OIL SANDS CONSTRUCTION AUTOMATION UTILIZING 3-D SOLID MODELING AND ANIMATION

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ABSTRACT

An estimated 1.7 to 2.5 trillion barrels of oil are trapped in a complex mixture of sand, water and clay (News-2). The Alberta oil sands comprise of 8-13% bitumen, 80-85% mineral matter, including sands and clay, and around 4-6% water. Fine tailings are a byproduct of the oil sands extraction process. This paper will show the methodology of using advanced CAD (computer aided design) software for successfully implementing design equipment techniques. Using CAD is a well-established practice, but sequences and real life scenarios are creating challenging situations that, for some, are hard to overcome The University of Alberta's Oil Sands Tailings Research Facility (OSTRF) was designed and built to help the industry develop innovative approaches for oil sands tailings treatment. Creating digital mockups of all existing facility and research equipment created a new level of understanding construction to many companies and their personnel. Through design and construction procurement, construction and/or design business develop innovative practices that modify and control project tasks. The presented challenge shows that this standard fashion of design can benefit all parties involved from owner, designer to fabricator. The project was done on time, met the budget to specific process requirements and obtained customer satisfaction. It was proven that digitally mastered equipments can promote a mistake free maintenance environment during production or research. A case study presented in this paper illustrates effectiveness of proposed methodology.

KEY WORDS

oil sands, tailings, 3-D solids, space optimization, design, simulation.

INTRODUCTION

Transforming the ideas, which owners or designers have, into drawings is not simple task, especially when many mechanical components are involved. These ideas usually starts with isometric sketch on paper and moved to different views and layouts (plan, elevation, sections). This process though proves to be effective remains on paper and often not recorded. Current development of computer technology makes this intellectual property transparent and useful information remains in the digital configuration in the repository

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context. Three dimensional (3D) applications have proven records of success in assisting the construction industry, providing useful information for construction fields. Some are used to analyze and test tower cranes (Al-Hussein. at al. 2005) and for building construction using tilt-up-panel method (Manrique J. at al. 2005). Visualization of the proposed design can also be of substantial help in the analysis and communication; decision makers can not base their decisions on proposed idea unless they fully understand those results. Dynamic graphical depictions, which are able to show the proposed design in the same way as the final product would be in the real world, give users a better understanding of the simulation results, and the operations as well. In addition the current limited paper-based process does not provide sufficient insight into the requirements and/or limitations of the working space; this information is usually crucial for construction operations. In addition, visualization can provide valuable insight into the subtleties of the modeled construction operations, and can thus be helpful in establishing the credibility of the proposed design (Al-Hussein et, al, 2005). For the past two decades, simulated construction operations have been visualized in several levels of detail and realism (Kamat et, al, 2001). Schematic models and iconic animation on schematic models (Zhang et, al, 2002) have been widely used to improve the conceptual understanding of modeled systems, but they do not provide much detail and do not reflect the workspace requirements and/or limitations of the modeled operations. 2D visualization systems illustrate the progression of simulated operations by continually describing the movements of resource elements on 2D layouts (Kamat et, al, 2002; Kamat, et, al, 2004). 3D visualization has already been extensively utilized in crane planning to experiment with the operation process and check for physical interference or clearance problems to avoid costly errors. These efforts include, but are not limited to, developing a visualized environment for heavy lifts planning (Varghese, et, al, 1997).

This paper presents a practical approach to the use of 3D visualization of complex design operations through the development of a visualization tool, which was developed in the 3D Catia environment. Catia as 3D solid modeling software, developed by Dassault Systemes, proved to be effective tool in design and modeling of construction operation. (Olearczyk J. Al-Hussein M. 2006), (Przybylski S. 2004), (Meczam M. 2005). The design of the University of Alberta new off-campus Oil Sands Tailings Research Facility (OSTRF) in Edmonton, Alberta, Canada, is used as a generic case study to illustrate the validity and essential features of the proposed methodology.

BACKGROUND AND INTRODUCTION TO DESIGN CHALLENGE

Conventional crude oil is either pumped from the ground or flows naturally. However, oil sands can not be extracted from reservoirs by means of conventional oil wells and pumps. Currently, oil extraction from oil sands is performed mainly by two methods: In-situ, which is used for bitumen deposits buried too deep (more than 70m); and transporting by trucks, which is used for deposits located near the surface. Fine tailings are a byproduct of the oil sands extraction process (Cymerman G., 2003). After bitumen is extracted from the oil sands with hot water, the leftover mixture of water, sand, silt and fine clay particles is pumped to the settling basin (web-1). The fast-settling sand particles are used to construct mounds, dikes and other stable deposits. The leftover muddy liquid, consisting of slow-settling clay particles and water, are the fine tailings.

