AUTOMATION OF OIL RIG FABRICATION

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SUMMARY

Despite worldwide financial crisis, a significant amount of oil rig fabrication work continues to prosper due to the huge order book backlog. Whilst some projects have been cancelled or delayed because of financing, the on-going projects are now under bigger pressure to save time and cost of fabrication. The obvious way to control cost is better project management, leading to cost efficient utilisation of material and manpower. In order to do so, management requires timely knowledge of all aspects of project execution in order to effectively manage workflow and material. More yards are relying on modern Computer Aided Design/Manufacturing, and Integrated Manufacturing (CAD/CAM/CIM) systems to achieve better cost savings.

Recent years of offshore engineering boom have taken advantage of the sophistication of engineering 3D models in projects large and small. This paper reviews the revolution in the use of 3D product model and its associated databases and how the amalgamation of CAD/CAM/CIM techniques has helped us to manage complex vessel from design to fabrication. It also reviews the applications of database driven CAD/CAM systems which are used to build three different designs of jackup rigs and production vessels. Experience of series production shows that by linking 3D models to databases, modern production systems not only manage many heavy piece parts from 3D models, but can also accommodate repetitive and last minute design revisions usually due to owner and classification society changes.

Complex multi-national and multi-fabrication-sites oil rig projects also exacerbate the need to enhance communication via the same 3D engineering model amongst designers, suppliers, and shipbuilders across continents. The many facets of demanding requirements in such large and sophisticated projects also drive the development of Product Life-cycle Management(PLM) so that every part originating in an engineering design will come with complete production and maintenance data. Our experience is that production systems employing open database to drive CAD/CAM is very efficient for factories to harness the capabilities of PLM and Enterprise Resource Planning(ERP) systems already operating in other industries.

NOMENCLATURE

CAD/CAM - Computer Aided Design/Manufacturing
CAE - Computer Aided Engineering
CIM - Computer Integrated Manufacturing
CNC - Computer Numerical Control
ERP - Enterprise Resource Planning
MRPII - Manufacturing Resource Planning
PLM - Product Life-cycle Management
VR - virtual reality

1. INTRODUCTION

Record high oil prices in recent years have contributed much to the investment in oil rigs and production platforms. In line with the number of new oil rigs and platforms being built, production technology in this industry has seen relatively higher level of investment. Many shipyards new to oil rig building are leveraging on technology to ensure success in the high risk business of oil rig fabrication where penalties are measured in terms of day rates to lease the drilling rig. The recent worldwide recession also leads to many established oil rig builders embarking on more cost-effective production techniques in order to reduce cost and remain competitive in the new world markets.

Most oil rigs are based on proven designs and are usually developed by a handful of well established designers and shipyards. The high cost of construction and the penalty of delayed entry into service forbid almost any venture into unproven designs or contracts with new yard. However, the oil rig boom in recent years has created such a big capacity shortage that many existing yards with financial muscle are entering into the jackup and rig building market. In order to mitigate the high risk involved in rig construction and delivery, these yards tend to leverage on new technology to manage the projects. This in turn puts pressure on established oil rig builders to improve productivity and technology in order not to be “leap-frogged” by new competition.

This author has been inspired by the works of McIntosh [1] in our early days of shipbuilding CAD/CAM development on personal computers(PC). Over the years, the software development for production engineering has moved from simple drafting techniques to complete simulation of fabrication processes. A couple of early projects were focused around scenario planning for oil rig fabrication processes and led to workforce training accordingly. However, the power of PC based workstations has proven to be insufficient to provide comprehensive fabrication process planning. Our recent projects focus on streamlining the engineering to production processes via automation of the creation of production drawings essential to a smooth fabrication in the field. Tremendous cost saving result from the ability to rely on PC software to automatically issue production drawings once a thorough check of the engineering 3D model of the oil rig has been made. Subsequent drawing revisions are also automatically issued via the amended 3D oil rig model in the PC.

To contain cost of development, we have made full use of proven shipbuilding technology and production and management systems from other industries. However, one must bear in mind that rig and platform building is a form of high end marine business. It is therefore important to differentiate the many common philosophies, methodologies and tools in the industry. To simplify the subject for this technical paper, we shall only examine key elements of engineering management systems, including the technology selection and adoption. Nevertheless, one shall always remind oneself that all these concepts and terminologies are just there to ensure a smooth flow of material, data and resources in the process of design and construction of a vessel to the best quality possible.

