Architecture of the Product State Model Environment: The QualiGlobe Experience of Production Efficiency

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Abstract

This paper addresses the issue of using product models to support product lifecycle activities with particular focus on the production phase. The motivation of the research is that products are produced more costly and with longer lead-time than necessary.

The paper provides a review of product modelling technologies and approaches, and the overall architecture for the Product State Model (PSM) Environment as a basis for quality monitoring. Especially, the paper focuses on the circumstances prevailing in a one-of-a-kind manufacturing environment like the shipbuilding industry, where product modelling technologies already have proved their worth in the design and engineering phases of shipbuilding and in the operation phase. However, the handling of product information on the shop floor is not yet equally developed.

The paper reports from the Brite-Euram project (No. BE97-4510) QualiGlobe focusing on the development activities of the PSM architecture. An example discusses how to handle product related information on the shop floor in a manufacturing company and focuses on how dynamically updated product data can improve control of production activities. This prototype example of welding a joint between two steel plates serves as proof of concept for the PSM architecture.

1. Introduction

Enhancing the manufacturability of products demands an increasing exchangeability of information (Alting 1994, Pedersen & Larsen 2001). This paper addresses the issue of using product models to support product lifecycle activities with particular focus on the production phase.

In a manufacturing company, production operations involve information about the product. This information normally has a relatively static nature because it is a specification of how the product is intended to be. Production operations also involve manipulation, generation and use of product information which has a dynamic nature and involve information which describes the current condition or state of the product.

The product state is changing as a result of physical processing (cutting, welding, handling etc.). The state of a product at a given time, is therefore the accumulated result of the processes applied to the product that given time, cf. Larsen et al. (2001).

The product state information includes logistic information as well as the physical properties of the product. Both types of information typically describe conditions, which in some way will influence the subsequent production steps for the product. It is important to notice that this product information describes the actual conditions or circumstances of the product, not the planned. In response to this, the Product State Model (PSM) is defined as opposed to the Product Model, cf Lynggaard (1996) and Sphitalni et al. (1998), which in this paper is considered as the model of the planned product.

2. Research Method

This research reports from the Brite-Euram project QualiGlobe (Product Quality State Based Fabrication in Global Production Environment), which started in 1997 and is finishing in 2001. The purpose of the project has been to define a so-called Product State Model and related applications.

The project partners were: Odense Steel Shipyard Ltd. from Denmark, Fundacion Robotiker from Spain, Institut für Schweisstechnische Fertigungsverfahren der Rheinisch-Westfälischen Technischen Hochschule from Aachen, Germany, Det Norske Veritas Ltd. from Norway, Svejsemaskinfabrikken Migatronics Ltd. from Denmark, and Fincantieri Cantieri Navali Italiani Spa. from Italy.

During the course of the project all partners have been involved in the development and testing of the prototypes. This paper will present some of the results from this work.

The research questions (RQ) pursued in this article are:

- RQ1: Why is a PSM needed in a manufacturing process?
- RQ2: What are modules in a PSM Environment that are necessary for the manufacturing process to execute efficiently?
- RQ3: How are the modules related?

The data founding this article was gathered through internal documentation and supplementary interviews. Extensive internal documentation were available, e.g. functional analysis (IDEF0) of the material flow of the production process and of the control of the production process, results and documentation of several Ph.D. and master theses, and other research project documentation from the QualiGlobe project at Odense Steel Shipyard (OSS). This material provided substantial empirical insight into shipbuilding at OSS. Furthermore, various applications of information technology in the production preparation and production were analysed, i.e. robot controllers, product models, and intranet applications.

One of the objectives of the QualiGlobe project is to specify the product and process quality state model. The model is the basis for the monitoring and pre-adjustment activities, and the calculation of the part quality after processing. The quality model considers both the product and the process aspects, and the relation between them.

2.1 The Case Company Odense Steel Shipyard

Odense Steel Shipyard (OSS) had in 2002 a turnover of over 8,5 billion DKK and more than 8000 employes incl. 3000 in Denmark. In 1997 and 1998 OSS acquired three shipsyards near the Baltic Sea, i.e. Volkswerft Stralsund GmbH in Germany (www.volkswerft.de), Baltija Shipbuilding Yard JSC in Lithuania (www.baltijos.lt), and Loksa Shipyard Ltd. in Estonia (www.ls.ee). OSS is a subsidiary of the A.P. Moller-Maersk Group.

