

Rules-based and Geometric Construction Connections for the Marine Industry

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Intergraph PPM is now re-focusing the design-for-production of marine structures

The offshore industry is changing target: the oil and gas and energy seekers are moving deeper into the sea while the offshore plant manufacturers are expanding the variety of floating objects, with the purpose of drilling, processing, storing but also hosting eolic and other generators. The floating denominator is pushing the offshore industry deep in the domain of the traditional shipbuilding industry. The major shipbuilders have reached the top in terms of produced ships (by number and DWT); they are merging the best practices of the shipbuilding mass-production with high value-added, one-of-a-kind, offshore floating plants.

The article is considering some aspects of the mentioned merger from the perspective of dedicated structural CAD applications. There are constructions like jackets and topsides that are commonly recognized as offshore specific; there are other constructions like double hulls and cambered decks that are commonly recognized as ship specific. There have been always transition areas, but today the need to mix "beams-plates" with "stiffened-plates" it is growing for two different reasons: because of growing interdependency and because of the tendency to handle complex models in a homogeneous environment. The second reason is even more important because it is the answer to the market pressure when it comes to control the engineering changes in limited time and budget.

Figures 1 and 2 report details of floating units for the offshore industry produced at Samsung Heavy Industry.



After decades of experience in supporting the design of structures for all types of plants, Intergraph PPM is now re-focusing the design-for-production of marine structures. Typical offshore beam constructions and typical shipbuilding stiffened plates constructions have been approached in a uniform way with dedicated tools to satisfy the growing requirements of new marine projects.

Automazione nelle connessioni di strutture per la cantieristica navale e l'offshore

Dopo decenni di esperienza nel supportare la progettazione di strutture di tutti i tipi di impianti, Intergraph PPM sta ora rivisitando la progettazione orientata alla produzione di strutture marine. Strutture tipiche dell'offshore (travi e tralicci) e strutture navali (lastre nervate) sono state approcciate in modo uniforme con strumenti dedicati per soddisfare le crescenti esigenze dei nuovi progetti di strutture galleggianti.



Geometric Construction in Nodal Connections

Geometric Construction are construction tools belonging to SmartMarine 3D Structural Task - Advanced-Plate Systems. The tools provide interactive associative 3D graphics capability to ease and extend existing structural modeling capabilities, in order to solve plate placement and modifications in different contexts and specific usage.

Geometric Construction are tools to expose API to create complex constructions from given geometry input and parameters. Following are some of the features of the tools:

- support multiple member participation;
- trim member to plate edge/face;

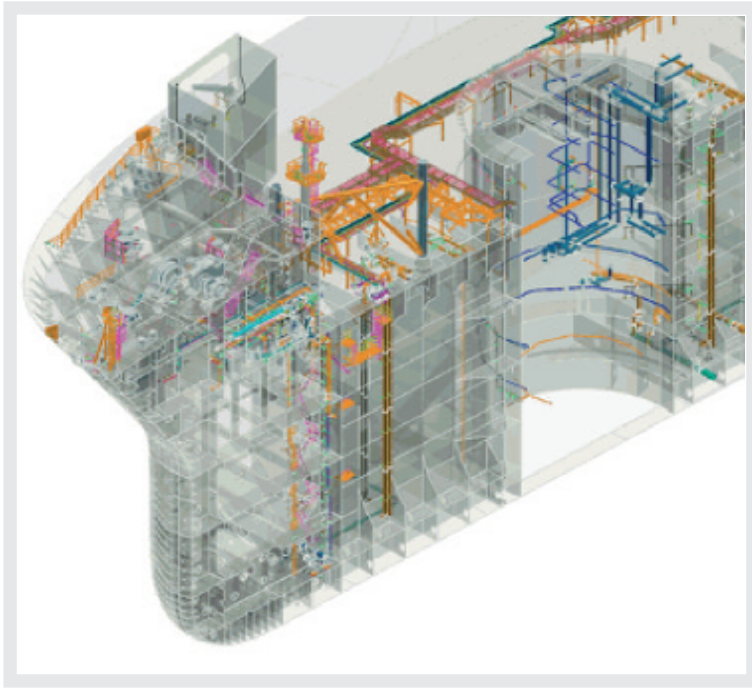


Fig. 1 - Details of floating units for the offshore industry produced at Samsung Heavy Industry

- bound plate edge to plate edge;
- plate shapes are driven by user defined construction parameters;
- establish connectivity between members and plates.

