ENGINEERING SCENARIOS, CREATING CONTEXT:
Product Development (Cryogenic Pressure Vessel)
Subsystem Replacement (Retriever's Rudder Redesign)
Year 2, First Quarter

by
Victor Mucino, Sam Sarovar, Aaron Montejo
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INTRODUCTION

When engineering projects are carried out, a number of engineering tasks are conducted in which information is created, transformed, retrieved and transferred within specific tasks, to ultimately generate the detailed description of what is to be built and how it is to be built, installed, operated, serviced and disposed.

Several scenarios can also be cited as "typical," in which a series of information exchanges and engineering tasks ultimately result in a "system change", which may well be the product of redesigns, repairs and adaptations, which in turn, may be needed in order to maintain a system or unit in proper operation through its lifecycle.

When a system is designed, redesigned, modified or adapted to comply with prescribed operating conditions, documentation of the engineering tasks is not customarily conducted in a systematic way to ensure comprehensive technology archival preservation. In most cases, a series of documents in various formats and media are generated, which have some relation to the final characteristics of the system but without a clear intent, on the part of the engineers involved, to provide a structured roadmap of documentation generated through the project development. The ultimate result of this practice is often the "reinvention of the wheel" due to the lack of "engineering context" in typical documentation available at the end of a project.

In this project, a generic engineering scenario is proposed that can serve as the basis for establishing a roadmap, conducive to a structured documentation with "engineering context." The main objective is to identify engineering tasks, document types and data classification, which can be supported by STEP application protocols, above and beyond to what currently is available in current industrial practice. The results sought will produce possible add-ons to current or non-existing STEP application protocols and will provide a perspective to expand the application of currently available application protocols.

PROBLEM DEFINITION

The problem being addressed here is the lack of a systematic approach to capture the majority (or much) of the data transactions and the sequence in which they occur in order to provide context to the final design characteristics for archival purposes. This problem is being addressed by defining clusters of engineering tasks that are typically developed in various engineering scenarios: Specifically the clusters are:

1. Geometric Synthesis, which implies any task aimed at defining the geometric features (2D or 3D) of physical systems, structures or components, at the single or multi-component system level).
2. Material properties characterization, which may involve the determination of material properties that are necessary to include in mechanistic models for analysis, simulation purposes or for design formulas.
3. Loading and boundary conditions definition, which involve the definition of loads from prescribed operating conditions and application site.
4. Failure mode criteria, typically involving the functional or operational failure criteria to be used in the design, including reliability and life expectancy.

The engineering scenarios that can be developed by grouping tasks into these clusters and having a flow of information and sequence of tasks that will produce the objectives required. The following generic scenarios can be created:

5. Geometric design. A scenario which results in the geometric determination of a particular system, given the loads and boundary conditions to carry, the materials to be used and the target failure criteria (safety factor, reliability, life expectancy).
6. Material selection. A scenario which results in a material selection based on properties that are relevant to the specific performance requirements, given a required geometry, prescribed loads and boundary conditions and failure criterion.
7. Load capacity determination. In this scenario, the load capacity of a system or components is sought based on the given geometry, material properties and failure criterion. Sometimes is not necessarily load capacity but some performance measure, for example acceleration capacity, flow or heat rate capacity etc.
8. Boundary condition verification. This is a scenario in which the main objective is to determine how a system or component is to be supported, or what interfaces it will have with the rest of the system. These interfaces are the basis for boundary condition definition for mechanistic modeling purposes but also for final configuration of system within its environment.
9. Failure verification. This is the scenario that results when all the information is available on geometry, materials and loads and boundary conditions. The main objective is to determine if the failure criterion to be used is satisfied or not. Typically this is the case of computational mechanics models (finite elements) but can also be the result of testing procedures, to verify that performance measures are appropriate.

GENERIC ENGINEERING SCENARIOS AS PROCEDURAL ROADMAPS

Combinations of these scenarios can give rise to more practical and typical engineering scenarios, which can be captured through information flow diagrams involving input/output data requirements in connection with tasks, functions and possibly resources, tools equipment etc.

Several scenarios can be developed for some cases that are typically encountered in the design of mechanical engineering systems and structures. These cases are described next:

10. Trouble shutting of malfunctions (Case of a leaky transmission).

    An example of this case scenario was illustrated in a previous report. The case used relates to a heavy duty transmission malfunction which required, testing, analysis, calculations, field observations, tabulations and finite element modeling in order to determine the cause of the problem and how to fix it. Many mechanical systems encounter problems when unanticipated conditions occur or when changes in some parts take place, which produce an effect elsewhere. That was the case of the transmission "trouble shutting" case illustrated in the previous report. Only the general diagram of Fig. 1 below is included here to showcase how tasks and data transactions were documented. The Green framed blocks designate tasks or functions that can be currently supported by STEP AP's. The blue framed tasks are the ones which can possibly be supported but are not readily available in CAD software. The red framed tasks are not supported by STEP AP's.

