Application of Standard Parts and Features in Ship Structural Design

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Abstract

The design process in the maritime industry is characterized by a close cooperation of many diverse partners working in parallel. In this phase standardization is used to reduce costs, to improve quality and to shorten time to market. A system for the definition, management and application of standardized solutions for ship structural parts and features in the detailed design process is presented. Information about the approach to data modeling applied and the interaction with existing applications is given.

Keywords

Ship detailed design, knowledge-based engineering, standardization of ship structural parts

Introduction

The design process in the maritime industry is characterized by a close cooperation of many diverse partners working in parallel. While the project design and initial design is mostly performed by the shipyard or a single design agent in close cooperation with the owner, class society and e. g. model basins, this holds especially true for the process of detailed ship structural design.

In this development phase design tasks are often outsourced to external design agents due to tight time schedules. Often, a number of problems related to one compartment or system are worked on by different partners. Here, a close coordination of all activities involved is required to optimize the overall result. Changes in regard to one aspect require other changes leading to an evolutionary design method. Communication plays an import role to synchronize the activities.

Design Process and the Role of Standardization

As shown in Fig. 1 the detailed design phase influences the total costs significantly. To reduce costs the main contractor, mostly the shipyard building the vessel, defines a set of regulations and best practice recommendations, the so called design standards. These standards are highly optimized to increase the productivity during manufacturing and to satisfy all requirements regarding strength, fatigue, etc at the same time.

Focusing on ship structural design, the initial design phase is used to adapt existing standards and to optimize these standards to manufacturing capabilities and applicable regulations taking experience from previous projects as well as contractor's requirements into account. During detailed design these standards are then applied by the engineer to design the vessel according to the rules defined in the standards.

Applying design standards the number of different solutions to similar design problems in a vessel or in a series of vessels can be reduced. With these series effects manufacturing costs can be improved. The workers on the shop floor are more familiar with the reduced number of solutions, leading to a decrease in labor time needed and at the same time to an improvement in manufacturing though product quality.

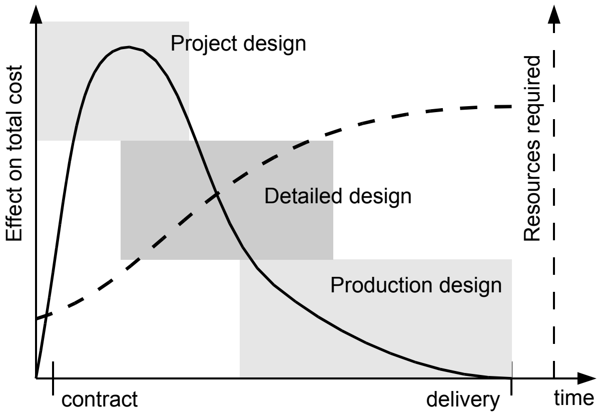


Fig. 1: Effect of process and total design time on cost

To reduce design time similar tasks concerning independent aspects of the design of a vessel are deployed to different partners. For example the design of all steel structural parts of the bow section is done by one design agent; the design of the aft section is done by another design agent or at the shipyard. Design offices, either at the shipyard or at design agents, are often working on many projects at the same time. This requires that the individual engineer

- has to work in different design contexts at the same time
- and has to get familiar with the recommendations and requirements of the contractor for each project.

For new projects engineers are required to get familiar and productive with the standards and regulations supplied within a limited timeframe. Working on different projects also requires a constant change of the standards used; the probability of using incorrect regulations or misinterpretation is increased leading to increased costs for necessary changes later on.

Standards offer a means to define solutions to similar problems. These standards are used by engineers at the shipyard and design offices to design a vessel in a way that is best for the manufacturing capabilities at the construction site. As a result manufacturing costs are reduced and the build quality is improved. If common standard parts are delivered or produced in large quantities they do not need to be manufactured individually. The control of material flow can be improved.

Standards – A Definition

For a given problem, even if limited to feasible solutions only, the number of applicable or possible solutions can be large. Based on this domain of solutions standards impose certain constraints with the objective to limit the solution domain. Constraints can

- either be placed on certain aspects,
- can exclude some solutions completely
- or can allow certain solutions only.