What makes tailings management so difficult is the amount of time it takes for fine tailings to settle. After a few years they reach the consistency of runny toothpaste, but it takes a few centuries for them to reach the consistency of soft clay. The other challenge is the volume of fine tailings to manage; by 2025 some companies will have produced an estimated one billion cubic meters of fine tailings (web-1). Environmental concerns about fine tailings focus on the sheer volume involved and their fluid nature. To address these concerns, the industry is working in collaboration with government and university scientists to either incorporate fine tailings into stable, coarse sand deposits or solidify them by squeezing out more water. The aim is to develop a number of options that companies can use to reduce the accumulation of fine tailings. There are two known methods used for treatment of tailings (web-1). 1) **COMPOSITE TAILINGS** - In this technique, gypsum and dense fine tailings from the settling basin are added to the fresh tailings slurry. This causes the clays to aggregate and the slurry viscosity to increase. Upon deposition, natural segregation processes are reversed and the fine solids, coarse solids and water stay together to form a deposit, very much like thick soup, and require containment. Clean water quickly seeps to the surface and runs off. With the release of water, the deposit becomes denser, until eventually a solid material is formed and the containment structures become redundant. The released water is recycled wherever possible. In regards to site restoration, this technique will leave either a wetlands, grasslands or treed topography. 2) **PASTE TECHNOLOGY -** Paste technology rapidly dewaters the fine tailings stream to produce a paste-like material which is still pumpable. The technique requires synthetic flocculants to achieve rapid settling of dense fine solids aggregates, a deep bed thickener to promote self weight consolidation in the settled solids and dewatering channels to relieve the excess pore pressures, hence forming the paste. Upon discharging, the paste deposit forms a slope and gains strength. The thickener overflow is recycled to the plant. This technique is relatively new and has been applied successfully in other industries, such as dewatering red muds produced in the aluminum industry. Research is underway to determine the parameters for its application in the oil sands. The paste would be incorporated within the coarse tailings deposits. The University of Alberta established an off-campus Oil Sands Tailings Research Facility (OSTRF) to develop innovative approaches for oil sands tailings treatment, to attract world-class students and researches, and to train highly qualified scientists, engineers and technicians. OSTRF was designed and built to help the industry to develop innovative approaches for oil sands tailings treatment. It is located at the Devon Research Facility, which is shared by the Alberta Research Council and the federal government's CANMET Energy Technology Center (News-1). Existing space was adopted from the Coal Research Facility, which was built over two decades ago. Figure 1 shows the Devon Facility's structure to illustrate the limited space under its mezzanine. The design started from modeling the facility and the proposed equipment. It allowed the team members to efficiently set-up the preliminary layout. Visualization and real-time modification of sizes and shapes made this important task clear to all participants. During the design stage, when all aspects of volumes and sizes for the equipment were clarified, team members closely monitored the safety requirements for the whole process. The mezzanines were originally designed to carry heavy loads. Its clearance above the main floor is only 3.05 m (10 ft), which for most of the proposed equipment wasn't sufficient. Main columns in the layout are at the perimeter of the suggested area, but secondary support beams are located in the middle of the facility.

Figure 1. Existing facility structure

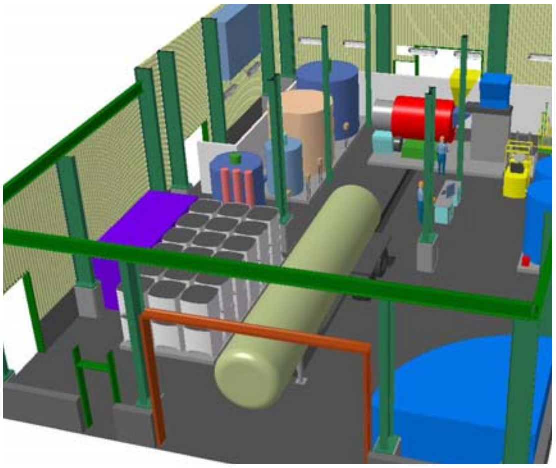


Figure 2. Model facility

Due to the space constraints and the amount of equipment needing to be located, the U of A Design Committee decided to make a physical model of the facility and the equipment. Modeling all the components allowed the group to create several preliminary layouts for a better understanding of the situation. An engineering company, which uses CATIA (3D CAD software), was chosen to model the existing facility. Walls, beams, columns and the floor were modeled in 3D (Figure 2). Limited information about the space of the building was available through drawings, so physical measurements had to be taken. When the facility was modeled in the system, the next step was to locate the proposed equipment (as rough block models) in the available space. At this stage, the Design Committee members were able to quickly visualize and understand the future laboratory settings and decide how to proceed with the development. Many modifications were introduced to satisfy all interested parties and owners of the building. The aim was to avoid costly modification to the existing structure. The owners raised safety concerns, and as a result, a safety corridor connecting different parts of the facility was incorporated. Committee members though were skeptical about using 3D modeling in its initial stage, witnessed the benefits of the technology, particularly the ease of instant modification. Different arrangements and sizes of the equipment were tested. This phase and the proposed visualization method were inexpensive and brought tangible results. All stake holders were convinced and the proposed methodology was successfully implemented (Olearczyk J., 2000).

PROPOSED METHODOLOGY

A pilot project can be described as a set of blocks representing steps in an operation and its processes. Figure 3 shows the proposed methodology’s main process. The Input parameters include information, which is necessary to develop new equipment, and assisting components such as standards, regulations and specifications which the designer has to follow and base all criteria for the project.