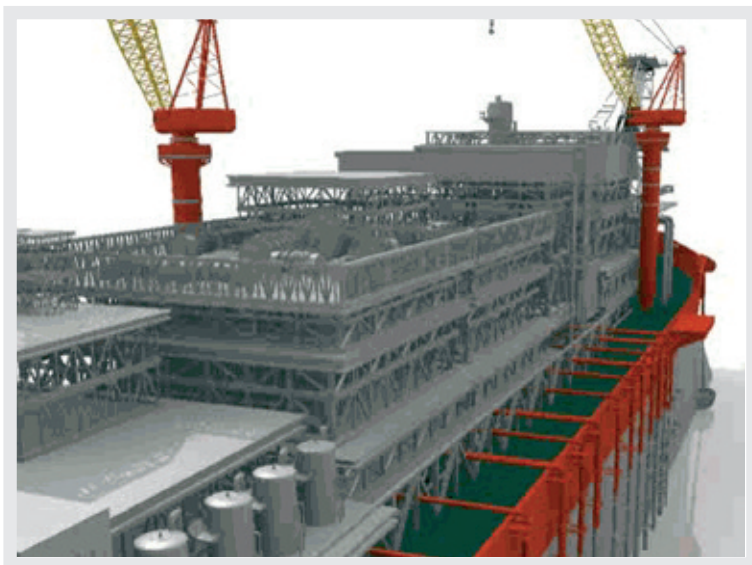
Side plates and continuity plates are the specialty of Geometric Construction where their shape changes following the angle of the incoming bracing in a robust and predictable way (figure 3).

What makes the tools specific is the way to generate the programming code i.e. the ability to transform a set of Geometric Constructions into executables.

Fig. 2 - Details of floating units for the offshore industry produced at Samsung Heavy Industry

Geometric Construction Applied to a Gusset Plate

This section illustrates the procedure to build a macro creating the support and the boundaries



for specifically shaped plate: a Gusset Plate at the end of a member (rolled) in a nodal connection context.

The whole procedure is divided in the following phases (figure 4):

- support definition;
- shape definition;
- plate definition;
- create macro (print graph).

When the Geometric Construction sets are created by the sequence above the user can create a macro with the Print Graph functionality (figure 5).

The level of adaptability (Changes compatible with the Gusset Plate definition) of the macro is summarized as follows:

- shape parameters yes
- change bounding member cross-section #1 TBD
- change bounding member cross-section #2 TBD
- change bounding member #1 size yes
- change bounded member #2 size yes
- rotation along member axis no
- move incoming member free end point yes
- move member end point yes

The created program is referenced by the given macro entry in the catalogue and as such it is made available to all the designers sharing the project, to be replayed in the same context. The end-user browses the catalogue and chooses the macro, then selects the pertinent inputs (members systems); the macro is placed and committed, then the user places a plate system using the outputs of the placed macro (supports, and boundaries).

The procedure can be applied for other shapes of the Gusset Plate, as shown on figure 6.

The Geometric Construction interactive programming allows for:

- quicker development for modeling;
- better debugging due to granularity of the input;
- clear association log identifies failing semantics;
- modular implementation (from simple to complex nodes adding macros);
- rapid evolution of the end-user modelling tools.

Stiffened Plate Connections (Joints)

The Stiffened Plate Connections illustrated in this section belong to the SmartMarine 3D Structure – Bracket Plate System. The modeling tasks are following the design workflow from the early-stages to the production. The tasks are named:

- Molded Forms;
- Structural Detailing;
- Structural Manufacturing.