Generally speaking, aspects can be anything that concerns the problem at hand and that influences the result. Constraints limit the parameter space for aspects. This limitation is performed using mathematical operations like value assignments, or solving equations. As an example the class rules defining certain requirements regarding stiffener dimensions in relation to plate thickness can be named. Description logic allows the definition of relationships between different aspects hence forming a network of rules for a given standard.

Here, a distinction between

- constraints that only affect aspects of the standardized object
- and relations that also encompass information from the surroundings of the object, the design context

needs to be taken (Pierra 2003, Zimmermann 2005).

As an example in Fig. 2, a bracket for a stiffener-stiffener connection is shown. Looking only at direct first-order relationships, the length of the flange *l* and the thickness of the bracket *t* are properties of the object alone. The selection of the bracket also requires information of other objects. In this example the section module of the profiles to be connected needs to be known. These can be derived from the type of connected stiffeners and the stiffener dimensions.

In addition to these strict constraints descriptive constraints can be imposed. Descriptive constraints are constraints that are complex to state explicitly in terms of equations or boolean expressions but are provided as e. g. explanatory text. Often, this type of constraints requires complex information about the location in the ship, strength and fatigue levels, manufacturing procedures as well as additional information normally not given in the data model. In detailed structural design the selection of the best solution from a list of permissible solutions is heavily influenced by weak information.

Here, the knowledge of the engineer is required to evaluate the information provided with respect to the problem at hand and to decide if a specific weak constraint is applicable or not. The possibility of misunderstandings is given.

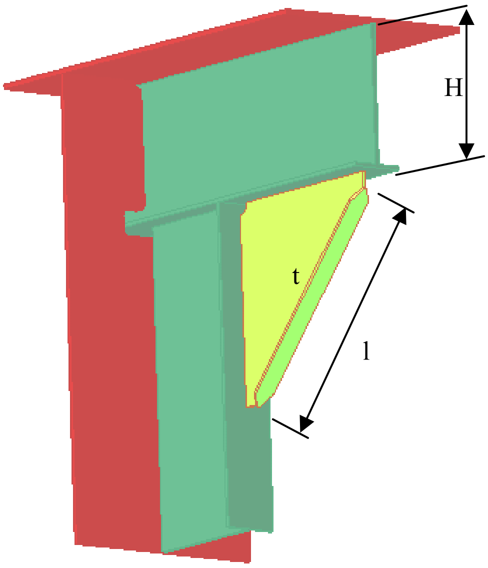


Fig. 2: Local and Context Related Aspects

In practice the number of aspects applied for a given standard is limited by issues like maintenance, complexity and the availability of information. Therefore, solutions that are applied often in a typical design scenario or solutions with high error rates and high costs for correction are candidates for standardization. Also, from an economic point of view standardization is only used if the effect of standardization gives substantial benefits regarding cost or quality compared to the effort needed to define, document, distribute and apply these standards. For a standards database the cost involved in defining certain information explicitly within the data model or in a separate application needs to be taken into account, too.

Therefore, in ship design standardization is mostly applied in the area of steel structural design. Here, high numbers of identical solutions like parts or features are used. The identification of all relevant aspects determining the decision for or against a specific solution is feasible yet complex. An opt-out option for uncommon problems with special requirements needs to be provided to allow the engineer to overrule the solution given by a standard.

A Database for Standard Parts and Features

Today, the definition and management of standards is mostly performed using office applications. In most cases distribution and deployment are based on paper. A shipyard needs to create a new document describing all relevant standards for each project. Changes in the standards require an update of all standards documents in use as well as distribution of these updated documentation to all parties involved. Due to delays in the distribution process or due to delays on the side of the receiver “incorrect” designs might occur because deprecated standards are used or changed standards are not followed in time. A consolidated management of information about standardization improves the process of knowledge management.