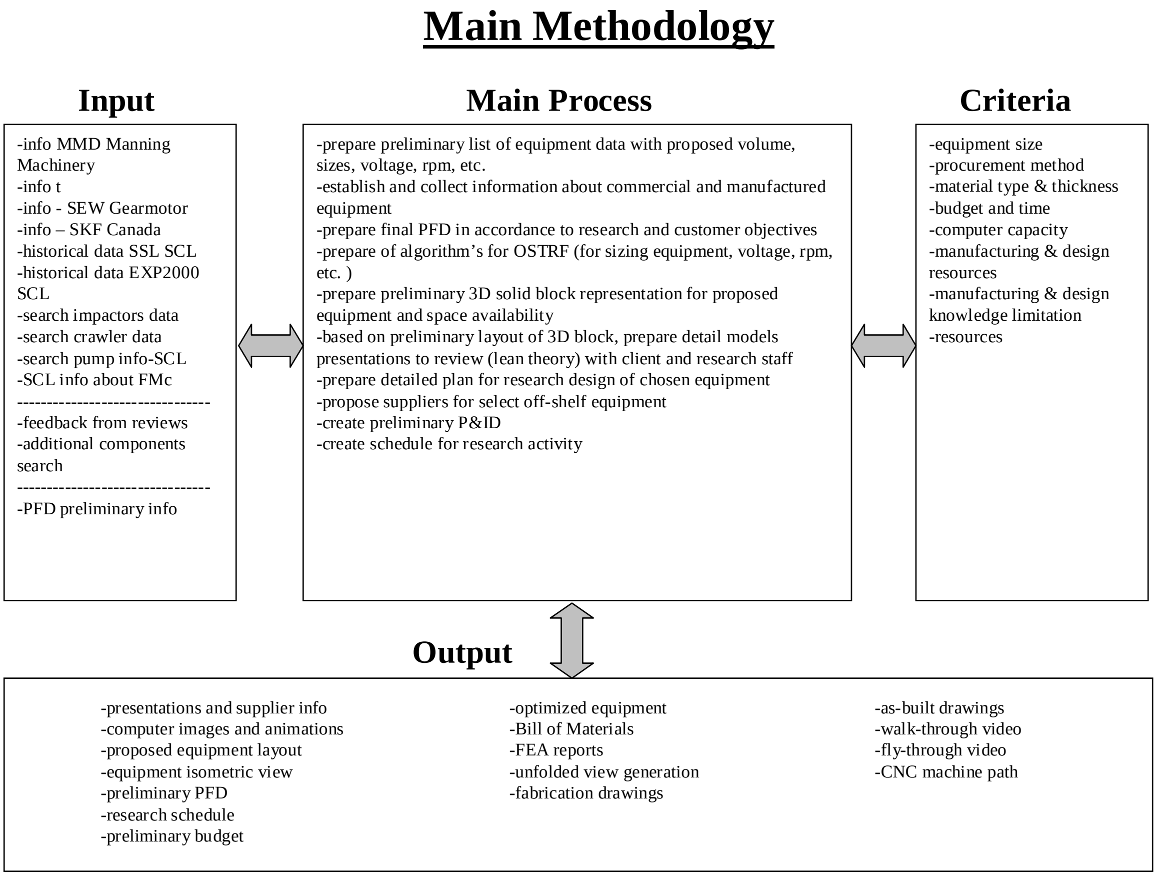
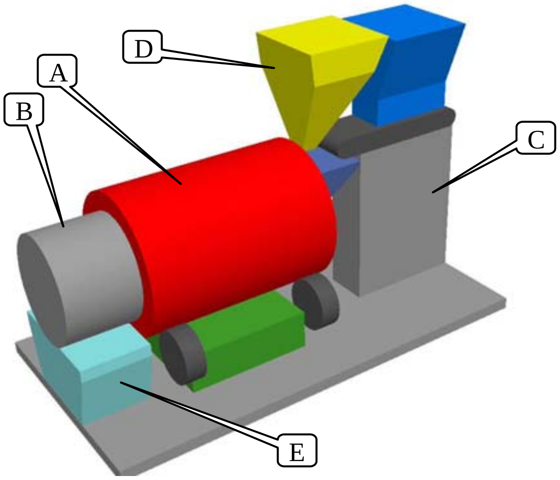


Figure 3. Main methodology process

Other information such as the location, availability of space and constraints are also crucial data to be considered. In addition, supplier's equipment data are important and must be included. The Main Process represents activities that are performed directly to create specific parts, subassemblies and assemblies of the proposed equipment. Based on all input information, future machineries are virtually present in the system. These virtual models can be modified, analyzed, simulated and stored for collaboration between all interested parties. The main process tasks are time consuming, but if equipment is precisely designed and tested at this stage, they can be used in different variations for many other purposes. The Output section includes all the data that could be extracted from the solid models and used for physical equipment creation (fabrication drawings). This main purpose of the project scope follows other information, which in some cases could be even more important than the actual drawings. Detailed analysis of forces and constraints inside designed parts or assemblies provide the designer and the owner with virtual working conditions for the equipment. If certain criteria are not met, the particular part is redesign and tested again. Kinematics and simulation operations of assemblies or subassemblies allow designers and owners to test designed equipment for interferences. The designer can also create pictures in many different formats or store movies of the simulation. Kinematics operations create Computer Numerical Control (CNC) machine paths or generate layouts and Bill of Materials.

