator.

Spanning automation and human processes many information system solutions, sustaining process control, can be found on the market. Two major difficulties are encountered: (1) Homemade programs or off-the-shelf ones point out relevant information from useless ones. If architectures of such tools are not led by a clear vision, information system suppliers can decide what is relevant in the business. This way, the risk of loosing control of the business process is high. (2) A large scale information system development project can be split into several modules: one for maintenance management, one for product life cycle management, one for manufacturing executive system, another for statistical process control. This leads directly to islands of automation and isolated information systems. The risk of poor integration is high and in that case has to be performed after development. Integration then becomes a huge constraint rather than being a development input.

To tackle theses Computer-Aided Manufacturing System integration issues, three models can be built. (1) The description of business activities helps in controlling the adequacy between information system functionalities and business needs. It is detailed into sub activities and linked procedures at the operational level; (2) The data model linked to theses activities fix business data relevance, preventing the loss of their control; and (3) The information flow between these activities represents a graph. Run over the time, it constitutes business process. Business processes can be sustained by information system in an integrated manner, preventing the island of automation.

The literature provides several process control models. They deal with quality issues (Snee 2003), (Pan and Kolarik, 1992) or tool regulation (Sachs et al. 1991). Focused on day-to-day operations some models are lacking of rigorous semantic (Pinaton 2004) and are not understandable. To make the link between these approaches while keeping an eye on operational aspects, this paper proposes a model in three parts:

* The first part presents activities based on IDEF0 constructs (Fips, 1993).
* Using UML, the second part presents the data model sustaining these activities.
The last part uses IDEF3 (Mayer 1995) constructs for business process representation. This threefold process control framework is based on our industrial experiences in thin film plastic (Bassetto, 2001) and in microelectronics industries (Bassetto, 2005). Enterprise modelling is adequate to fit this process control framework (Vernadat, 1996).

The paper is structured in five parts and a conclusion. The paper starts by defining the purpose of the model. The second part presents the activity model for statistical process control. The third part explains the conceptual data model, sustaining activities. The fourth part presents extracts of business processes from the activity graph. The fifth part presents the use of the model in industrial case studies.

2. ENTERPRISE MODEL ACTIVITIES

For a given enterprise, the model detailed in this section can be applied to products, processes and manufacturing facilities. Each of these features will be called “element” in the remainder of the paper.

This section presents four activities: collect, analyse off line, analyse on line and synthesise.

The formalism used in this part is called ICOM as in IDEF0. Each activity is represented by a verb and possesses an identifying number. It transforms Input into Output under Control using operating Mean. An activity can call other activities during its operation. This connectivity is represented by an arrow going out of activities’ bottom and labelled with the number of the called activities (Fips, 1993).

2.2 A1 Collect

In order to orientate working labour on relevant action plan, managers look for fact-based decisions. For that purpose, raw data about the element have to be collected in order to produce information. This constitutes the first activity of the process control model, called “Collect” and represented Fig. 1. Data coming from an element are collected by means of methods and tools. These operating systems are driven by a control plan. This plan determines what and how to collect. It also possesses a data collection indicator (Pillet, 2003). The A1 activity provides validated data and information on data collection.

2.2 A2 Analyse off line

The second step in making a fact-base decision relies on the ability of analysing data. The second activity is called “Analyse off line” and is presented by Fig. 2. It represents analyses performed by data analysts in duration not comparable to the time in which the element is evolving. For example, analyses of facility deliveries are performed in a laboratory whereas production continues. This activity involves experts and data analysis tools. It is placed under the control of calculus algorithms and interpretation rules. It transforms validated data and analysis needs into analysis results, action plan (qualified as off line) and information about how the analysis has been performed.

If validated data do not contain relevant information, the activity creates a new analysis need requiring more relevant variables and a sampling plan. This leads directly to a call to A1 through a new control plan.

2.3 A3 Analyse on line

The other way to analyse data is to perform analysis operation systematically and automatically in a comparable time of which the element is evolving. For example, production control operations are performed just after production operation, systematically. This connection changes the way of performing analysis. This particular activity is called “Analyse on line” and is represented by Fig. 3. It is performed by automatic
analysis tools, analysis methods and support engineers. It is ruled by calculus algorithms, specifications files, interpretation rules and a constraint, which translates that specifications are placed on measured parameters. This activity transforms analysis results and validated data into action plan and information about the way analysis has been performed. Specific analysis can be required for example to understand a long range parameter drift, statistical process degradations. This involves a call to activity A2 upon an analysis need.

This activity involves control chart building, control limit management and statistical indicators (such as Cp, Cpk) management.

This organisation is not unique and is a proposition to understand the impact of the model. It can rule an organisation and is well placed at the particular enterprise level for its instantiation.

2.4 A4 Synthesise

The last activity of the model is to aggregate results to help management in making fact-based decisions. This activity is called “Synthesise” and is presented by Fig. 4.

It transforms information and also actions plans from theses activities to produce aggregated information about off line and on line levels of control.

3. PROCESS CONTROL DATA MODEL

These activities and related processes rely on a data model. This section presents the second tier of the threefold model. It represents core information needed to sustain activities. These models represent directly information contained in the description of activities presented in section 2. For this reason, the description of Fig. 5, 6 and 7 it is not detailed. This section presents data required successively for activities “Collect”, “Analyse” (on line and off line) and “Synthesise”. Data models presented in this section are expressed using UML 2.0.