A computer based tool for the management of standards eases their handling. With a centralized database for the storage and distribution of standards, the deployment of up-to-date standards to all parties involved in a project is improved. Using knowledge-based engineering methods tools are provided to support the application of a set of standards by the engineer. Functions allow searching for solutions for a given problem.

As part of the collaborative research project “KonSenS” a system for

- the definition of multiple sets of standards,
- the management of standards,
- the distribution of standards to all partners involved in a certain project,
- and the enforced application of these standards in the design process

is developed.

For this purpose, an application server is realized. The system offers an information server that provides information about design procedures, standards and related documentation. Using a platform- and system- independent design, the client-server solution offers a flexible and centralized infrastructure.

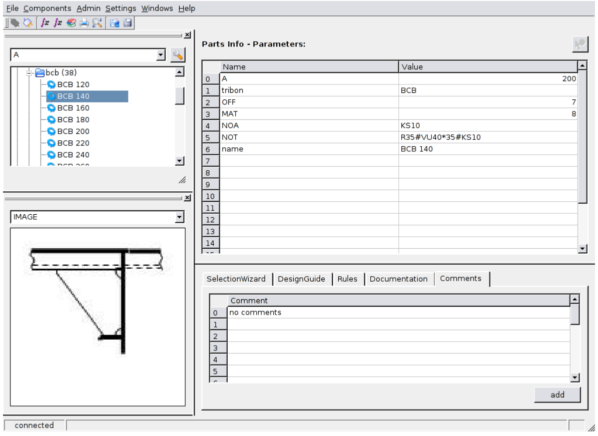
Standardized parts are stored in a database linked with additional information for a certain project, shipyard etc. Documentation and suggestions by other users, e. g. annotations, comments etc., are also stored in the application server. A rule module allows for the definition of either self-contained rules, which can be used by the engineer interactively, or as rules applied for dimensioning or selection of specific standardized parts. A screenshot of the current prototype application is shown in Fig. 3. Here, on the left side a tree structure represents one view onto the information stored in the database. Detailed information about the selected standardized part or feature is shown in the upper right table, additional information like related documentation, rules or comments in the table below.

Using a thin-client approach the application logic for the handling and management of the standards is implemented on the server. This reduces the work needed for the development of new clients. Also, this approach allows updating the capabilities of the system in one central location; further development on the client side is only needed to improve the functionality offered by this client.

With the help of adapter interfaces to CAE-Systems or other applications present in the heterogeneous environments found in shipyards it is possible to consolidate and centralize the management and configuration of different applications in the system. A stand-alone client can be used to access the data stored in the application server directly.

The functionality of the application modules is made available for client applications as web-services via SOAP (SOAP) and XML-RPC (Young-Soon 2005). Interfaces for search and retrieval of applicable solutions or for other information are offered.

Additional information is available providing sources for a better understanding of certain problems. Restricting the information presented to applicable solutions for a certain problem domain like e. g. the design of the superstructure reduces the domain of available options. The management of standards is improved because the work intensive and error prone correction and distribution of multiple standards is not required.



Parts Info - Parameters:

	Name	Value
0	A	200
1	tribon	BCB
2	OFF	7
3	MAT	8
4	NOA	KS10
5	NOT	R35#VU40*35#KS10
6	name	BCB 140
7		
8		
9		
10		
11		
12		
13		
14		

	Comment
0	no comments
1	
2	
3	
4	
5	

Fig. 3: Prototype of a Stand-Alone Client

For three shipyards the system currently provides information for the main groups brackets, clips, cutouts and stiffeners. About 80 different types of standardized parts with more than 1300 instances are available to the designer. Information about stock parts like plates and profiles are also stored.

Integration with Existing Tools

The information stored in the standards database is accessible via a platform independent stand-alone client via a network. The functionality implemented can be accessed from other applications via a SOAP-API. As part of the research project the Vitesse framework of the CAD-system Tribon is used to offer the engineer the benefits from the standard database within the CAD-system.