DESIGN CHALLENGE – ROTARRY MIXER ASSEMBLY

OSTRF as a unique project contain several different equipments in very confine space. One of the main and important parts is Mixer Skid Assembly. It includes many items with specific constraints between each other. At the preliminary design stage, equipment was placed on available floor space to address accessibility, functionality and maintenance. Being aware of vertical space limitation equipment dimensions were modified accordingly.



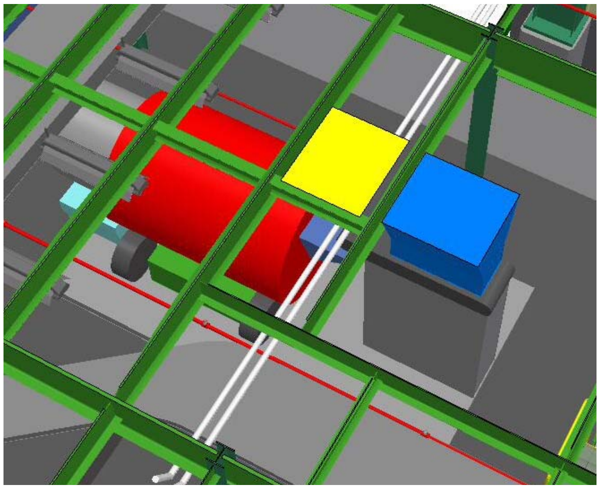


Figure 4. Mixer Skid Solid Block Model

Figure 5. Mixer Skid at facility

Working around that constraint, a preliminary mixer block solid model skid was placed at a proposed location. However, dedicated space was reserved for this assembly; it wasn't obvious that this would be its final location. Figure 4 represents a preliminary solid blocks model and reserve space for future equipment. This configuration was created fast. Although volumes and sizes were closely representing process requirements and were approved by a process engineer, these dimensions could vary by some degree. The C block represents a dry hopper, which is located over the belt conveyor and attached to a separate structure. The D block is a wet hopper, which has to be mounted independently from this structure. At that step, it was not clear how and where this chute would be attach. Existing mezzanine structure beams were the only place that the chute could be connected. The A and B blocks represent a rotating mixer with attached trommel (round frame with screen around). These parts sizes were critical so no "movements" on dimensions were allowed. E block is a reserve size for the horizontal mixer and was fitted exactly under the screen trommel to collect slurry. Dimensions weren't locked. However, volume and resident time was important but not critical. Figure 5 shows the preliminary location for the Mixer skid in respect to available space in the proposed facility. Locating dry hopper (C block) at this stage allows for the delivery of tar sands, in one ton bags, to be lifted and discharged directly to the chute. This facility location has already installed a five ton winch, which could be utilized. It was suggested during design meetings that the same winch could also be used to lift bags for wet hopper feed. The modeled equipment shows two white lines (steam pipes) crossing proposed assembly. Due to the fact layout could change, this issue wasn't significant at this stage of planning. However, interference could create problems and that was noted for future references.

During design analysis, it was spotted that the discharge from the mixture is within proximity of other equipments and access with a forklift is limited (Figure 6). Looking at specifications for safety forklift operation and maneuver instruction, a decision was made to leave chutes at their original place and only rotate the mixer (A block) with horizontal mixer (E block) 90 degrees. This increased the space in front of the proposed tank skids, which also gave safer access to other components located close to safety corridor (Figure 7).