3.1 A1 / Collect / Data Model

The model of Fig. 6 presents the data model linked to A1 / Collect activity.

3.2 A2 / “analyse off line” Data Model

The model of Fig. 6 presents the data model sustaining on line and off line analysis activities.
3.4 A4 / "synthesise" Data Model

The model presented by Fig. 7 presents data involved in the activity of synthesis.

3.5 Data Model conclusion

The data model is another activity representation. Instead of focusing on functionality, it underlines concepts required for each activity. It shows concepts redundancies such as: validated data, control plan, analysis need, <activity> action plan, <activity> information, off line analysis results. These common concepts are key issues for integration. If they are neither shared among software nor supported in a model database, they can evolve separately. The integration issue discussed at the beginning of this paper becomes then a reality.

The next section will exploit these overlaps or links to build the enterprise activity graph and the resulting business processes.

4. PROCESS CONTROL BUSINESS PROCESSES

This section presents the last model part, which consists of business processes. It relies on the temporal sequencing of activities.

4.1 The activity graph

By sharing common data, these four activities are linked and can create an enterprise activity graph as presented by Fig 8.

This model underlines the complexity of the process control and aims to help CIM engineers to build a consistent system. It presents existing links between these activities. Operationally, this structure is temporally reviewed by people to form the business processes of process control. The next paragraph presents two ways to temporally chain these activities.

4.2 Process control processes

The A0 – Control Process decomposition leads to an activity graph, which can be analysed in a temporal manner. Each of the sequence path is called a process.

To describe how these activities are operationally chained, we propose two processes:

(1) the “on line” analysis process (Fig. 11)
(2) the “off line” analysis process (Fig 12)

The graphical symbols used are given by Fig. 9.

Fig. 9. Graphical symbols for process representation.
4.3 Processes robustness and organisational deployment

The two previous processes produce information and action plan on the elements under their control. Action plan and information can be involved by BP1 only if Collect and Analyse off line are performed. Synthesis is not required. For BP2, Action plan can be produced if Collect and Analyse on line are available.

The process control model represents invariants in an organisation and how to control processes. This helps planning business process development and deployment in the organisation. It is possible to control elements progressively by implementing activities with priorities for example in this order: Collect then Analyse off line then analyse on line then synthesis. We will see in the next section how the property of robustness helped in implementation and migration path.

5. USE OF THE MODEL AS INFORMATION SYSTEM VISION

Experiments have been made in a manufacturing facility representing over 150 millions dollars budget per year. The facility has to be up 100% of production time and must not influence in any negative manner the production. The best facility behaviour is when it is transparent for production. Such constraints lead to master installations during their use in a preventative manner rather than only being confident in their design and on alarm management. For each study, the paper presents the industrial case, the AS-IS state, developments and results.

5.1 Thin film plastic industry application

Industrial case:
The first application has been developed for thin films plastic industries and has lead to the instantiation of the second business process.

5.2 Semiconductor industry application

Industrial case:
The second application has taken place in the semiconductor facility. The scope of this project was to control production sustaining installations: buildings, ambiance regulation, industrials raw materials and wastes management.

AS-IS state: In classic facilities control room, a schematic plant representation is used as a background for alarm pop up. These warnings result from the comparison of data collected through sensors and alarm levels. This level of information management is not enough. When an alarm occurs the process deviation has still happened, the mechanical part is already broken and facilities delivery is wrong.

Results:
Developments: Both business processes have been experienced all on element called facilities tools. “Analyse off line” business process led to identify...
4326 relevant variables in the facilities control plan, their specifications and control limits. “Analyse on line” business process has been experienced by putting 826 of them under statistical process. Half of them have been previously collected in a particular structure developed for that purpose. User interface of SPC on facilities is presented Fig 13.

Model usage: The model has been instantiated for BP1 and BP2 and followed as an information system goal during all developments linked to statistical process control. Processes robustness has been used to implement progressively these two processes as presented in 4.4.

5.3 Experiment conclusion

These experimentations allow us to instantiate progressively activities and business processes in particular enterprises, while answering operational requirements.

To fit the enterprise needs, the model has been detailed each time at sub activity and procedure level. The data model has always been completed with organisational particularities. Each time, it has been used as development reference for integrating system at operational level

6. CONCLUSION

Starting with the need of having an integrated approach for information system development, this paper is more concerned with process control issues. In order to master development and complexity of process control systems, the paper presents a particular enterprise model made of enterprise activities, a data model and business processes. Each of these parts has been described in a specific section of the paper.

Two instantiations of the model have been experienced: one in thin film plastic and another one in semiconductor industry. In each case, at least one business process has been implemented. These progressive implementations underline what is contained in the model: business processes are robust toward information and action plan production.

Further work is currently pursued in semiconductor industries to achieve the model implementation and integration onto products, processes and production facilities. The integration of a specific risk management activity is also carried out as further developments.

REFERENCES


S. Bassetto (2005), Contribution à la qualification et amélioration des moyens de production - application à une usine de recherche et production de semi-conducteurs, PhD Thesis, ENSAM, Metz, France.


FIPS (1993), Federal Information Processing Standards Publication, IDEF0, (FIPS Publication (Ed)).


J. Pinaton, P. Campion (2004), De l’efficience de la production par une approche ‘Qualité Totale’ de type PDCA, GDR MACS, Journées de synthèse Aix.