2. FABRICATION & PROCESS SIMULATION

2.1 PRODUCT LIFE CYCLE MANAGEMENT

The biggest challenge facing shipbuilders venturing into oil rig construction is to connect people and information together, not just technologies. In order to do so, it is sometimes necessary to get back to the basics (refer McIntosh [1]) to understand the real business issues which really help the marine industry to grow. It has been said that some technologies have been "distressed purchases" in the industry only when companies concerned have begun to encounter combinations of documentation, management and resource problems.

To simplify the complex processes of building oil rigs, one has to create a typical life cycle of a oil rig from design to maiden voyage. The key issue is that the client wants an efficient product designed and engineered to the highest standard and built to the best quality in a planned timescale. However, one should note that any simplified diagram does not even cover all the necessary interaction between designers, class societies, owner, operator, etc.

The objective of whatever computer based management systems we put together is simply to ensure all documentation of the product are made timely and accurately to help to produce the vessel. This is actually a very challenging objective as the volume of data is immense in rig building. In fact, the aerospace industry started computer based management tools when it realised the weight of documentation was catching up with the product. In the same way, we will see increasing use of computer managed databases for current and future rig construction.

2.2 SIMULATION OF ENGINEERING MANAGEMENT SYSTEMS

During the design and construction stages of oil rigs, engineering plays a big part towards timely delivery. Due to ever-changing environmental and operational demands of drilling deeper for oil, both owners and operators are usually amending and upgrading specifications as fabrication takes place. All these late changes in terms of data and drawings have to be managed efficiently and implemented swiftly in order not to impede the usually tight delivery time-scale. The presence of good management and proximity of a strong engineering team to implement late changes to original basic design hold the key to successful delivery.

Key elements of a good data management system are well known and can be listed below although not all the elements can be achieved in practice (refer Gomez [2]). Since most management systems evolve with available technology, the adoption of any system at any point in time fixes the methodology of how the elements of a system are handled. Many legacy systems in place today have to live with established rules and practices which are no longer efficient towards integration of resources in an entire organisation. For brevity, we shall only focus on the key elements which have demonstrated positive influences in new methodologies and in practice.

- A database with a management system
- A database structure with relationship and historical (change control) information
- Authority hierarchy and Access Control
- Change control and management
- Configuration management
- Project management including scheduling information and MRPII
- Automated data search facilities
- Enable safe and easy data sharing across systems

Based on the above, some of the early work (refer Lee [3]) made use of procurement and engineering databases to drive fabrication simulation. The methodology then was to create 3D visualisation of key shipyard facilities and relate these to the production processes whilst taking into account manpower and other key resources. The objectives were to flush out critical path issues in the complete procurement, engineering and fabrication processes of the ship or oil rig project as would occur in the yard. As depicted in figure 1, typical key production scenarios are tested via a 3D model of a virtual reality (VR) shipyard. The results expected of such VR trials are mainly to smooth the flow of production via:-

- Identification of critical path issues
- Synchronisation of resources and facilities
- simplify fabrication and enhance cost control
- maximise use of yard plants and facilities
- work force training via fabrication simulation
- improved safety and reduce downtime

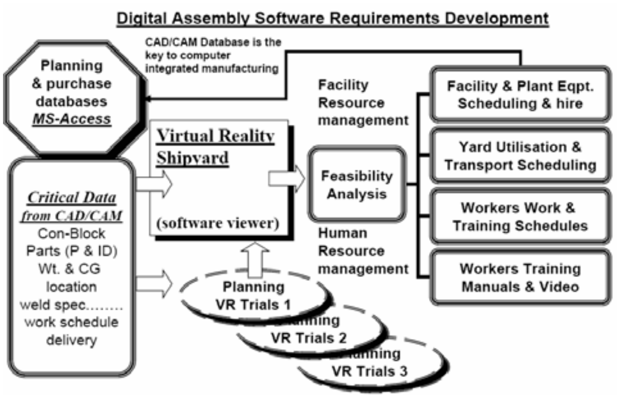

Figure 1: Database driven fabrication processes

3. PLM DATABASES & MANAGEMENT

Early versions of computer based rig product models define geometry and similar aspects of design, but leaves the management of and production from the design via hardcopy drawings. Modern approaches enhance the flexibility of CAD system by linking it to databases to improve productivity, quality, reliability and maintainability. However, the way databases are linked to three dimensional(3D) ship models differs widely and in some cases can lead to a rather inflexible system. This is a more obvious problem in legacy systems where all the materials and parts attributes are stored in the same file as the geometry design of the parts concerned. As management information technology matures, these legacy systems can end up storing far too much data in the drawing files to the extent that it makes the operating system clumsy. In the worst case, these legacy systems would demand more expensive hardware and systems to cope with the bulk of data which need to be handled.