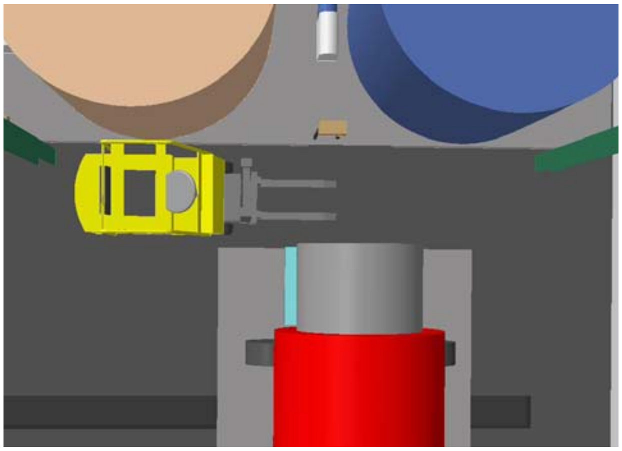


Figure 6. Forklift access analysis

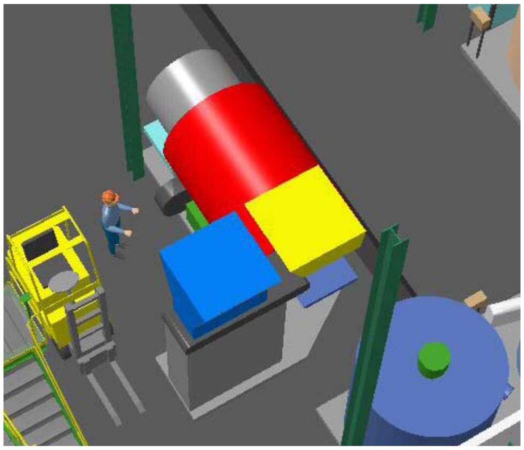


Figure 7. Modified mixer location

Visualization of this replacement option was monitored directly on the computer. All Design Committee members were present and actively participated in this modification. They were notified about steam line collision with wet hopper. Maximum volumes and maximum dimensions for both horizontal agitated tank and rotary mixer were presented and discussed in detail. The Design Committee was aware of its affect on process requirements. All group participants were aware of space constraints and fitting all equipment was a challenging task. Being present and participating in the virtual relocation of the equipment made them fully involved in the design process and shared the responsibility of making constructive decisions. The original design idea for the rotary mixer was to locate a drum (A-cylinder) on four wheels that attached to the end of the axle. Then, the one axle gearmotor was attached to mobilize two wheels. This configuration could be simulated by reversing a car with wheels in the up position (sitting on the roof). Additional ring had to be attached to the drum with a small device to prevent horizontal movement. Due to the fact that this idea was previously implemented and patented by a different company, this configuration and solution was not acceptable.

It was difficult to create a different solution within the given time frame. The Design Committee held a meeting and brain stormed ideas in an attempt to surface different ways of mixing tar sands. Figure 8 shows the sketch, which was introduced and approved by the team members. A gear motor would be placed at the R1 location and it would have strong support to take partial loads from the drum and give torque to the shaft. The shaft would be attached to the drum and a trommel would be constructed around it. Wheels would be placed at the R2 location and would take most of the weight of the drum and oil sands mixture inside. This idea eliminated conflicts with patented solutions, but created other challenges. These challenges would surface at the later stage. After checking and evaluating patent restriction by the designers and process engineers in order to avoid breach any of the patent restriction; the Design Committee members approved the concept design for this subassembly.

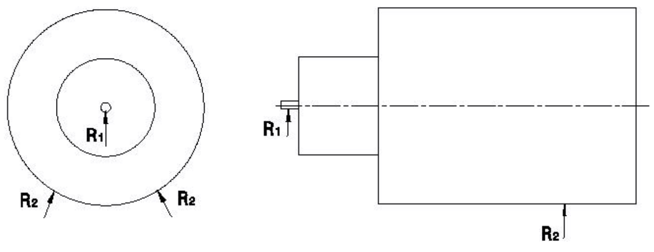


Figure 8. Rotating drum sketch

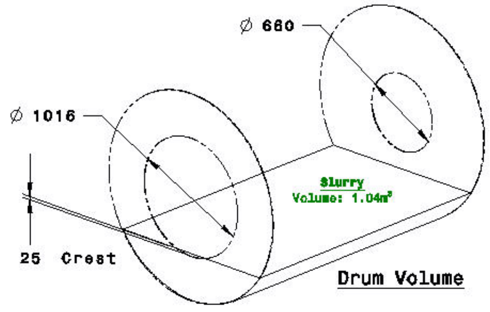


Figure 9. Mixer volume

One of the many challenges experienced during the detail design stage was to choose proper and functional gearmotors. Two suppliers were consider; Lenze and SEW Eurodrive. SEW provided solid model, which was available for downloading and was directly placed in the proposed design. The SEW gearmotor was already tested in the market TorqLOC gear units. TorqLOC is a keyless hollow shaft based on a standard shrink disk and offers interchangeable bushing for mounting SEW-Eurodrive hollow shaft reducers onto various sized solid shafts. This mounting solution is suitable for those applications that traditionally are using hollow shaft reducers or applications requiring the most efficient means to transmit torque (SEW-2002). This particular feature (as will be presented later) was useful because it eliminated expensive shaft key cuts and simplified assembly and maintenance. As a result of the investigation, design team decided to implement similar configurations for dry oil sands conveyor gear motor. However, specifications and ratios were different. Having models for gearmotor ready, designers concentrated on creating proper supports and the detailed designs of the drum. As a main component the mixer drum with attached trommel was specifically designed to hold an amount of volume restricted by crest. Figure 9 shows that sketch. The weight and adequate thickness of the drum were calculated and also drafted.