For selected design tasks information about standardized parts are stored in the standards database. Required functions are added to the CAD-system providing access to the information. If the engineer selects a design task required information is either retrieved from the data model of the CAD system automatically or entered by the engineer (Kim 2005). Default values are specified for input masks. If necessary values are calculated by the standards database using the rules defined. See Fig. 4 for a sequence diagram showing the communication between the designer, the CAD-System and the design standards Server.

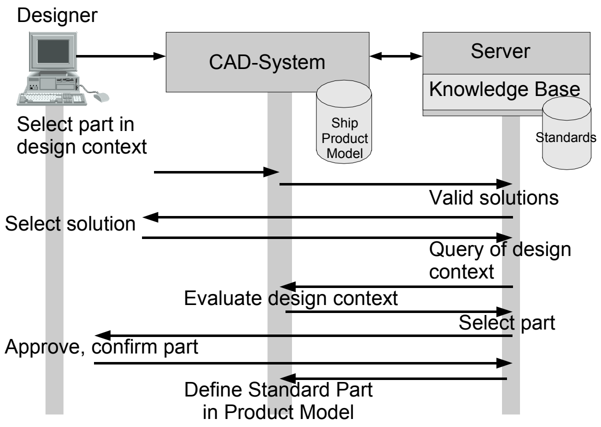


Fig. 4: Interaction of Designer and CAD-System with Standards Server

As a result, the number of user interactions within the CAD-systems necessary for the definition of e. g. a bracket connecting two stiffeners can be reduced by 50% using the standards system compared to interactions required by the built-in Tribon functions. The probability of incorrect data entered is therefore reduced also.

The Data Model

Standards cover various aspects of objects and the relationships of these objects to e. g. the ship structure. Taking up ideas from the STEP standard a flexible data model was developed. The main components of the data model are shown in Fig. 5 in UML notation.

In most cases standardization encompasses not only a single solution but defines a series of applicable solutions. Using a top-down approach a generic *Abstract Model* is used to model arbitrary relationships between different pieces of information. Arbitrary information objects like documents, notes, rules or visualizations are stored in the database. Based on the *Abstract Model* a *Meta Model* is used to describe the structure of all standardized objects stored in the database. Comparable to an object oriented programming language objects like stiffeners or plates and their attributes can be defined using a custom XML file format. For each type so called instances with specific information about a certain characteristic configuration are defined, see Fig. 5 for an example. At the level of the *Instance Model* values are assigned for each object. Instances have attribute values that are either calculated by the included rule based computing system or saved as static values in the database. In Figs. 6 and 7 three instances of the bracket type "BCB" are shown. Following an approach developed for the storage of context information for the construction industry (Tolman 2002) systematics are applied for grouping of instances etc. into logical categories.

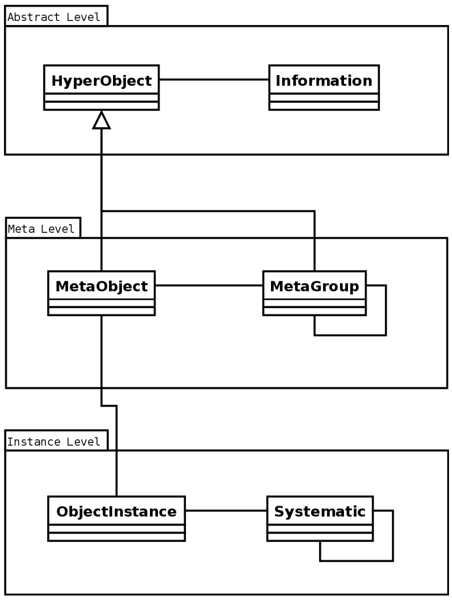


Fig. 5: Data Model of the Standards Database

The design process of an engineer working on a project is characterized by the search for suitable solutions for a given problem. A tree structure with parent-child relationships is automatically generated using information from the type definition. With the type-instance approach grouping of standard solutions is possible allowing for an initial structuring of the data available. The engineer is able to search for the best solution in the category or group suitable for the given problem. Also, using a generic query language and custom tags all standards can be sorted based on arbitrary conditions. This allows for a customization of the standards database for individual projects or for the problem at hand.