OSS (www.oss.dk) builds double hulled VLCC's (very large crude carriers), crude oil carriers, and container vessels e.g. the worlds largest container carrier and reefer vessels (length: 347, breadth: 43 m, depth: 24 m, draught: 14,5 m, and 6600 TEU, 20 foot containers including 700 Reefers, operated by only 17 persons). In addition to the subsidiary yards in Estonia, Lithuania and Germany, the OSS Group has acquired a subsidiary repair yard in Egypt. Over the years, the primary customer is the owner of the shipyard, i.e. the A.P. Møller Group. In addition, the shipyard also charter ships to the A.P.

Møller shipping company.

3. The need for a Product State Model

Today information applied for controlling processes in production is mainly provided by process planning systems and process specification documents. In addition, static product data (CAD drawings, bill-of-material, etc.) serves to support the manufacturing process. Production staff on the shop floor further adds (or modifies the) process data based on experience and knowledge. Finally, to some degree, they take into consideration specific facts about the current and actual conditions of a particular part. Automated processes are also able to adapt to real conditions by use of sensors, and thus compensate for the difference in the planned and actual circumstances. However, this is only true within limitation and depends on the magnitude of the variations. So far humans are better to adapt the process to the real product conditions than the automated equipment.

Following the above, we realise that we accept that the actual conditions differ from the specifications and consequently allocate human effort and skills, and make investment in technology and new operating procedures, in order to compensate for variation. Additionally, we establish buffers in production plans in order to compensate for the temporal aspect, i.e. possible delays in production due to prolonged processing time or extra time required for repairing.

Hence, it is a fact that in order to achieve the desired quality, the cost is higher than necessary and the lead-time is longer than necessary.

The alternative of gaining more accuracy in the production process is extremely expensive in the manufacture of large, complex, one-of-a-kind products like a ship. Therefore an approach is needed, which allows us to handle the variations as natural phenomena and not as disturbances with damaging effects on logistics, cost, time and accumulated quality.

4. Product Modelling

This section reviews the product modelling literature in order to give insight to the development and elaboration of the Product State Model. Product modelling is an approach to structure knowledge and information related to a product. The traditional purpose of product models is to facilitate the specification activities of the manufacturing company. In the following some of the dominating schools within the Product Modelling community are presented.

University of Erlangen-Nürnberg: Product and product related models to support the Design for X engineering design (e.g. Meerkamm 1993). This Design for X approach contains knowledge and information regarding the application domain. In the paper the focus is on Design for Manufacturing (DfM). The system contains three parts: a component model for definition of product components. The component model is again divided into four elements: a geometry element, a technology element describing tolerances, surfaces, materials, and material characteristics. Furthermore, the component model contains a function element describing the components function surfaces, forces and moments, etc. The fourth element is the organisation element assigning an identification number, a responsible person, and the status of the component. The synthesis part contains generic object oriented descriptions of the components. These are building blocks that by synthesis lead to the product components. Finally, the analysis part contains analyses of consequences for the particular solutions in relation to e.g. tools or tolerances. The analysis proposes courses for corrections.

Helsinki University of Technology: Feature modelling and product models supporting reuse throughout the lifecycle of the product (e.g. Ranta et al. 1996, Ranta & Mäntylä 1997). Mäntylä et al. have been engaged in the discussion of the requirements regarding the structure for product models supporting reuse over the lifecycle of the product model (Ranta & Mäntylä, 1997). As an analogy to design patterns used in software development, the reuse entities are categorised into three types of presentation entities, i.e. macroscopic principles for the early stages of the lifecycle containing physical laws, mechanical structure, etc. The second type is product design patterns for the intermediate stages representing key aspects of a common structure, and microscopic features for detailed description at the late stages of the lifecycle.

Product modelling in a lifecycle perspective is an upcoming research area, whereas feature modelling is a matured area at the Helsinki University of Technology, cf. Laakko & Mäntylä (1993), Mäntylä et al. (1996), and Ranta et al. (1996).

Royal Institute of Technology (KTH), Stockholm: Feature modelling and the concept of Product Model Driven Direct Manufacturing, where the process parameters and scanning patterns are derived from the product model and from the use of a process model (e.g. Kjellberg & Carleberg 1993, Kjellberg 1995). The product model contains geometric, dimensions/tolerances, functional surfaces, and technical data. Moreover, it also refers to company specific information, product background, history, synthesis & analysis results, reasons for decisions etc.