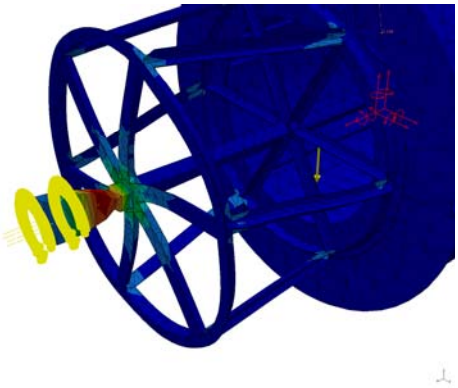


Figure 10. Torque analysis

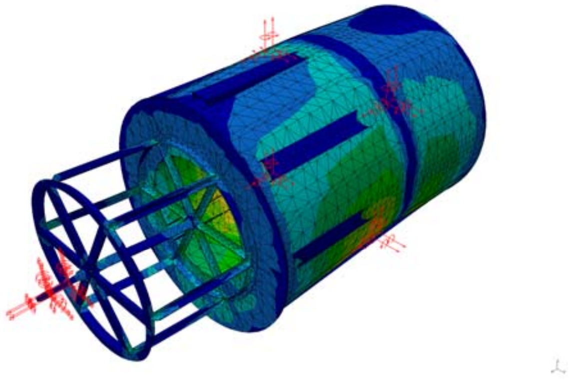


Figure 11. Weight distribution

Due to specialized design configuration for these components, certain considerations have to be taken. The way the trommel would be attached to the drum was critical since only three points were considered for support. Also, the trommel frame has to be tested for its ability to carry the torque from gearmotor to the whole assembly. Since critical spots were identified, it was decided to run a Finite Element Analysis (FEA) for the whole assembly (Figure 10 and Figure 11). The FEA module is directly available in software user (Catia) and designers can quickly analyze questionable areas and assign proper conditions for a performed analysis. This particular feature is handy since in most other software programs, either translation or modulation has to be performed before the analysis is done. Drum assembly was created and located on the back side on two 178mm (7 in) wheels. At the front of the assembly, the gear motor was attached to a specially designed steel structure. The mixed pump box would be placed directly under the trommel to collect slurry falling from the trommel screen. A dilemma in this design was with the agitator. A process engineer specified the exact volume of which a horizontal mixer should contain and any deviations weren't allowed. Designing the agitator option was chosen in order to meet the process requirement specification. However; the Design Committee members didn't participate in the decision regarding the horizontal mixer agitator. This stage of the design was truly dependent on computer graphics and the ability to fully visualize interlocking parts. Placing a rotary mixer at the maximum distance from the floor and with enough clearance from the mezzanine shows the exact space available for a bathtub shape horizontal mixer. SEW gearmotor was chosen to accelerate the agitator and all additional fittings were welded in exact place. Figure 12 shows the horizontal mixer and all its components. The horizontal mixer had to be independently supported; shields, plates and gates were attached to the horizontal mixer structure. Tandem paddles are movable on the square tube and can be placed at any distance, including from the center or side of the mixer. In the front of the mixer is a small chute that discharges non-dissolved materials (ex: rocks). They are lifted from the drum by three unique rock ejectors. Also, the horizontal mixer has specially designed seals – teflon plates on both sides of the vertical walls to prevent abrasive material (oil sands slurry) from directly contacting the rubber O-ring. Side wall small cover opening made unit more accessible operator would have visual control for paddles operation. Available space was utilized and the components were tested for static interference.

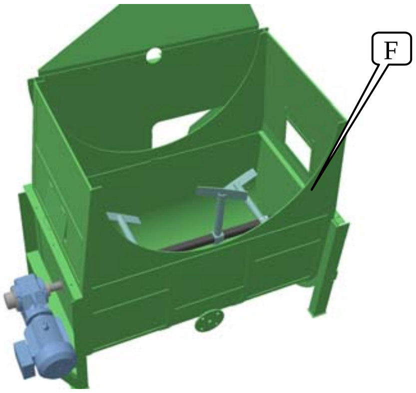


Figure 12. Horizontal Mixer

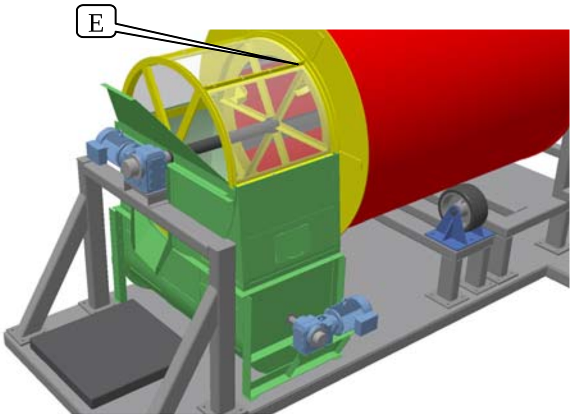


Figure 13. HM with Rotary Mixer

Simulation of these two interdependent components shows no collision or any disruption in the performance. The Design Committee was particullary concerned about the transition area between the rotating trommel part section (E plate) and the stationary back wall of the horizontal mixer (F cutout plate); a potential spillage of slurry, which could complicate operation and grime the walls. To prevent this occurrence, a special lip was designet at the end of the trommel. Six sections of the framed screens were designed so that operators could safely and quickly replace them from outside of the trommel. All front or discharge assembly of the rotary mixer were aproved by the Design Committee.

The next challenging subassembly was a combination of two hoppers. A process requirement was design for two mediums that will access rotary mixer; dry oil sands and wet slurry. Also, consideration has to be taken for the following aspects: proximity to the opening for both hoppers (media would be transported in one ton bags) to utilize the available five ton winch, design custom conveyor for dry oil sands, hoppers volume for process specification, location and support for wet slurry hopper, safety area for operator accessibility and two steam line interference locations. Presented challenges would be presented in details.