The subject of modern product model has been addressed by Oetter et.al[4] as reproduced in Figure 2, so only key points relating to managing databases will be discussed further here. As shown, a modern product model is now a database or set of linked databases that defines the rig to the extent desired by the users and developers of the model. Although the 3D model may be created by the design and engineering teams, both the geometry and associated material data are critical to other functions in the shipyard. Without some form of direct data links between the many departments in a shipyard, material flow and production resources cannot be organised in a smooth and timely process. To make things worse, offshore rig projects are getting more complex and challenging that design changes initiated by Owners, Operators and Classification Societies must also be addressed quickly. Clearly, the days of relying on printed paper drawings being approved are numbered but it remains to be seen what configuration the ideal data management systems would take to take advantage of modern computer systems.

4. PLM DATABASE MANAGEMENT IN SHIP AND RIG BUILDING

In building oil rigs, the high cost and quality requirements of oil rigs and the need to minimise down-time fostered the development of three dimensional models. The piece parts resulting from these models are immense and so are the routine but tedious processes of extracting information for automated tools to build the model. In order to automate all these processes, it became necessary to extract data from the model in various formats and to link data both to databases from the model. Every step in technology development have brought us back in a circle to a true, 3D model, though now in full scale virtual reality in the computer system. The model also has substantial non-graphical, or non-geometric information either internal to the CAD file or dynamically linked to it.

Oetter et.al [4] highlighted the need to understand the significance of a true 3D model linking to databases as against a big 3D model file containing much data as in legacy systems. Though a 3D product model may provide more or less conventional drawings, the drawings are views of the model, (usually automatically derived) and hence they are not themselves the 3D Model. Such models can no longer be a single massive file, but a series of linked CAD and data files. As long as they are set up so that each component is uniquely defined once and once only, and that it is possible to interrogate and view any component or combination of components through their linkage, the essential advantages of a 3D product model are obtained.

In practice, we have observed that modern projects generally involve many organisations each are specialists in their field of work. The 3D model now has to link to other 3D models as well as databases which are so specialised that it can no longer be assimilated by additional parameters and fields created within one 3D model or its associated database.

5. CASE STUDIES

5.1 DEVILS' TOWER SPAR – MCDERMOTT

Five years after its deployment in the Gulf of Mexico, the fabrication of the Dominion Devils Tower spar at the J. Ray McDermott Batam shipyard in Indonesia remains the most technologically challenging project in Asia (for more details, refer Lee [5]). The spar is a huge structure designed for deployment in some 5,600 feet deep water to support oil production. The lower structure consists of a framework of pipes and plates weighing some 12,000 tons and almost 650 feet in length (refer figure 3).

Building a spar at Batam Island of Indonesia was a new venture which immediately posed new problems in production, logistics and planning in general. The island is remote and most of the material, machinery and human resources have to be supplied via Singapore which is the closest city but not the same sovereign state. To accomplish the bulk of the project within an 18 month time frame, many computer planning and visualisation tools were developed and utilised in order to move the rig material and human resources to the island at the right time for the rig fabrication process.

Great efforts were involved in the linking of database information across the world to co-ordinate the design and engineering of the spar from the start. The 3D product model was created in ShipConstructor which stores the source drawings of all Geometry in AutoCAD format and keeping all the material information in standard Microsoft SQL database format. Such an open material database offered the opportunities for other computer based management systems to pick up key material data and schedule events to resource availabilities. Figure 5 is a composite picture showing in a clockwise manner the way the project was driven. Project planning via Primavera software schedules design and production whilst complete 3D modelling via ShipConstructor simulates all the critical events in the fabrication processes.

Having the standard 3D model built in ShipConstructor had another advantage as all the AutoCAD based drawings were readily used for virtual reality events programming to simulate the construction processes. The fabrication simulation was intensive in this project due to the tight timescale and the relatively new venture of Batam yard into building deep water spar. Advanced virtual reality simulation of key fabrication activities in the shipyard were necessary to highlight the critical path issues as well as to plan resources and train new workers.