Fraunhofer Institute, Berlin: Product and product related models containing of (1) the product model, which contains geometric description, structure description, and process description, (2) the factory model, entailing an equipment model, capacity and scheduling model, and a plant layout model, (3) the process model, which contain an operation model and a tool path model, and (4) the application model, containing application knowledge derived from service and maintenance (Krause et al. 1993).

University of Tokyo: The product modelling activities are focused on geometric constraints and geometric reasoning. Also, a generic product model for representing all types of artefacts is developed to appear in course of manufacturing and to support a virtual manufacturing environment. The product model contains description of material, intermediate products and manufacturing resources such as tools, machines, etc. Process modelling includes kinematics models, assembly models, form-feature modelling, dimensioning, and tolerance modelling, cutting process simulation, etc. (e.g. Kimura & Suzuki 1986 and Kimura 1993).

The Technical University of Denmark: The Chromosome Model is based on the Theory of Domains by Andreasen (1980), which explains product development as a synthesis of three different views on the product (domains), which are incorporated in the model: (1) Process. The process domain describes the interaction between the product, the operator and the surroundings. (2) Organ. The organ domain describes materialised design solutions, which provide the product's intended functionality. (3) Part. The part domain contains a description of the physical components and assembly structures (e.g. Andreasen 1980 and Mortensen 1998).

Institut National Polytechnique and the Université de Nancy, France: Co-operative Computer-Aided- Integrated Design (CAID) is a methodology and product model for integrated design using a multiview system. The integrated design methodology is based on the co-operative work between all actors of a product life cycle (e.g. Tichkiewitch & Véron 1997).

Eindhoven University of Technology: The Relation-Based Product Model is suited for integrating Design and Manufacturing as manufacturability checking is embedded into the design process (e.g. Net et al. 1996). The product model is based on relations between geometrical entities with a tolerance model. For example, when assembly analysis is performed, numerical code for a machining centre, or command code for a co-ordinate measuring machine (i.e. verifying geometry) is created, then the product description is interpreted for implications in those specific applications.

University of Twente, Netherlands: Product models based on features, and product models for Model-Based Maintenance are based on Function-Behaviour-State modelling. A State aspect of a system is considered as a set of object attributes, which physically can be measured or monitored by sensors. A system's Behaviour is here defined as a set of transitions of states, and the Functional aspect is the top-level description of what the user can perceive from the system's Behaviour.

Function-Behaviour-State modelling describes faults and deterioration of mechanisms in terms of user perception and measurable quantities. The product model is used as a reference for monitoring, fault diagnosis and prevention of breakdown (e.g. Houten et al. 1998).

Summing up the above mentioned schools of thought it shows that product modelling is an approach to structure knowledge and information related to a product with the purpose of facilitating the specification activities of the manufacturing company.

The various product modelling approaches differ in application domain and their level of detail. For example, the DfX tool by Meerkamm (1993) is more focused on implementation of product and product related models focusing on the particular analysis and synthesis tool, and consequently the interaction with the engineering designer, as opposed to the approach suggested by Krause (1989).

The concept of the Product Model Driven Direct Manufacturing (Kjellberg & Carleberg 1993, Carleberg 1995) focuses on the manufacturing process. The concept does provide same functionality as what is intended with the PSM of feeding realised production information forward to further production process activities – however this is limited to geometrical features, whereas the state description of the PSM may contain a wide scale of different attributes.

A product model being representative for the product throughout the production has to a product and product related model, cf. Krause et al. (1993). In order to optimise the production process, a product model should be used as a reference for monitoring. A feedback of realised process parameters Kjellberg & Carleberg (1993), i.e. from use of a process model, should be supplemented with product properties. These product properties represent the state identified of the realised product.

5. The Concept of the Product State Model

The Product State Model stores information about the product generated during production. Through a feed-forward mechanism the information can be made available in the subsequent productions steps where it can be used for adjusting the planning and control of processes. Naturally, the Product State Model describes the output quality of a certain process and thus also can be used for adjusting that same process before it is performed to the next product. The Product State Model's historical data also provides a solid basis of production information for design of new products as well as definition of production methods. However, the main idea explored in this paper is the ability to feed the product information downstream in the manufacturing process so that subsequent processes for the same product are carried out based on individual and updated product data.