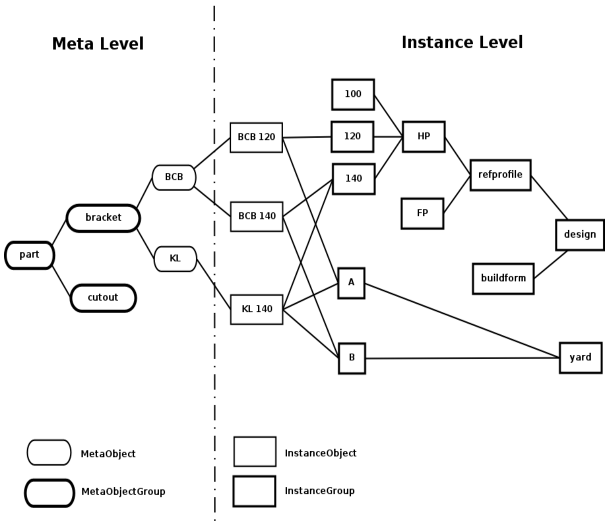


Fig. 6: Data Representation for Brackets

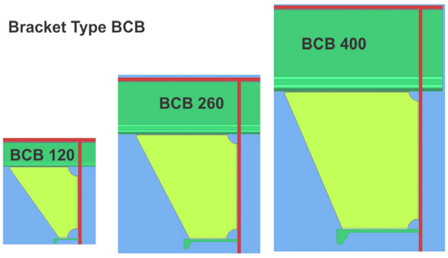


Fig. 7: Instances for Bracket Type BCB

Within the data model a distinction between aspects only relevant for the object to standardize and aspects that link to the context is made. Furthermore additional information is stored that is used to define the domain of applicability of a solution.

The first mainly pertains properties of the solution like shape, plate thickness or material, i.e. properties that can be expressed with key-value definitions and that are required to define the 3D representation in a CAD model or to add information required for manufacturing.

Because most CAD-systems used in the maritime industry offer functions to define the geometry of parts or features parametrically, currently the standards database does only include the parameters needed to model the actual geometry of a standard object from the parametric description provided by the CAD-system, i.e. the database provides the values for parameters given by the CAD-system.

Contextual aspects are used to tie a standard solution in the specific design context. As an example, the relationship of a bracket to the connecting stiffeners can be given. Also, the contextual aspect is important to find the best solution for a given problem as shown in Fig. 6. Here, for brackets of type BCB valid profiles for a stiffener-stiffener connection are defined. BCB120 is valid for HP120 profiles while BCB140 and KL140 are valid for a HP profile of 140 mm height.

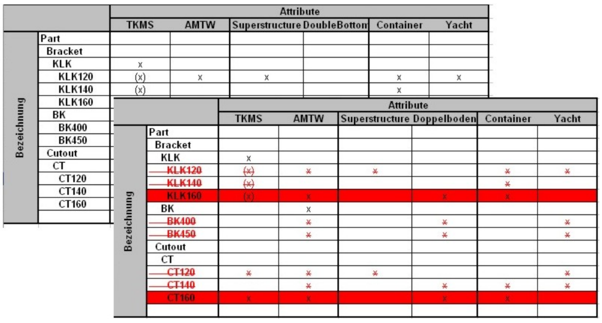
Based on the problem at hand and with the experience of an engineer a range of possible solutions is derived. The contextual information defined for each standard solution is evaluated to find only solutions that are valid for the specific problem. For example, strength requirements have to be fulfilled; the plate thickness must match the thickness of connected members etc. For the search for possible solutions constraints are defined using rule expressions. In the future it is planned to include more complex logical expressions using first order description logic.

In addition the application server provides the functionality to also store and serve unstructured information that can not be defined by constraints or rules. As examples documentation or visual representations can be given.

Views, Filters

With the system holding information about parts and features for detailed ship structural design the definition of views or systematics is possible. Using the contextual information defined for each object these do not only specify the fields of applicability but also to use this information to group objects valid for a given purpose or task. Views can be used to quickly query the standards database for a given problem.