Although the project went short of linking all the open databases fully automatically in tracking events, the manual linking of project events in planning the fabrication processes were a major feat in harnessing the benefits of open databases across many disciplines

5.2 CJ-46 JACKUP – LABROY OFFSHORE

The first time ShipConstructor system was applied on a complex drilling rig with the implementation of full CAD/CAM at a brand new rig building yard facility. In 2006, contracts were signed between Standard Drilling, a drilling contractor from Norway, and Labroy Offshore Ltd for the delivery of four jack-ups. The basic design package makes use of GustoMSC CJ-46 systems for leg fixation, leg jacking and cantilever x-y skidding system for the jack-up.

The project was a significant technology challenge in that Labroy Offshore makes use of a brand new offshore yard in Batam, Indonesia specially set up to build the first series of oil rigs by Labroy, a company hitherto more known for shipbuilding activities in tugs and offshore supply vessels. In 2007, the company was purchased by Drydocks World and is now called Drydocks World – Graha but this paper shall refer to the old names as CAD/CAM implementation was complete before corporate merger and acquisition took place.

The design and development teams involve staff from China, Holland, Indonesia, Norway, Thailand and also Singapore, where Labroy is a public listed company. The basic design package from GustoMSC consists of basic construction plans and system diagrams for the major drilling and marine systems. The detailed CAD/CAM work is managed from Singapore and fabrication will take place in Labroy Batam yard.

Although it did not realise the full CIM capacity that this paper promotes, many complex modules have been designed and fabrication complete at Batam yard. The 3D model geometry from the ShipConstructor database is being shared across different disciplines on the shop floor in order to facilitate module fabrication. Figure 4 is a composite picture showing the process of detailed design, 3D model for CAD/CAM production details and the final launch of the jackup, the picture also depicts the way CAD/CAM is helping the different teams to interface and construct the oil rig smoothly