The idea of the PSM is directed towards the reduction of accumulated manufacturing errors based on experiences from the development of a Product State Model (PSM) (Lynggaard 1996, Larsen 2003). The main sources of variation in mechanical assemblies are dimensional variations, form and feature variations, and kinematic variations. In particular, the manufacturing deviations caused by cutting and welding of steel plates are due to the high heat input, shrinkages and deformations (Larsen et al. 1999, Langer et al. 1999).

The PSM is designed to collect the state changes of a product or a product part at each step in the production process. Hence, it is possible to perform a geometric quality control of the production process, as the collected product state information is available for later production processes. For example, as the state of each product part is documented in the PSM after the cutting process (using a 3D vision and theodolite system), a global optimisation of the assembly process is feasible in order to improve conformance. Furthermore, the collection of state based descriptions of a product provides an automatic documentation of the product. Exchange of information between the PSM and the sources of the shop floor data collection is based on standardisation, here using the eXtensible Markup Language (XML).

5.1 Definition of the Product State Model

A Product State Model records and stores information about the product generated during production. It enables that information can be made available in the subsequent production steps where it can be used for adjusting the planning and control of the processes. The product state information is a supplement to the information provided by, or derived from, the product model, which is the specification of the product. By providing product state information along with the static product information the basis for planning and executing a process is enhanced. Here we define the Product State Model based on the following tasks that it should be able to facilitate or perform, cf. Lynggaard et al. (2001).

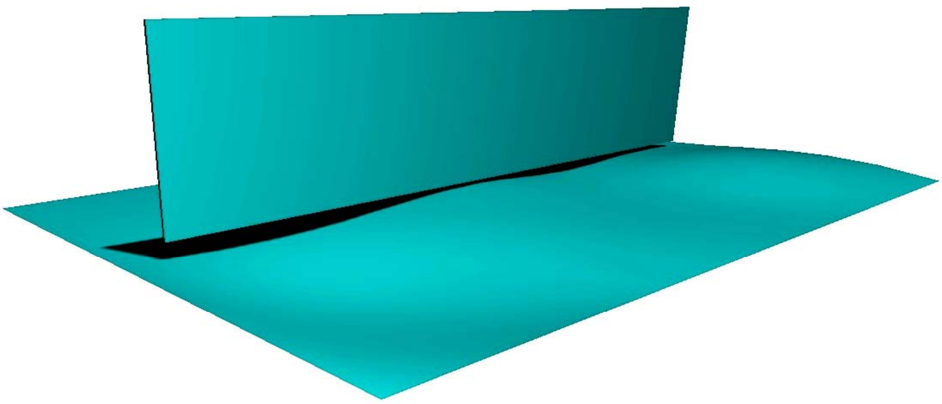
A product state model should

- uniquely identify individual products and parts and their assemblies/aggregations
- formalise the information about the actual conditions regarding the product
- store information from multiple sources
- collect information continuously

- enable exchange of information between applications.

In the QualiGlobe project a concept for the Product State Model has been defined in terms of a data structure and formats for describing product properties. Properties may be physical information, e.g. dimensions, surface conditions, material characteristics, position and orientation in space as well as other quality measures. It is required that this information is described in such detail that it can be applied for planning and controlling processes. E.g. the actual edge geometry of one plate is measured after the cutting process, so that it is possible to estimate the gap measure by use of the information about the two plate surfaces that constitute the joint. See the example in figure 1.

Figure 1: Gab between plate surfaces.



6. The Case Study of the QualiGlobe Project

6.1 The Architecture of the PSM Environment

The basic approach taken in the QualiGlobe project was to document the actual conditions of individual parts throughout the production process. The general scenario is described in the following.

In a given process for a given part, the state in terms of output quality is registered. The information is stored in the Product State Model, which also holds product state information about that particular part, collected during previous processes. Then the part is transported to its next processing operation.

Before it arrives and starts processing, detailed information about this particular part has been fed from the Product State Model into the process-planning loop where processing parameters, processing time, etc. are determined. The processing time has also been fed into the production-scheduling loop in order to update the current schedule. When the part arrives at its processing station, detailed information about this particular part again has been fed from the Product State Model into the process control system so that the processing station is configured exactly to the conditions of that particular part.