Proposed one ton bag dimensions are approximately 1 m (42 in) x 1 m x 1 m, with a design chute that would have a minimum opening of 1.17 m (46 in) x 1.17 m (46 in). For both hoppers, this critical opening dimension should be kept and fitted in an available access area. Figure 14 shows a preliminary layout for both hoppers in relation to the available winch access area. Shaded areas in the wet slurry hopper indicated that floor grading had to be modified. Two existing mezzanine support structure beams would support wet slurry hopper and allow them to reshape it with discharge in order to collect the rotary mixer hopper. The reason for locating wet hopper independently from dry hopper was to accurately measure intake of dry oil sand to the rotary mixer. A custom made conveyor was placed on sensitive weight cells and was supported from a separate structure.

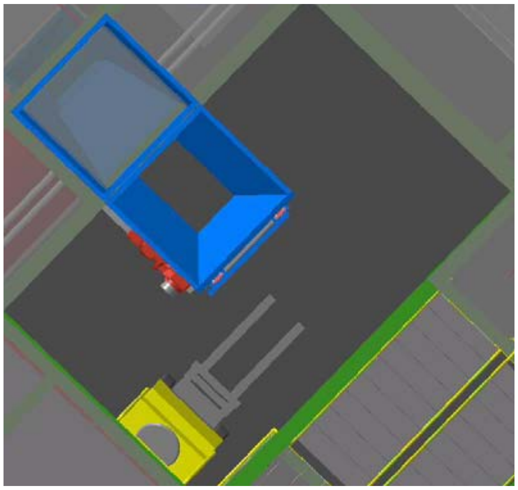


Figure 14. Hoppers top view

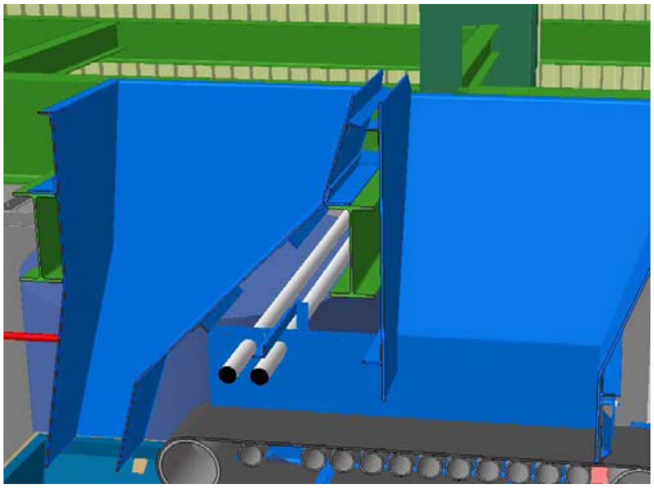


Figure 15. Hoppers section

Figure 15 represents a cross section of described hoppers and a “perfect fit” support location for wet slurry hopper. The same figure also shows two steam lines crossing conveyor subassembly. Seeing this collision clearly, the Design Committee could negotiate with the owner of the building. Relocating this line before the fabrication of the drawings was vital. The created section was particularly helpful for the Design Committee in their efforts to convincing the building owner of the problem. Dry hopper was also designed for the same bag size. However, hold volume on the conveyor belt had to be 1.8 volume of the bag. This was dictated by process to provide continuous feed to the rotary mixer over 2 hours of operation. Virtually created hopper was placed in the space at an exact location in relation to the wet slurry hopper. After that, the remaining custom conveyor belt was designed to accommodate already available parts like rollers, pulleys or bearings. Operation of this conveyor was designed to be approximately 0.25 ft/min. As a result, directly under the area of the hopper opening, more holding idlers had to be placed to evenly distribute weight of stored oil sands. Specially designed and fitted support structures had to lodge specific instruction for placing load cells and additional horizontal movement locators to prevent damage during research operation. Digitally created structure supports not only dry hopper conveyor assembly but also collect hopper for the rotary mixer. Lifting one ton bags in proximity of weighted conveyor belt with dry hopper created possibility of damage hopper shell and/or misplace load cells operation. To avoid this situation, designers came up with the idea of placing additional sliding plate assembly around critical areas to guide lifted bags at specific locations. As in two previous situations to mobilize belt conveyor, SWE Eurodrive gearmotor were chosen. However, toque arm for this gearmotor was proposed to be located directly on the driving shaft in an attempt to save space from additional support. Figure 16 shows guide plate assembly mounted to the support structure. Figure 17 represents picture of rotary mixer assembly after customer commissioning approval.