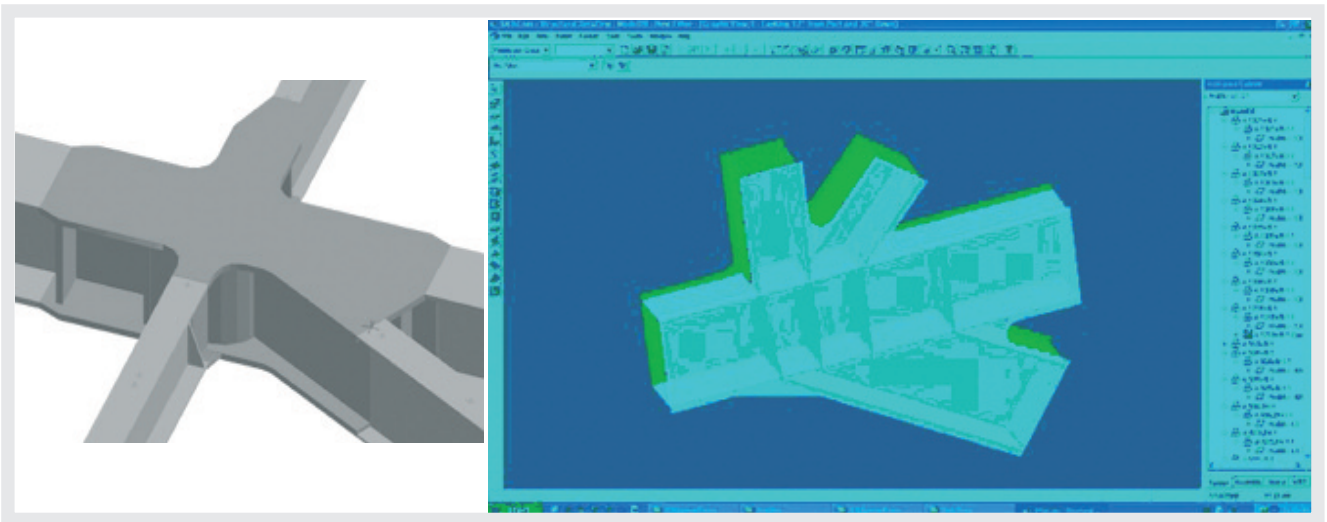


Fig. 3 - Typical nodal connections modeled with Geometric Construction

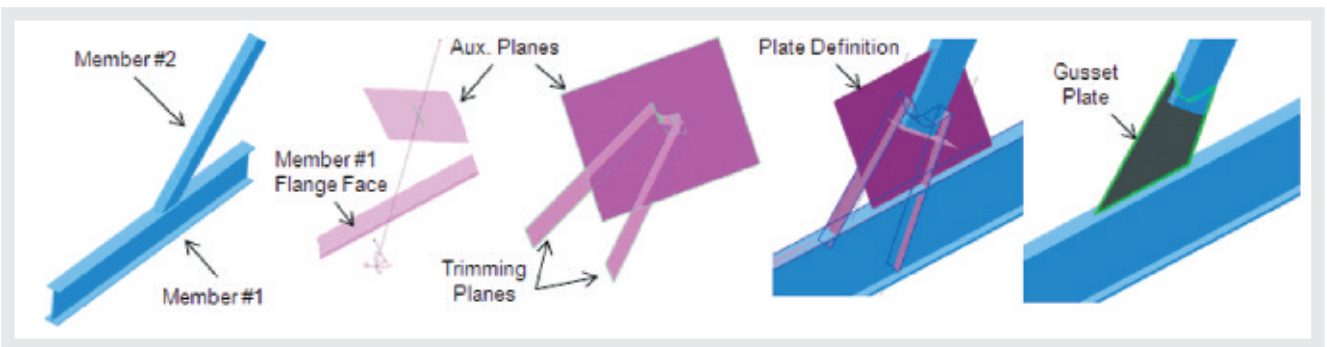


Fig. 4 - Support, shape and final plate definition

```

Private Sub IJGeometricConstructionDefinitionService_Evaluate(ByVal pGeometricConstruction As SP3DGeometricConstructi
Dim oGCFactory As IJGeometricConstructionEntitiesFactory
Set oGCFactory = New GeometricConstructionEntitiesFactory
Dim oGC1 As SP3DGeometricConstruction.GeometricConstruction
Set oGC1 = oGCFactory.CreateEntity("CSByLines", Nothing)
oGC1.Inputs("AxisLine1").Add pGeometricConstruction.Input("AxisLine1")
oGC1.Inputs("AxisLine2").Add pGeometricConstruction.Input("AxisLine2")
oGC1.Parameter("AxesRole") = 1
oGC1.Parameter("CSOrientation") = 1
oGC1.Evaluate
    
```

Fig. 5 - Portion of the VB code generated by the print graph functionality

At any stage there are different rules that are governing the design. Molded forms rules control how tripping stiffeners, brackets, bracket flanges, and profile knuckles are placed. Structural Detailing rules solve the penetrations by clips or collars, add the edge and the corner features, manage the endcuts to the profiles etc. The Detailed Design begins when the early-stage design goes through the detailing process. The detailing process trims the parts to their final 3D shape, and creates assembly connections in the way of the logical connections created by the topology in the placement process. The assembly connections are triggering the entire rule-based modeling process. Depending of the relationship between two objects (bounded or penetrating) the complete detailed solution with child features is generated. The newly created features can subse-