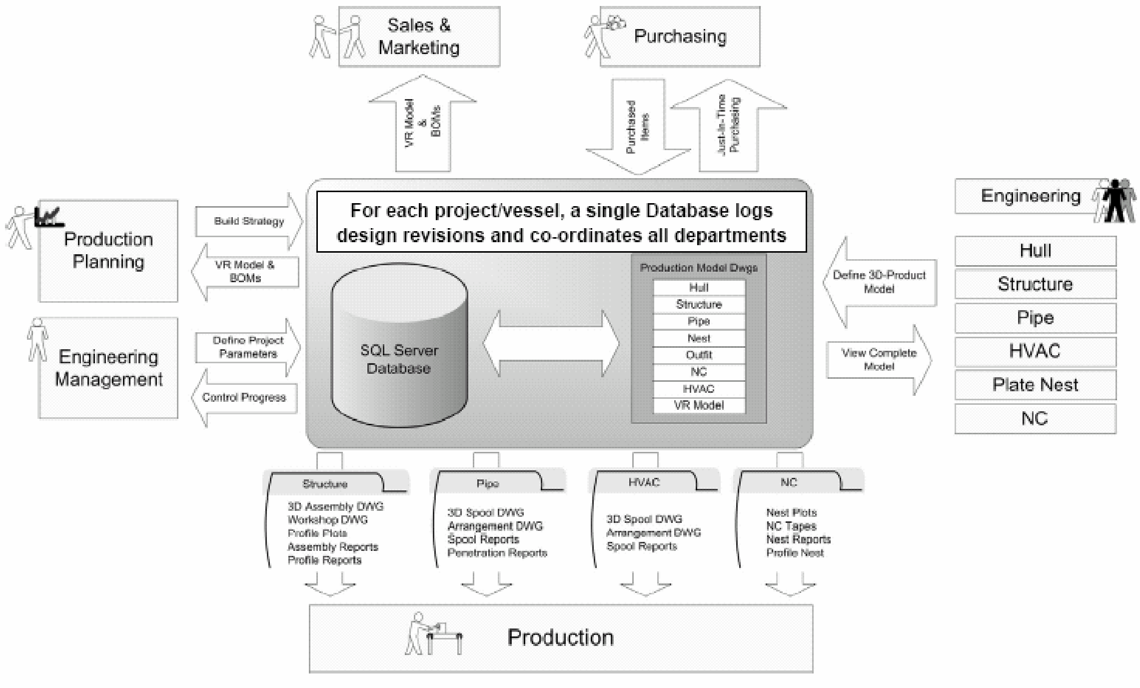

Figure 2: Idealised and Simplified rig construction life cycle processes

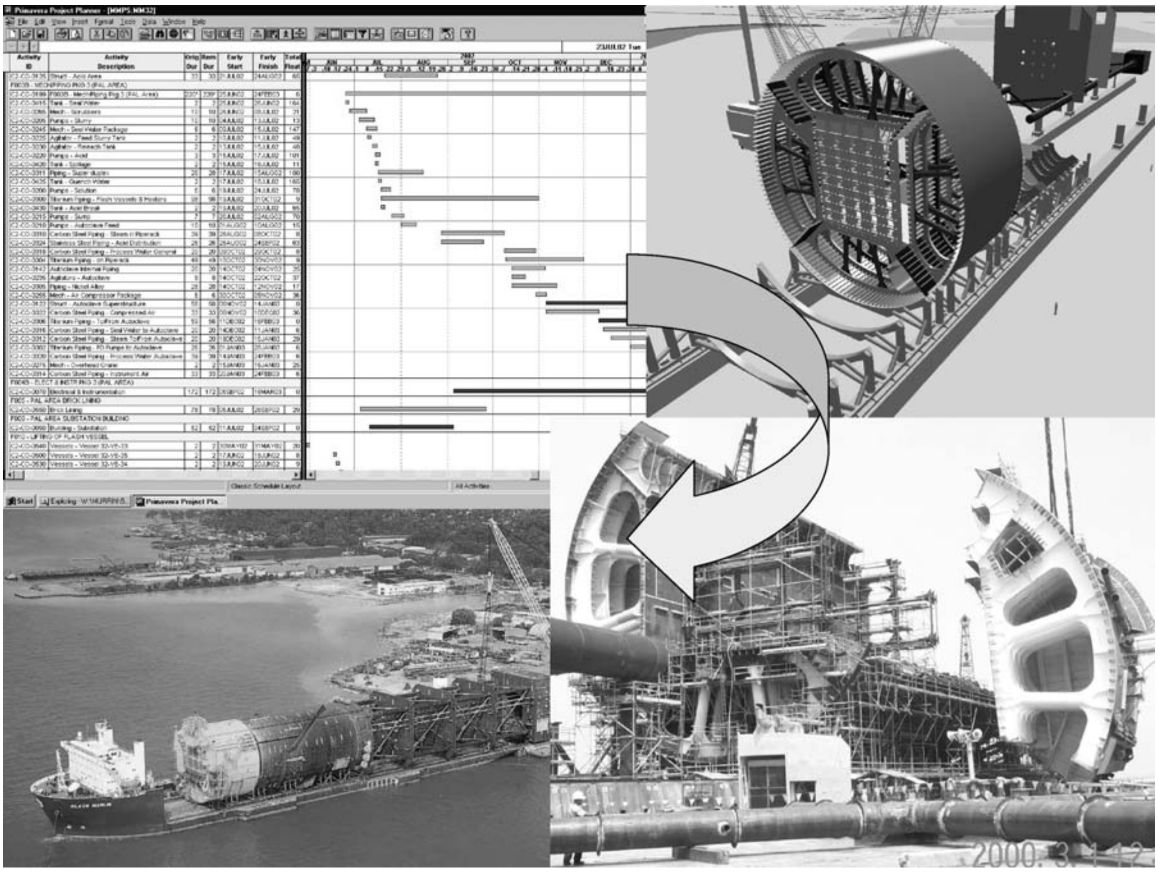

Figure 3: Composite picture showing project planning, 3D-design, fabrication to delivery processes largely driven by databases (pictures and design courtesy of J.Ray McDermott Far East)