As shown in Fig. 8 the definition of a view is based on object related and contextual properties. With this approach the validity of certain solutions can be restricted (constrained) to certain locations (superstructure, tanks) or for problems with specific requirements (high stress levels). Using these filters it is not only guaranteed that the designer uses the correct standards for a specific project but also for e. g. a given section of the vessel. Still, in the end the engineer actually using the standards database is responsible for choosing the correct filter for a problem.



		Attribute					
		TKMS	AMTW	Superstructure	DoubleBottom	Container	Yacht
Bezeichnung	Part						
	Bracket						
	KLK	x					
	KLK120	(x)	x	x		x	x
	KLK140	(x)				x	
	KLK160						
	BK						
	BK400						
	BK450						
	Cutout						
	CT						
	CT120						
	CT140						
	CT160						

		Attribute					
		TKMS	AMTW	Superstructure	Doppelboden	Container	Yacht
Bezeichnung	Part						
	Bracket						
	KLK	x					
	~~KLK120~~	~~(x)~~	~~x~~	~~x~~		~~x~~	~~x~~
	~~KLK140~~	~~(x)~~				~~x~~	
	KLK160	(x)	x		x	x	
	BK		x				
	~~BK400~~		~~x~~		~~x~~		~~x~~
	~~BK450~~		~~x~~		~~x~~		~~x~~
	Cutout						
	CT						
	~~CT120~~	~~x~~	~~x~~	~~x~~			~~x~~
	~~CT140~~		~~x~~		~~x~~	~~x~~	~~x~~
	CT160	x	x		x	x	

Fig. 8: Example of Views

Single Source for Data Consolidation

Today, most shipyards are specialized and build a limited range of different types of vessels. Mostly, for these vessels a similar set of standards optimized to the facilities on the shipyard and to the type of vessel is used for all ship newbuildings.

Using the facilities provided by the standards database it is possible to consolidate the different sets of standards into a single yard standard (Lum 2005). The effort needed for the management and synchronization of all standards for all projects is no longer required.

For each newbuilding the standard valid is derived as a subset from the yard standard. Certain design solutions are excluded; additional standards might be defined as part of the yard standard.

The definition of a standard for a project is performed using the views mentioned above, i.e. for each project the valid standard parts and features are identified. Subviews, i.e. views that are valid for a given project and a given task or location, can be derived by combining multiple views.

Workflows

With the information defined in the information base as well as in the additional modules the semantics of complex problem domains can be captured (Bronsart 2005). The domain of applicable solutions can be configured on a per-project and/or per-problem basis by the engineer hereby easing the process of choosing the optimal solution.

While such an approach is helpful for the inexperienced engineer or third-party design agents the engineer working on detailed steel structural design at the shipyard is familiar with the current standards applied. Still, incorrect design decisions occur due to overlooked details or oversight. In the domain of standardized parts and features, experience shows that this is especially true if the process of choosing and defining an optimal solution requires many parameters about dimensions etc. that are highly context sensitive.

In ship structural design the selection of an optimal standardized solution for a given problem can be defined as a series of steps, a so called workflow. As an example the selection process for cutouts based on contextual information is shown in Fig. 9 (provided by O. Feltz, Hamburg University of Technology).

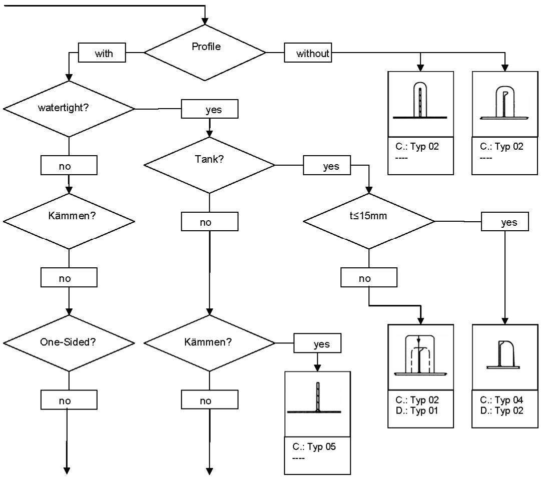


Fig. 9: Part of a Workflow for Cutout-Definition

For this purpose a custom workflow engine is integrated into the system. A modular approach was chosen to allow for the extension of the system at a later phase of development, see Fig. 10. With the workflow engine as central part of this component adapters are developed for information retrieval from other sources or for communicating actions to recipients. With the help of adapters access to programming APIs of other applications is provided. Using a subset of STEP AP 218 a product data model was developed for data exchange between applications.