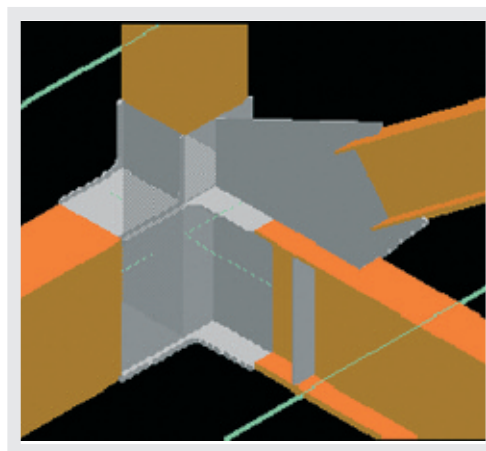
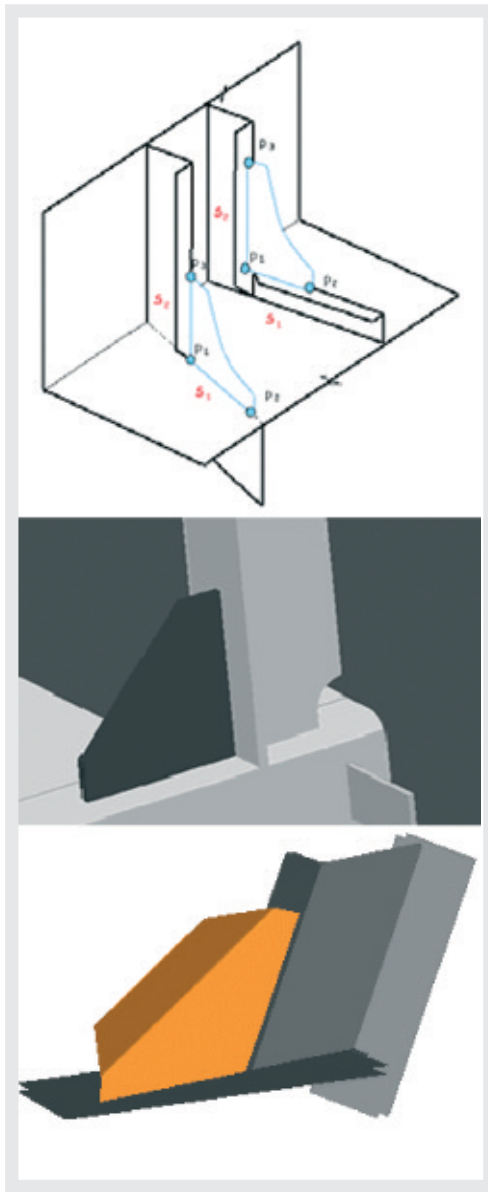


Fig. 6 - Reused Gusset plate macro in similar context

quently trigger other rules with the placement of corresponding new features. Rules are written to control customized reference data; each set of rules is delivered as a Visual Basic project which can be customized.

Fig. 7 - Typical brackets in a stiffened plate construction



VB rules control the output by:

- analyzing connection and boundary cases;
- accepting user input;
- selecting default features;
- controlling parameter output to size the feature.

Rules control how and when the Structural Detailing objects are used in the Model. Structural Detailing rules place the following objects:

- Assembly and Physical Connections;
- Brackets;
- Clips and Collars;
- Edge, Corner and Sketched Features, Slots and Chamfers;
- End Cuts (Free and Constrained);
- Edge Treatments;
- Welds.

Other data (Reference Data), like profile cross-sections and materials (types and grades) are part of the catalog, and do not use rules.

Rules-Based Design Applied to the Bracket Plate System

The Bracket Plate System represents a typical connecting element between Stiffened Plates; it can be stiffened (as any other plate), penetrated by stiffeners on the bounding structure and split with seams. A Bracket Plate System is supported by a plate along one of its edges and supported by profiles or plates along its other edges (figure 7). The supports are used to define the plane of the bracket plate system as well as its boundaries. The first two supports must intersect in a manner that allows the plane to be defined. Bracket orientation is driven by the orientation of one of the supports, a profile whose web is used to drive the orientation, or a plate whose plane is used to drive the orientation.

Following are the necessary steps to create and customize a Bracket Plate System:

- Definition of the Bracket Symbol (adding separately the Flange Symbol if this is the case);
- Definition of the Tripping Bracket Offset Rules (when it's necessary to re-position the Bracket System from the given plane defined by the connecting elements);
- Bulk-load of Bracket's Definition Data (plus optional Flanges and Tripping Bracket Offset Rules) to the Catalog.

Each type of bracket requires the definition of a Part Class and the related 2D Symbol.

The definition Parameters must be loaded into the catalog.

For a 2-Support Bracket the Parameters are the Height, the Width, the two Noses, one Radius in case of a curve on the bracket edge; a second Radius for the Scallop in the way of the 2 supports intersection and the Lap distance to cover the case of a bracket overlapping the support(s).

There is a powerful Symbol 2D Environment supporting the definition of all the 2D Symbols; the environment is allowing the definition of the constrains that are critical to proper symbol behavior (figure 8).

A spreadsheet is containing the necessary information to be loaded into the Catalog, i.e. the Selector Rules, the different Parameters matching each type of 2-Support bracket, the Names of the Symbol files and of the Definition Rules.