This approach allows process planning and control as well as detailed production scheduling to take the actual conditions of each part into account. Thereby the processing is improved, i.e. higher quality at lower cost and with shorter throughput time, and the scheduling nearly becomes deterministic because the estimated processing time is more precise.

A range of modules has been defined and developed in the QualiGlobe project. Table 1 describes the individual models, whereas Figure 2 illustrates the modules and their interaction on an architectural level.

PPM	Product Part Measurement (PPM) refers to different types of measurement systems used for determining the characteristics of parts and products. Examples are vision and laser systems for dimensional measurements. Any type of measurement systems could be adopted depending on the type of product state information required.
PPD	Prediction of Process Data (PPD) is a process planning application. As opposed to other types of process planning applications it is able to take information from the Product State Model as input. For example, this means that it is able to divide a welding line in segments and applying different process parameters to each segment.
OPC	The Online Process Control (OPC) module is used to adapt the welding process parameters to the current conditions and hence adjust for smaller deviations, while the welding is taking place. It is similar to existing adaptive sensor systems, except the fact that it applies more advanced algorithms and that it resides outside the robot controller. The latter means that it can be used for different types of robots.
PS	The Power Source (PS) is similar to existing welding power sources, except for improved interfacing capabilities. The interface is used for improved reading and writing of power source parameters when controlling and monitoring the welding

	process.
DAS	Data Acquisition System (DAS) refers to the sensors and acquisition device, which collects physical signals from the equipment involved in the welding process.
QM	The Quality Monitoring (QM) is an application, which visualises and analyses the data collected by the DAS. It is able to detect some types of welding errors automatically.
QAR	Quality Assurance Report (QAR) refers to an application used on top of the Product State Model (PSM). It is used to document the quality of a welded part with respect to the requirements of the quality assurance procedures.
CE	Compensation Estimation (CE) is another application used on top of the Product State Model (PSM). It is used in the production scheduling loop because it provides information on the required extra work on a certain work piece due to insufficient quality.
RC, CAD, OLP	The Robot Controller (RC), Computer Aided Design (CAD) and Off-Line Programming (OLP) are existing systems involved in the PSM Environment. However, these systems are not directly involved in any QualiGlobe project developments, although they are necessary modules of the manufacturing process.

Table 1: Module description of the PSM environment in the QualiGlobe Project.

The architecture of the PSM Environment is described below. A file from the CAD system (i.e. the Product Model) in IGES standard provides the input for the Product State Model (PSM). The IGES standard was chosen for the prototype, as it was sufficient to use a 2D wire frame model instead of a 3D solid model. The PPM is the interface with the measurement tools from where the detailed geometrical representation is coming, unless it has been collected previously in the process. Measurements of out of plane, i.e. how wavy the plate has become as result of previous production process (here welding), and the fluctuation from a straight line of the edges of plates that are going to be welded on the part block is available from the PSM already. In this way the fit between block and plates can be evaluated.

The OLP plans the welding sequence and distribution of welding capacity on the welding tasks, and generates robot programs and a configuration file for the robot and welding equipment. Furthermore, the OLP provides data for the PSM for later analysis of the realised goodness of the planned quality. The QM is calculating the quality of the product part. Moreover, the QM organises the information received from the RC and DAS into a product state report and stores the information in the PSM for later analysis.

As a part of the near environment, the RC co-ordinates the movements of the robot and the setting of power source parameters, whereas the OPC assures that the welding parameters are according to the input from the OLP, and on basis of the immediate signals of the measurement of the gab from of the (arc-) sensor. During the welding process, the DAS measures and collects data about the welding process via sensors and directly from the RC in order to evaluate the quality of the weld. DAS forwards the signals onto the QM for evaluation.

The architecture of the Product State Model Environment is summarised in the following figure.