    It should be noted that the scenario presented in this case study does not contemplate fabrication, manufacturing or assembling operations, which are to be addressed in future examples, in which the approach to manufacture or assemble a system may have an impact on the design decisions to be made.

    It should also be noted that during the development of the above described tasks, the documents produced were not meant to be archived for long term preservation purposes. However, the cases study provided a good example to illustrate the various tasks functions and the variety of data and information documents and formats.

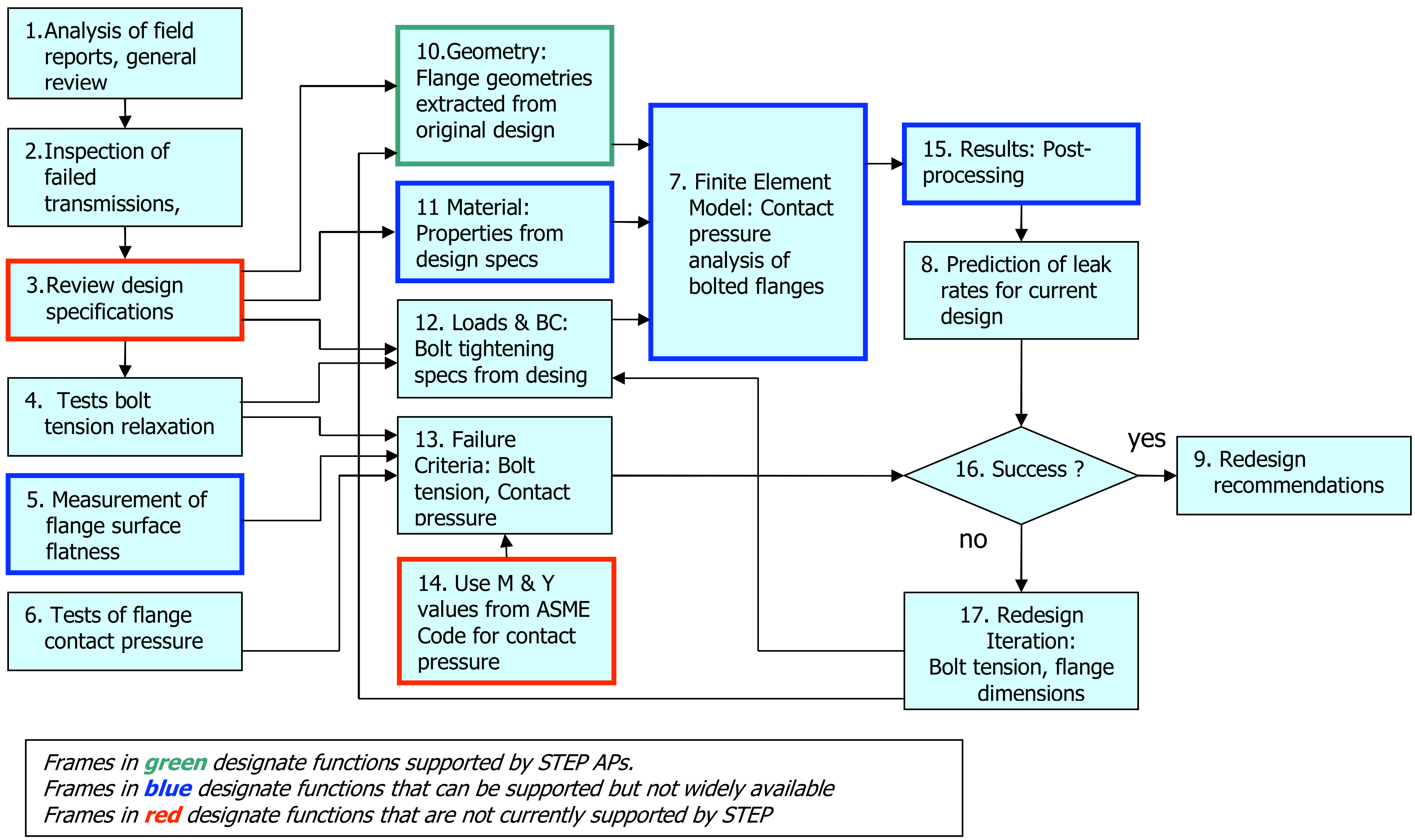


Figure 1. Engineering scenario for trouble-shooting of a heavy duty transmission.

11. <u>Technology development from scratch (Case of a Cryogenic Pressure Vessel)</u>.

This is a case in which a mechanical system is designed from scratch, based on user or customer requirements (defined in very general terms). This scenario will use prior experience in systems design to select appropriate configurations and will produce a series of iterations of design synthesis, material selection and failure verification with a "redesign" cycle aimed at producing a final design to satisfy customer requirements.

A case study is being developed as an illustration for the design of a pressure vessel for cryogenic application. A tank manifold is being designed to contain and supply liquid nitrogen for a superconductor line. The tank is to operate at cryogenic temperatures, which call for very specific conditions for the design. The diagram describing the engineering scenario is shown in Fig 2 below, in which again the green, blue and red frames indicate the applicability of STEP application protocols.