The Bracket Plate System can be placed individually, where necessary, at designer's discretion (figure 9); but the real power of the Rules-Based Design is implying the automatic placement of additional objects following the Company preferred solutions (standards or best-practices).

In the case of a stiffener bounded by the flange of another stiffener (belonging to a different



Fig. 8 - The 2D graphical symbol and the spreadsheet with relevant data for the catalog

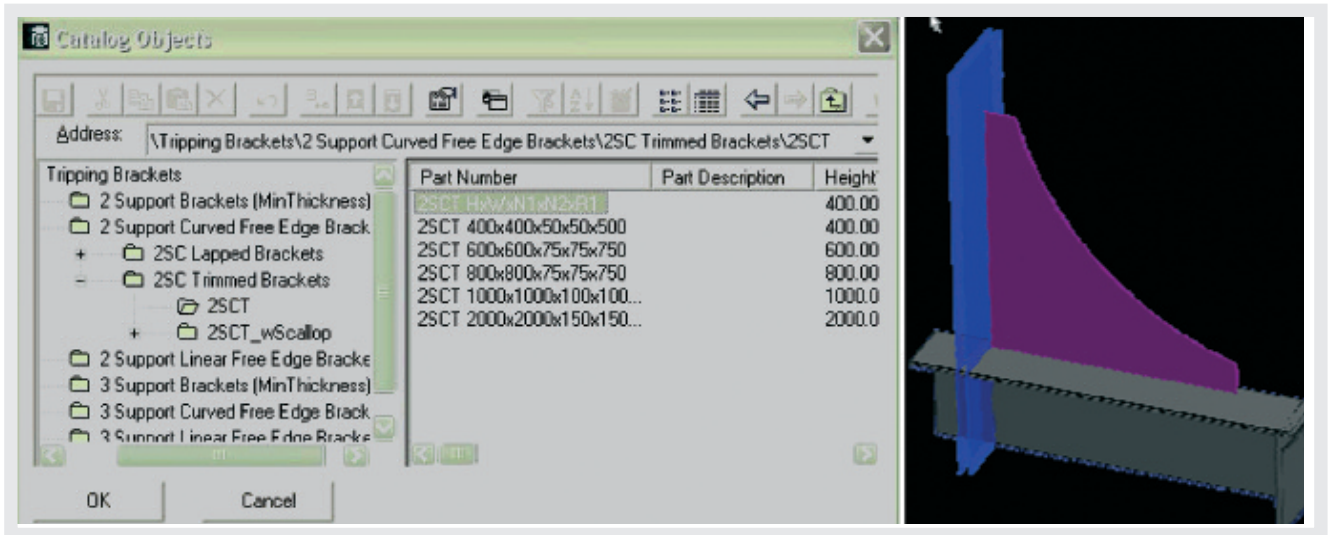


Fig. 9 - The way a 2-support bracket is selected in the catalog and in a 3D view

Plate System) the resulting Assembly Connection can generate automatically some edge and corner features and create a slot, a clip, a 2-Support bracket and all the welds (figure 7 central).

The Rules-Based Design as it is deployed in Molded Forms and Structural Detailing tasks allows:

- faster and better detailing;
- focusing the design intent;
- skipping the repetitive job;
- applying company standards whenever applicable (by the rule);
- more homogenous and consistent dataflow to production;
- selection rules (reduced skill level required).

Managing Changes and Re-use

Essential in both described cases it is the creation of associative relationships among the elements concurring in the generation of the connection. The associative relationship is the prerequisite for the "smart" change and re-use of each solution. In both cases the system is exposing the relationship to the end-user (Workspace Explorer in figure 3 - right). The Design changes are facilitated by the fact that low level details that can be inferred from the design and are automatically computed when-

ver necessary.

Following the different nature of the "beams" and "stiffened plate" structure the typical cause of modification it is also different:

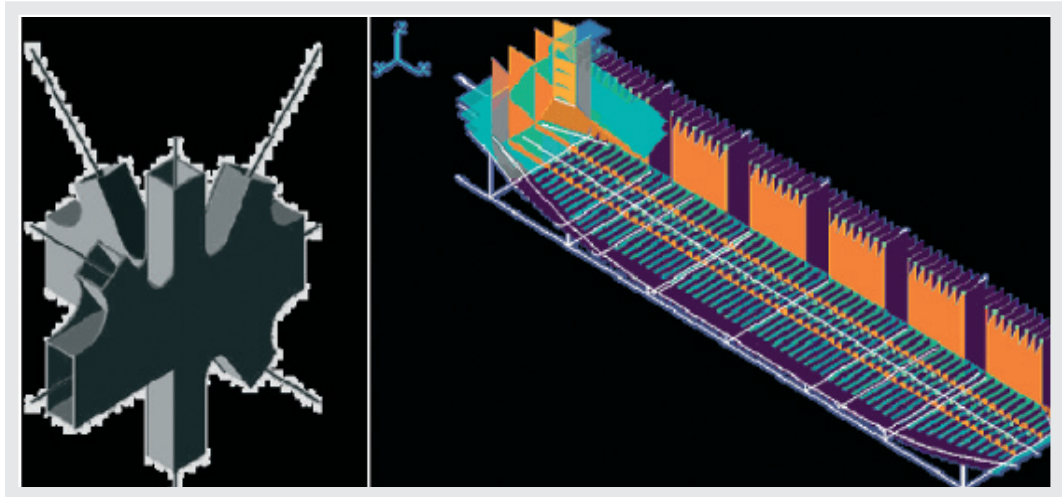
- Modified bracing angle (axis orientation or position for members);
- Modified supporting Plate System (surface shape or position for stiffened plates).

It is the associative relationship that enables:

- All the connections based on Geometry Construction to re-compute automatically re-running the macros and interpreting the new conditions;
- All the connections based on rules to re-compute since the rules will automatically propagate the effects of the modifications. As if the plates coming together in the Assembly Connection are modified, the rules will run through the selection process again. In case that it is the Hull to change and that the ship is already far into the design cycle the change would cause the re-compute of a massive amount of already detailed objects.

SmartMarine 3D structural tasks embed a high-level, abstract definition of the design that not only captures the geometric result, but the design intent. When this feature is combined with powerful tools to describe the product structure (where "structure" means "arbore-

Fig. 10 – IGCC-MeOH – COE case vs. costo of coal



science”), and user-friendly ways to define aggregations of objects (topo)logically linked; it results in and permits efficient reuse of the design within the model.

There are two high-level commands in Molded Forms performing “smart” copy/paste:

- The Copy Similar, that replicates major portions of the model with the ability to automatically update the replicas as changes are made. The best example comes from the shipbuilding industry: define a transverse bulkhead in a mid-ship area (including profile stiffeners, brackets, seams, openings, etc) and copy the bulkhead to another transverse location (outside the mid-ship area as well);
- The Copy Symmetry, that replicates portions of the model based on symmetry. For each symmetry family of objects a coordinate system is selected. Again in the case of a ship (figure 10 right) the Copy Symmetry is performed across the longitudinal centerline symmetry grid plane. The Copy Symmetry Family consist of groups of structure on both the port and starboard sides of the symmetry plane. One group is reflected about the symmetry plane to the other group.

In addition to the described reuse of design there is the possibility to store the aggregated objects into the Catalog and perform multiple subsequent “copy/paste” within the same project or within a group or projects sharing the same Catalog.

The re-use of the same design may result in a different detailed model since the boundary conditions may be different.

The benefits of efficient reuse of design are multiple:

- Standardization of complete functional solutions (rather than details);
- Faster and safer design;
- Shorter delivery time;
- Better and Faster materials estimation;
- Preserved Company know-how;

- Flexibility with human resources (unevenly skilled designers producing comparable results).

Feeding Production

In spite of the different tools and workflows applied in the modeling phase (Molded Forms) all the created objects are equally made available for the detailing and manufacturing phases. The objects are also made available to the Planning task for production planning and assembly hierarchy definition (once the attributes are assigned the assembly hierarchy is analogous to a manufacturing bill of material that can be considered the specification of how to build the structure assemblies and their sequence). The Structural Detailing objects are generated using the information inherited from the Molded Forms System.

Detailing uses the parent system’s properties, such as thickness, continuity and molded conventions, to create parts containing neat, fully defined geometry, including edge and corner features, chamfers and bevels.

The associative relationship that greatly supported earlier modeling phases is having an important role in the detailing phase as well. The Assembly Connections are created automatically as children of the Logical Connections and the Physical Connections are created automatically as children of the Assembly Connections. It is at the level of Physical Connections that the Weld and Bevel information are stored.

The Structural Manufacturing task is adding manufacturing-specific information to the detailed parts and also creates supporting parts such as pin-jigs and templates.

Manufacturing data output is Rules-driven by user-defined Visual Basic rules. As each manufacturing plate (or profile) is extracted from the detailed part, rules control how the object is processed i.e. distorted, featured and annotated.