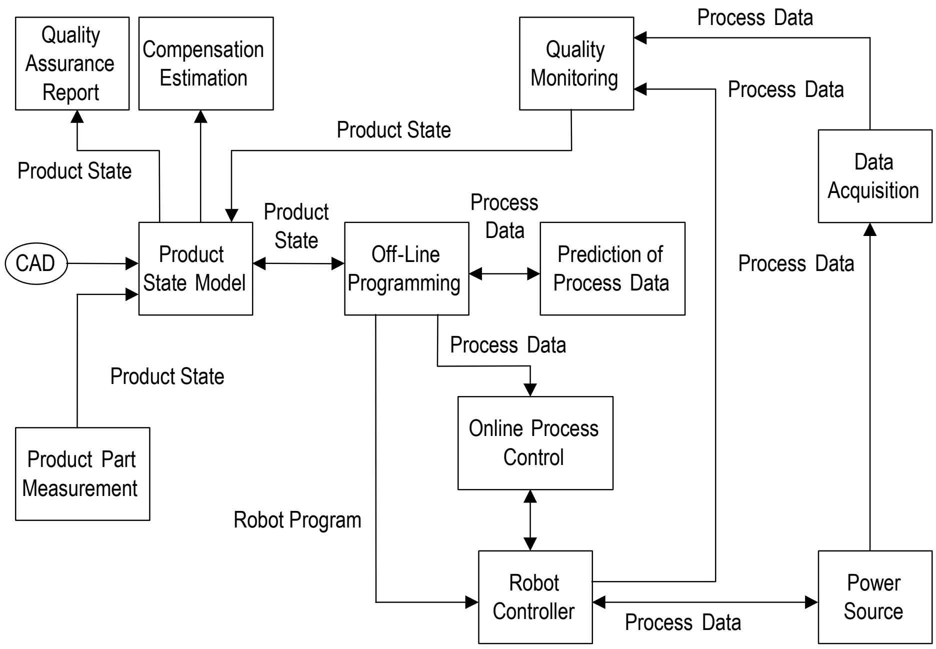


Figure 2: Architecture of the PSM Environment in the QualiGlobe Project.

The foundation for optimising the subsequent production processes based on product state information is that the PSM continuously contains updated data from the feedback from PPM and QM.

6.2 Module Dynamics of the PSM Environment Architecture

In order to illustrate the dynamics of the PSM Environment Architecture, the following section describes a typical example of robot welding of ship elements. The example contains five steps, which are:

- Step 1 – Measurement of product state

- Step 2 – Processing planning of welding and rescheduling
- Step 3 – Welding of the work piece
- Step 4 – Determine the output quality from the welding process
- Step 5 – Reporting of quality and compensation work

The individual steps are described below.

6.2.1 Step 1 – Measurement of product state

Step 1 involves measurement of the output quality of one or more processes. E.g. plate edge measurement of two plates to be joined, or the edge of one plate and out-of-plane deformation of the surface of another plate. The information from each measurement is transferred to the product state model. This step involves the PPM and PSM modules from the PSM Environment architecture.

Alternatively the two plates could be erected and tack welded and measured immediately after. This would give a more precise measurement and it would include information about the tack welds as well. However, it would delay the product state information and thus prevent more precise scheduling.

6.2.2 Step 2 – Processing planning of welding and rescheduling

Based on the part measurements the gap can now be estimated. This provides us the opportunity to perform process planning including generation of robot programs based on more precise part information. This again gives us the possibility to calculate a more precise robot welding time based on process parameters, which are derived from the actual state of the part.

This step involves the PSM, OLP and the PPD from the PSM Environment architecture.

6.2.3 Step 3 – Welding of the work piece

Upon configuring the robot and its process controller with the newly generated robot program, the welding process is carried out. Still, inaccuracies in the prediction of the groove geometry from a Product State Model or a measurement system necessitates that the process is adapted in real-time. Also deformation due to heat input while processing results in changes of the product properties during the process. Therefore the process is controlled in real-time with a seam tracking-module and an advanced module for adaptive process control.

At the same time, while welding, a range of parameters is acquired and stored from the process for further analysis.

This step involves the RC, PS, OPC and DAS from the PSM Environment architecture.

6.2.4 Step 4 – Determine the output quality from the welding process

After completion of the welding process it is required to know the result. This is in order to determine whether the result is in accordance with quality requirements, whether the output quality has any impact on subsequent manufacturing processes. The first aspect is to some extent handled by automatic evaluation of parameter sets from the welding process. In this way we are able to determine some types of possible errors automatically. Hence, not all types and instances of common errors are necessary successfully identified.

The second aspect is performed by collecting data from the process itself and by performing structural 3D measurements of the work piece after the welding process.

Again, all product information is stored in the Product State Model. This step involves the QM, PPM and PSM modules from the PSM environment architecture.