Currently, adapters as shown in Fig 10 are available. The *User Adapter* is a highly generic general purpose software component to retrieve user input and to display information to the user. Configuration etc. is done automatically using the information given in the XML configuration file. The *Tribon Adapter* acts as interface between the custom API of the CAD-system and the standards server. For the API of the CAD-system the Vitesse framework is used. As part of the development in the CAD-system additional checks for validation etc. are implemented. The *KonSenS Adapter* provides access to information stored in the standards database as well as any other source to the workflow. In the future additional adapters providing information about global and local strength levels etc. are planned.

Taking up ideas from the *XML Process Definition Language* (XPDL) defined by the *Workflow Management Coalition* (Wmfc) a XML format for the definition of stateful workflows was developed. For each step in the decision process the options available are defined; required information and possible information sources are given. Using concepts from *Yet another Workflow Language* (YAWL) and as an extension to the XPDL definition “deferred choice” can be used.

With “deferred choice” the decision which source to use for information retrieval can be defined by the environment, for example a prioritized definition of available information sources. This allows the application of an identical workflow from within e. g. the CAD-system as well as stand-alone.

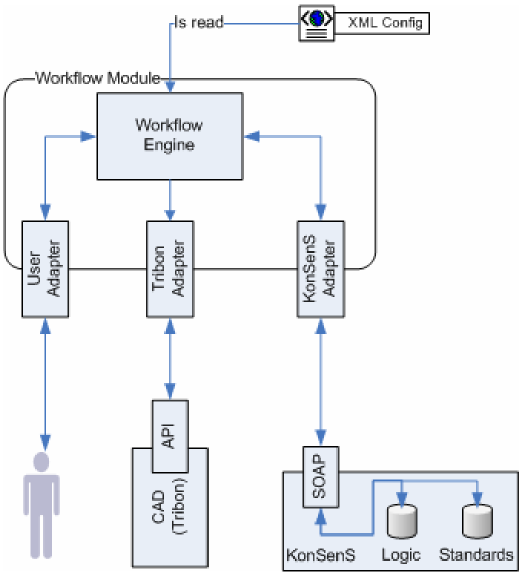


Fig. 10: Conceptual Model of the Workflow Engine

If e. g. for a certain step in the definition of a bracket for a stiffener-stiffener connection the height of the connected profiles is needed the system would first try to retrieve the information from the CAD-model available within the CAD-system using the *TribonAdapter*. If no connection to the CAD system is present or the information required is not available any additional information sources available would be used with manual input as final fall-back option.

If a CAD system is present and the data model offers the option to define custom information relevant user input can be stored in the data model for future use. E. g. the definition of a certain plate as tank wall is assigned for the first cutout defined. Subsequent cutout definitions reuse this information herby reducing the user input required; the work load of the engineer is reduced.

In future versions a top-down approach for the definition of additional contextual information will be used. The engineer will be asked to provide information about functional and other contextual aspect for each Tribon panel defined. Then, this information is available for following design steps.

Summary and Conclusions

A standards database can be used for a consolidated, centralized management of standards used in detailed ship structural design. With the improved application of standards series effects can be achieved; the total cost of a vessel can be reduced. Designers are given access to up-to-date information about standards to be applied. Views can be applied to provide a selection of valid standards for a given problem hence reducing the probability of incorrect design decisions. Documentation and additional information about standard solutions supply the user with additional knowledge required for a sound decision. With the integration into CAD-systems the standards database reduces the workload of an engineer considerably. A guided decision process prevents incorrect or not optimal design solutions.

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