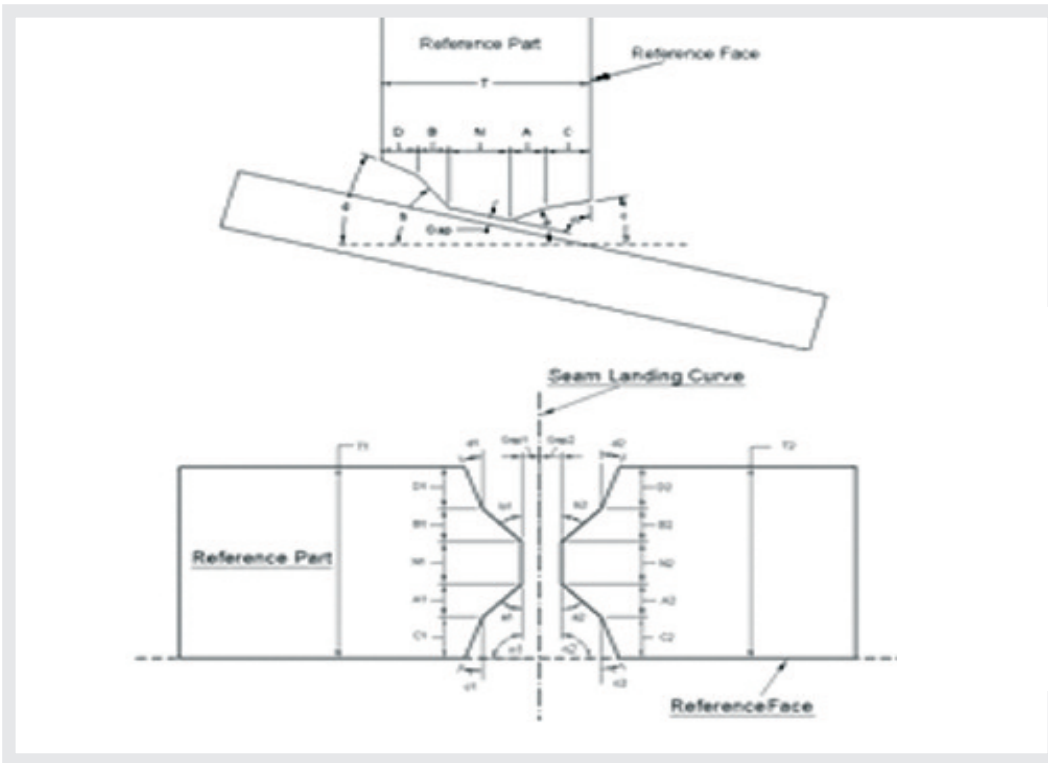


Fig. 11 - Weld preparation

Different set of options controls the plate orientation and marking directly from the rule. To summarize the provided process information:

- shrinkage;
- marking lines and text;
- fabrication and assembly margins;
- bevels and welds.

Figure 11 shows T and Butt Weld preparation. Figure 12 shows examples of outputs related to a nodal flat plate.

The manufactured part relies heavily on the result of the rules that were run at the detailing level. Bevel data is taken directly from the physical connections, If a design modification forces a change to the bevel data, the manufacturing part is notified that a change was made, and it is marked as out-of-date.

The user can approve the update to the manufacturing data, and send the update to the production-planning system.