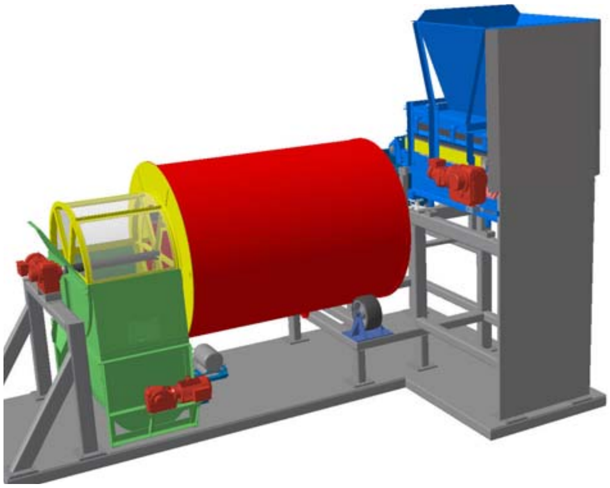


Figure 16. Rotary Mixer Assembly

Figure 17. Mixer Assembly

CONCLUSION

This paper represented a methodology that involved solid models to analyze a complex design within a constrained space. The proposed methodology proved to be effective and eliminated guess work. The proposed methodology provides the user with an optional on-screen analysis for “what if” scenarios (before fabrication) and eliminated on-site errors. The utilization of the 3D software (Catia) with all of its essential features was of value to the implementation of the proposed methodology. The methodology was tested in a number of challenging case studies, one of which was presented in this paper. Users of this methodology include owners, designers, practitioners or contractors; where in addition, the proposed method lends itself to become a tool for teaching at the universities. The presented methodology is limited to the fact that it was mainly used on the basis of visualization on the computer screen; algorithms that involve finite element analysis and optimization model have moved the knowledge to scientific approach.

LITERATURE REVIEW

Akinci B,. Staub S., Fischer M., "Productivity and Cost Analysis Based on 4D Model", Construction Information Digital Library http://itc.scix.net/paperw78-1997-23.content.

Al-Hussein M., Alkass S. and Moselhi O. (1999) "3-D Animation for planning crane operation." The 16th IAARC/IFAC/IEEE International Symposium on Automation and Robotics in Construction, Madrid, Spain

Al-Hussein M., Athar Niaz M., Yu H., and Kim H. (2005) "Integrating 3-D Visualization and simulation for Tower Crane Operation on Construction Sites" In the press for publication in the *International Journal of Automation in Construction*.

Al-Hussein M. and Yu H. (2005) "Mitigating Risk for Critical Crane Operation Though 3-D Modeling and Animation." *Canadian Civil Engineering*, No.22.0, PP. 18-21

Cymerman G., (2003) "Oil Sand Tailings Research Facility – Design Basis Development." Syncrude Canada Ltd. Research Department Discussion Presentation, 2003.

Cymerman G., (2003) "Oil Sand Tailings Research Facility – Design Basis Development" Syncrude Canada Ltd. Research Department Discussion Presentation (2003)

Manrique J., Al-Hussein M., and Teylas A. (2005) "Constructing a Unique and Complex Tilt-Up-Panels Structure Utilizing 3-D CAD and Animation" Proceedings of the 22nd International Symposium on Automation and Robotics in Construction (ISARC), Italy, September 12-13, 2005

Manrique J., Al-Hussein M., Teylas A., and Funston G. (2005) "Case Study-Based: Challenges of constructing an Architecturally Complex Structure Utilizing 3-D Modeling." Prepared for submission to the *ASCE Journal of Construction Engineering and Management.*

Mecham M. (2005) "Good Relationship" Aviation Week & Space Technology June 2005

Moselhi O., Alkass S. and Al-Hussein M. (2004) "3-D Animation for selecting and locating mobile cranes." *International Journal of Innovation in Architecture, Construction and Engineering*. Volume 11 (5), PP. 373-380

Niaz M.A., Al-Hussein M. and Kim H. (2004) "Integrated 3-D object transformation and simulation for tower crane operation on construction sites." Accepted for publication in the proceedings of the International Symposium on Automation and Robotics in Construction (ISARC), Jeju, Korea, September 21-25, 2004

(News 1) (2004) University of Alberta – Department of Civil & Environmental Engineering. "OSTRF – News, Oil Sands Tailings Research Facility." May & October 2004.

(News-2) (2005) Canadian Association of Petroleum Producers "Canadian Crude Oil Production and Supply Forecast 2005-2015" July 2005

Olearczyk J., (2000) "EXP 2000 Slurry Preparation". Ferrotech 3D Design Ltd. Discussion Presentation for Syncrude Canada Ltd. Research Department. 2000.

Olearczyk J., Al-Hussein M., (2006) Utilization of 3D Catia Solid Modeling for Oil Sands Tailings Research Facility Pilot Plant" Submitted for approval for 1st International Construction Specialty Conference, CSCE General Annual Meeting Calgary May 25-26. 2006

Przybylski S. (2004) "A new Paradigm for Digital Design" Enovia Corporation *White Paper* May 2004

SEW Eurodrive TorqLOC Mounting System F/K/S 2002 Product Catalog

(web1) Tailings Management www.syncrude.com last visited December 2005.

V. R. Kamat and J. C. Martinez, Visualizing Simulated Construction Operations in 3D, *Journal of Computing in Civil Engineering*, ASCE, 15(4), (2001) 329-337.

V. R. Kamat, and J. C. Martinez, Scene Graph and Frame Update Algorithms for Smooth and Scalable 3D Visualization of Simulated Construction Operations, *Computer-Aided Civil and Infrastructure Engineering*, 17, (2002) 228-245.