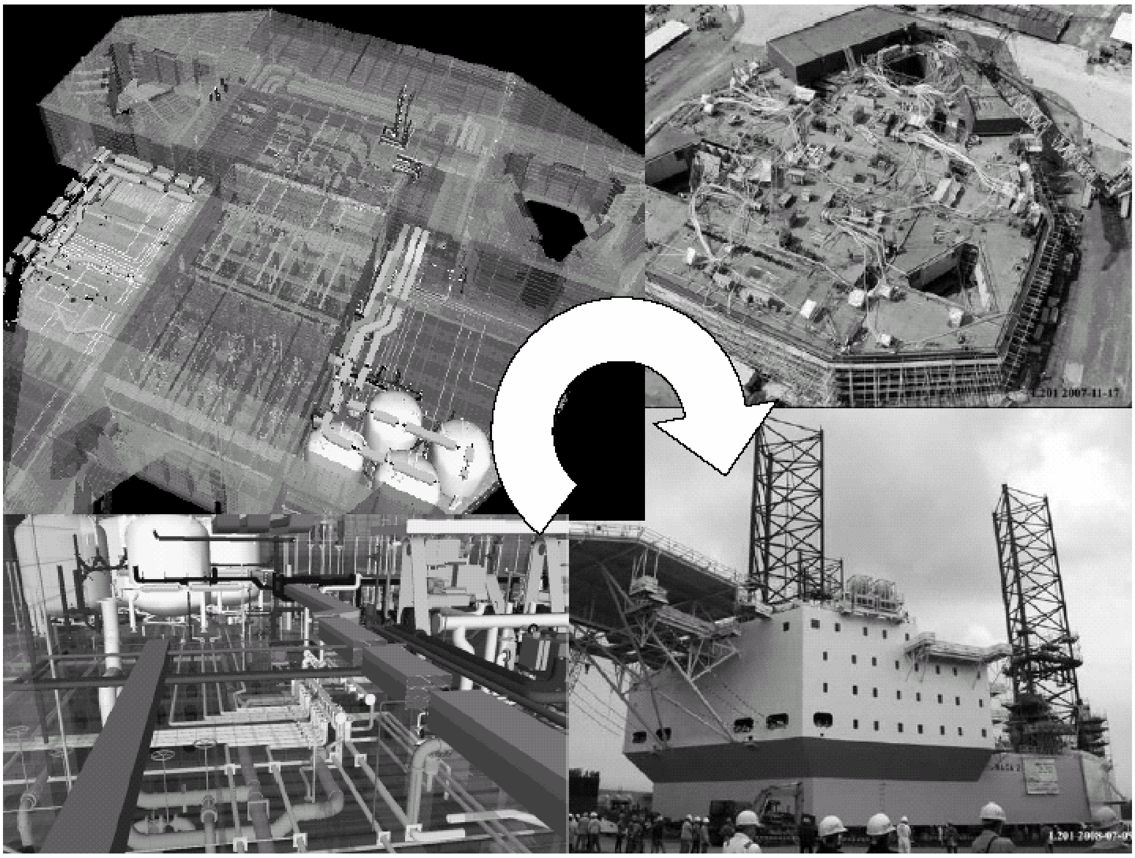

Figure 4: Composite picture showing product development life cycle of jackup fabrication from ShipConstructor 3D CAD/CAM model through yard construction to final launch ceremony (courtesy of Labroy Offshore, Singapore)