The XML files, fully describing the piece parts

Fig. 12 - Marking lines and XML output

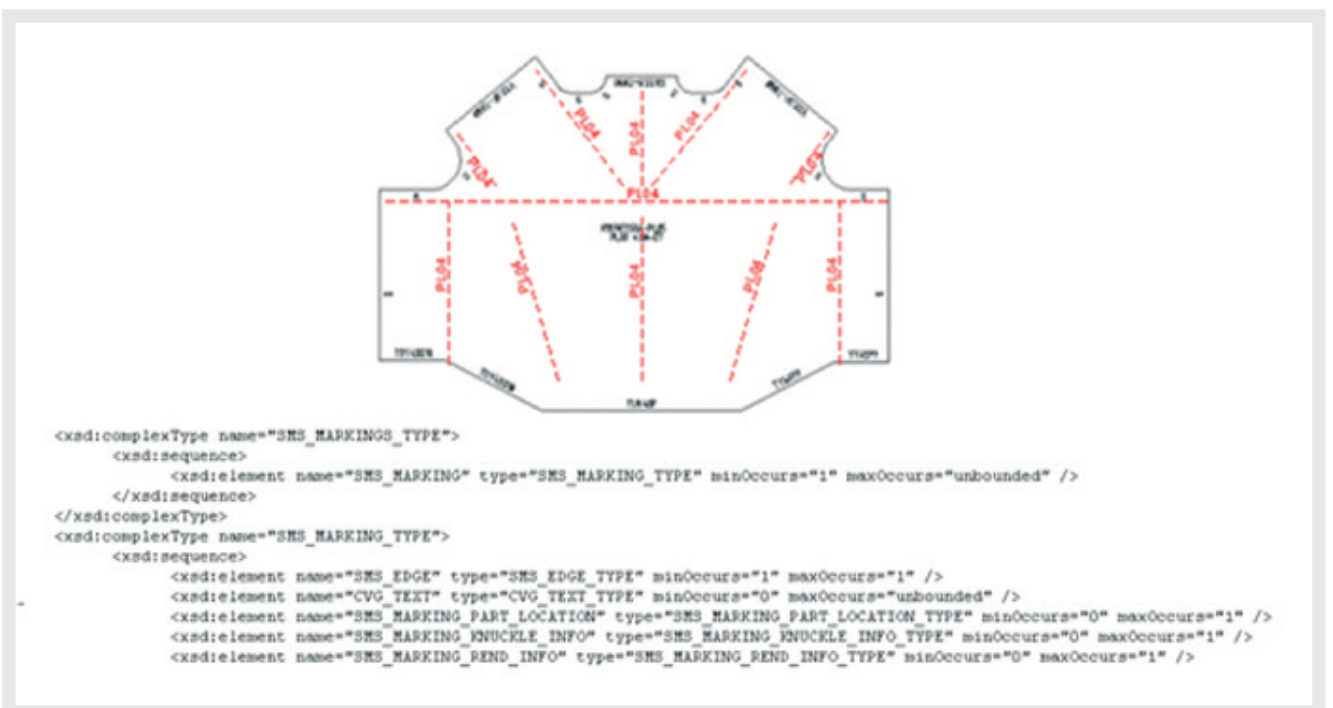
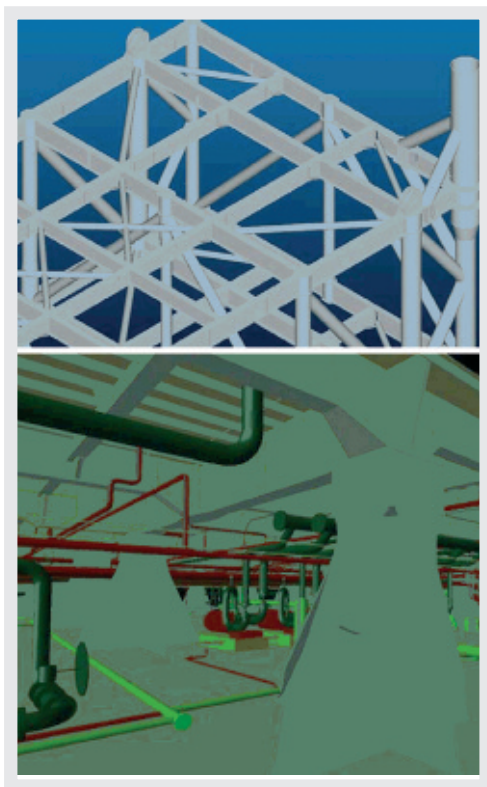


Fig. 13 - Typical “beam” construction compared to a “transition” structure



can be directly sent to the production-planning system.

Before finalizing the file the information, the XML is parsed through the Adaptor:

The Adaptor is a user-defined rule which parses through the default XML schema and allows to make replacements, modifications and deletions of entries before (excerpt in **figure 13**).

In case of demanding workshops or outsourcing specific needs, various drawings, sketches and other old-fashioned deliverables can be generated by the system automatically.

Conclusions

Current economical situation is stressing the need to manufacture the offshore plants (of any kind) at the fastest time with reducing budgets. Single vertical CAD/CAM/CAE applications, even if very efficient, are not enough to remain competitive on a market that is renown as a high-tech and top quality.

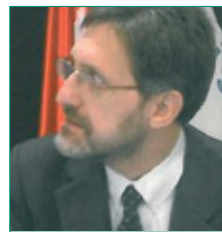
The interoperability among all the applications involved in the various phases of the project i.e. modeling, detailing, planning, manufacturing, material management is of continuously growing importance.

The aim in this article is at a single vertical 3D CAD application, the Structural one, where the two major streams in the marine industry (the “beam” and the “curved plate”) are required to co-exist and co-operate more than ever before. The goal is to keep the peculiarities of each construction type while maximizing the common terms in the design, the materials procurement, and the manufacturing technology. The paper focuses the two different ways to create typical connections allowing easy placement the first time and automatic re-computing in case of changes.

The Geometric Construction and the Rules-based design are both capturing industry and yard’s best practices, speeding up the design process and reducing mistakes and rework thus supporting the challenges of the advanced offshore industry. ■

References

- [1] Cochran K.: *Rule-based Ship Design - ICCAS XIII*, Portsmouth, UK, September 2007
- [2] Duparcmeur Y.L., Patience R., Butler J.: *Experienced Marine Design and Data Use - ICCAS XIII*, Portsmouth, UK, September 2007



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