6.2.5 Step 5 – Reporting of quality and compensation work

Based on the output quality measured in the previous step, conclusions are drawn and relevant reports are generated. One report generated is defining the compensation estimation, i.e. in case the weld requires repair or results in other types of compensation, the type and amount of repair work including additional required lead-time are reported. This report is used for production managers in relation to production scheduling. Another report is used for documenting the quality, and is thus used in the quality assurance procedures.

This step involves the CE, QAR and PSM modules from the PSM Environment architecture.

7. Discussion of Results and Benefits

The QualiGlobe project is a research project and therefore full scale benefits remain to be seen.

However, as described below some commercial products are already made available based on the research results.

7.1 Results

A result of the QualiGlobe project is the identification of, description of and relation between all the modules described in this article. In addition, the concept of basing the manufacturing on a Product State Model (PSM) has been developed and tested in a small scale. Nevertheless, the concept may not in its entirety be viable at this time. One reason alone is that Product State Models that are mature and feasible for industrial applications remain to be seen. The PSM in the quality project is a dedicated and limited pilot system, which may be used accordingly, in industrial applications. Another approach, in order to implement this concept, is to add product state data structures to existing product modelling systems.

Some of the other results of the Qualiglobe project are immediately ready for manufacturing applications. The Data Acquisition System (DAS) is today a commercially available product; Robotiker (Spain) as well as Migatronic (Denmark) have improved their Power Source (PS) products with an open communication interface developed in the project.

Yet some modules, e.g. the Quality Monitoring (QM) and Online Process Control (OPC) developed by ISF (Germany) are examples of industrially applicable systems that improve the current level of process control and monitoring.

Finally, the quality monitoring and process control applications at Fincantieri (Italy) and Odense Steel Shipyard (Denmark) have adopted some of the results.

7.2 Benefits

The experiences and benefits gained from the QualiGlobe project are:

- experience on how to implement a Product State Model, which can be used in future development initiatives
- several vision and laser measurement technologies developed and adapted for shipyard applications
- improved process planning for robot welding applications, resulting in better quality

- improved online process control for robot welding applications, resulting in better quality
- an enhanced welding power source technology for integrated control and monitoring applications
- a data acquisition system, ready to use, for robot welding applications
- a quality monitoring application that is able to detect some types of welding errors
- a quality assurance report generator based on production data collection
- a support application for production scheduling using information from quality monitoring

The Product State Model approach, and related technologies, as described in this paper has been developed in order to reduce the direct and indirect cost of lack of quality in manufacturing processes. In terms of benefits provided by this new concept, it is relevant to mention the increased focus on quality, not only as a measure of output from processes and awareness among employees – but also the consequence of quality as an input to subsequent processes. Thus adapting all processes to the real conditions is making sure that the correct process is being applied – as opposed to a robust process that will work, though this is not without undesired side effects such as unnecessarily high heat input.

Another benefit is in terms of logistics. By preplanning processes based on measured part data, the processing time is calculated more precisely. Thereby, production schedules can be made more precise and are likely to be observed. Finally, the QualiGlobe project is providing applications for improved process control and automated documentation of quality.

8. Conclusions and Perspectives

The paper provides a review of product modelling approaches as well as empirical insight from the efforts on reducing the accumulated manufacturing errors based on enriched product information. Hence, the article contributes to the design structure for a PSM environment identifying the interacting modules as a basis for information sharing in the shipbuilding industry.

This paper has presented a new manufacturing concept based on a Product State Model. An architecture for the PSM Environment is suggested determining a set of relevant application modules and their relation. In theory, this concept leads to shorter lead-time, improved product quality and reduced production costs in shipbuilding and similar production environments.

The QualiGlobe project has validated central elements of this new concept by developing and testing prototypes. In addition, several technologies that are improving current monitoring and control of welding processes have been developed.

In perspective, standardisation and digitalisation of information is of increasing interest as Odense Steel Shipyard, Ltd. is in the middle of outsourcing part production activities, primarily to the Baltic region.

The Product State Model opens new possibilities for e.g. process planning. In fact several systems involved in industrial process planning, control and quality monitoring applications need to operate in a new way when adopting the Product State Model (PSM) approach. Therefore the QualiGlobe project has developed new applications for process planning, control and monitoring.

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