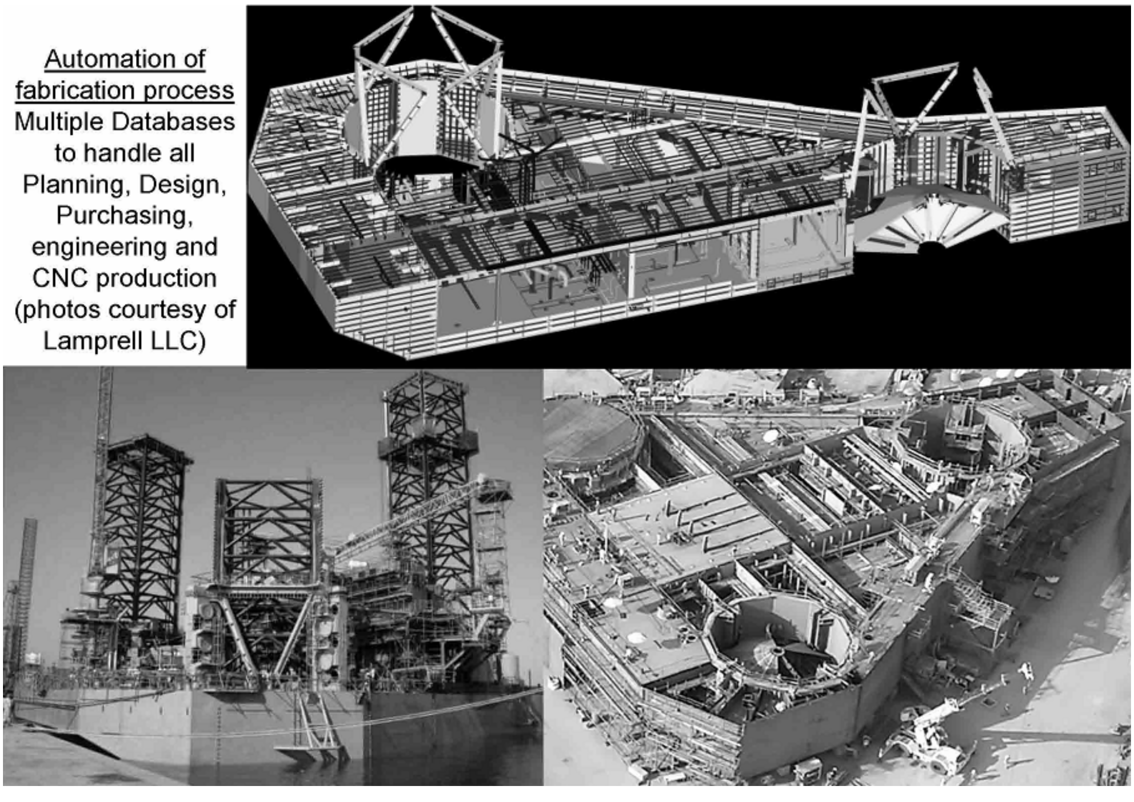

Figure 5: Screen capture of ShipConstructor 3D Model of half of jackup for CAD/CAM and fabrication details with photos of the rig during fabrication and loading out (photos courtesy of Lamprell, UAE)

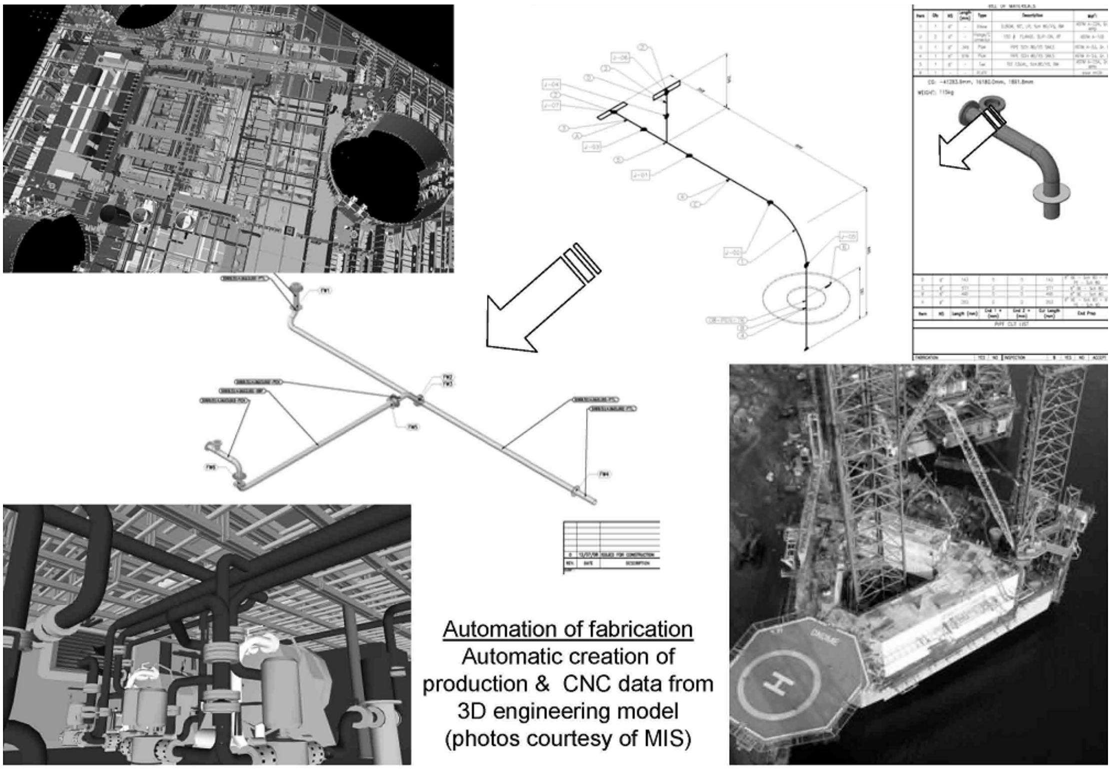

Figure 6: Composite picture showing delivery processes of 3D detailed design, ShipConstructor 3D-model for production and final fabrication of oil rig in water (pictures and design courtesy of MIS, UAE)

5.3 LT-116E JACKUP – LAMPRELL

Lamprell Energy Ltd planned the implementation of the ShipConstructor 3D software to enhance their engineering capabilities when they decided to add new rig building to their existing rig repair business (refer Lee [6] for more details). The first rigs have been ordered by Scorpion Offshore and are of the LeTourneau Super 116E design. The Lamprell staff being very experienced with the engineering required for repair of Jackup rigs, found the implementation of the new 3D software to be fairly easy and very useful from planning the production logistics of jack-up fabrication right from the outset.

The project is a significant technology challenge for Lamprell to implement the new engineering software at the same time as the setting up a new rig building yard in Hamriyah about 20 km from their existing yard in Sharjah. The yard being in a new Free Zone area where facilities are not fully built, the setting up of new buildings, communication and logistics with the main yard also proved challenging for the operations.

The design and development teams comprising of staff from Asia, Europe, and Australia and with the client from USA made communications interesting. The design package from LeTourneau consisted not only of basic construction plans and system diagrams, but also construction details and experience from previously built rigs. This helped in shortening the learning curve considerably and this facilitated the setting up new building facility and the detailed CAD/CAM software of the first Jackup in a record schedule. Figure 5 is a composite picture showing half of the 3D product model and the rig being fabricated and loaded out into water. The Jackup rig was launched within 13 months from initiation of training for the implementation of the 3D CAD/CAM software so it is quite an impressive record in engineering. At the time of planning this paper, Lamprell delivered the first rig within 18 months of project start and is well on its way to produce the second and third jackup rigs and we expect complete CIM techniques to be applied at yard level for later projects once the pressure of building the first rig is over.

5.4 F&G SUPER-M-2 JACKUP – MIS

Two jackup projects were underway in Maritime Industrial Services Co. Ltd. Inc., (MIS) in Sharjah, UAE in 2007 when management planned upgrades to full CAD/CAM/CIM. The first two Mosvold ordered jackup’s are of Friede & Goldman (F&G) Super M2 design and MIS anticipates series production opportunities. It is a bonus for system integrators to learn from the difficulties encountered in the construction of first two rigs whilst planning the implementation of the full CAD/CAM/CIM system.

As a result of learning from existing projects, the implementation of CAD/CAM/CIM can be streamlined accordingly to the work flow of the fabrication yard. A very cost-effective methodology is used in the design of build strategy so that the logistics of design and production are all taken care of at the outset. By customising the build strategy, all parts on the shop-floor have full traceability back to the basic system drawings provided by the F&G designers. Almost all production drawings are driven directly by the build strategy so that fabrication methods are planned even before the parts are cut or assembled in workshops. Figure 6 is a composite picture depicting the way CAD/CAM is helping the different teams to interface and construct the oil rig smoothly.

Currently, all production drawings for all stages of design, nesting, CNC, assembly and erection of new rigs come automatically from the ShipConstructor 3D model (refer Lee [7] for more details). Minimum manual drafting is required by designers and engineers once the final 3D model is checked to be good for final design approval with automatic interference checks for all parts. This arrangement reduces workload and ensures quality production and operation as human errors are less likely to occur when no repeated drafting takes place. It is predicted that the implementation of ShipConstructor system at MIS represent the most efficient use of full CAD/CAM/CIM once the database can be shared further by management information systems and ERP databases.

6. CONCLUSIONS

In 2008, more than 20 offshore oil rigs have been delivered by Singapore yards alone due to the immense oil field activities driven by higher oil prices. Despite the current financial crisis which threatens to cripple world economy, oil prices remain relatively high due to the continual tight supply situations. As more oil exploration and production go into ever deeper waters everywhere in the world, we can expect many more large offshore projects involving owners, operators, designers, engineers and shipyards collaborating via computer based 3D product models with more databases. Opening up a common project database for linking into all other specialists' design and management tools is the obvious option for a better quality product via a well co-ordinated production process.

The efficient utilisation and linking of information and engineering databases for oil rig construction will gather momentum as more and more technologically challenging projects have to be co-ordinated across the world. In fact, established oil rig builders have to regularly review technology application in order to take advantage of the latest automation techniques. Initially, the complete change of CAD/CAM and PLM tools may be painful. However, the long term benefits of linking open databases will smoothen data and material flow in project management. The benefits of a project with full automation will certainly outweigh the continual struggle with bulky data being forced into the storage of existing drawings in older systems.

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