The tasks and functions point to various documents in various formats, that convey the information needed and produced in the various tasks. For example "Customer requirements" of block 1, points to a simple documents which can be a work order, a simple (high level definition) description of requirements for the component. This document would be in any text-table format. The task involving the geometry definition (blocks 4 and 5) of the system involve hyperlinks to jpeg pictures of the tank solid models (CAD), and also provide a connection to STEP files produced in the process. But an important task of mechanistic models (block 8) involves tabulations, which invoke material property tables, worksheet calculations, and reference to ASME Standards, which provide a "context" to the geometry at which the designer arrived.

The details of the various tasks so far developed in this case student are provided in Appendix 1 of this document, in which the design of four components are described with supporting interconnected elements in the worksheet tabulation. **Appendix 1** below, thus contains the steps and data exchanges

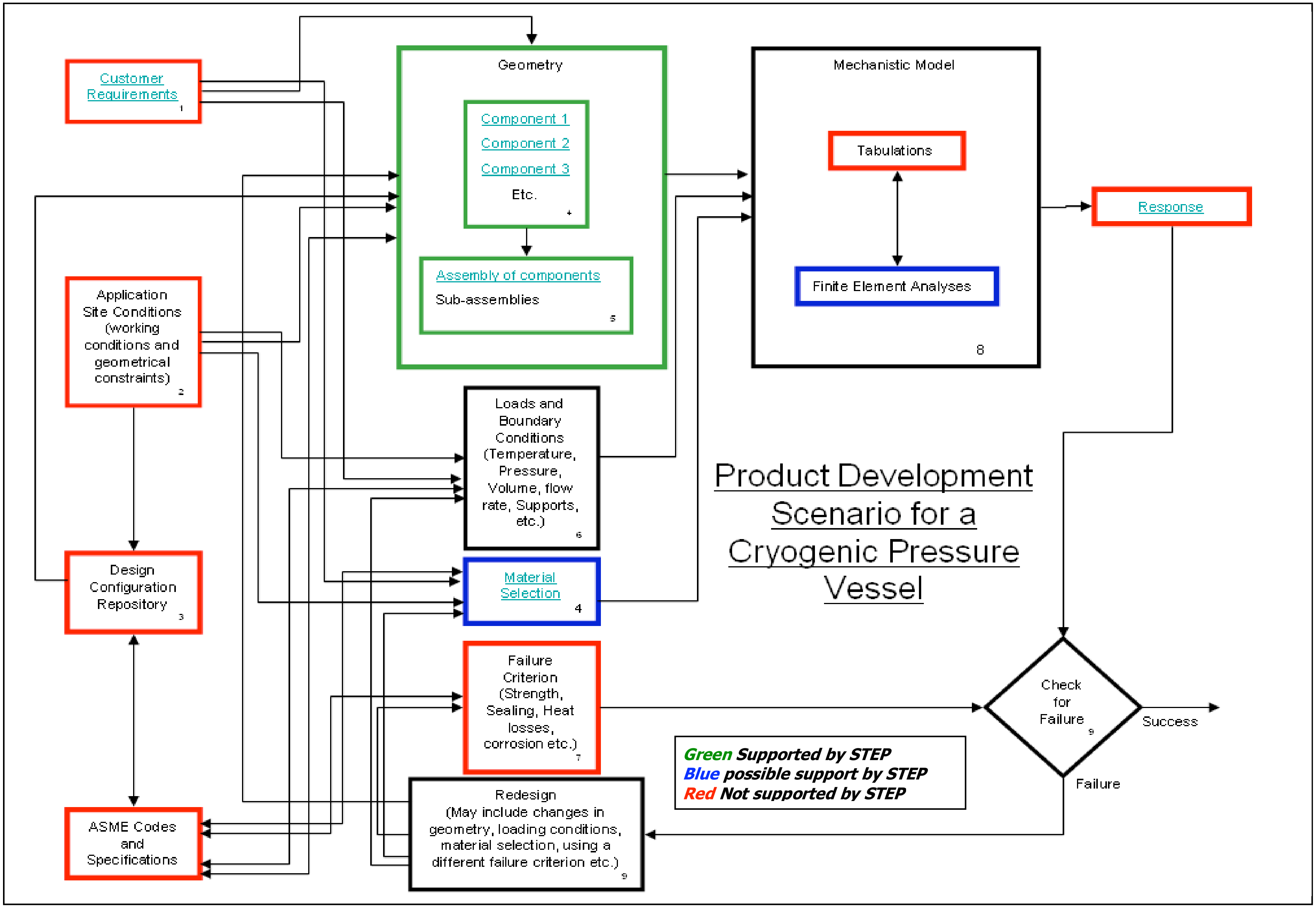


Fig. 2. Engineering Scenario for the design of a cryogenic pressure vessel

This function is in red because no STEP AP currently exists that can capture tabulations, like the one illustrated in this example. A translator from Excel to Express language, would provide the functionality of capturing worksheets typically used by engineers to conduct engineering calculations, with references to STEP files, jpeg's and other materials

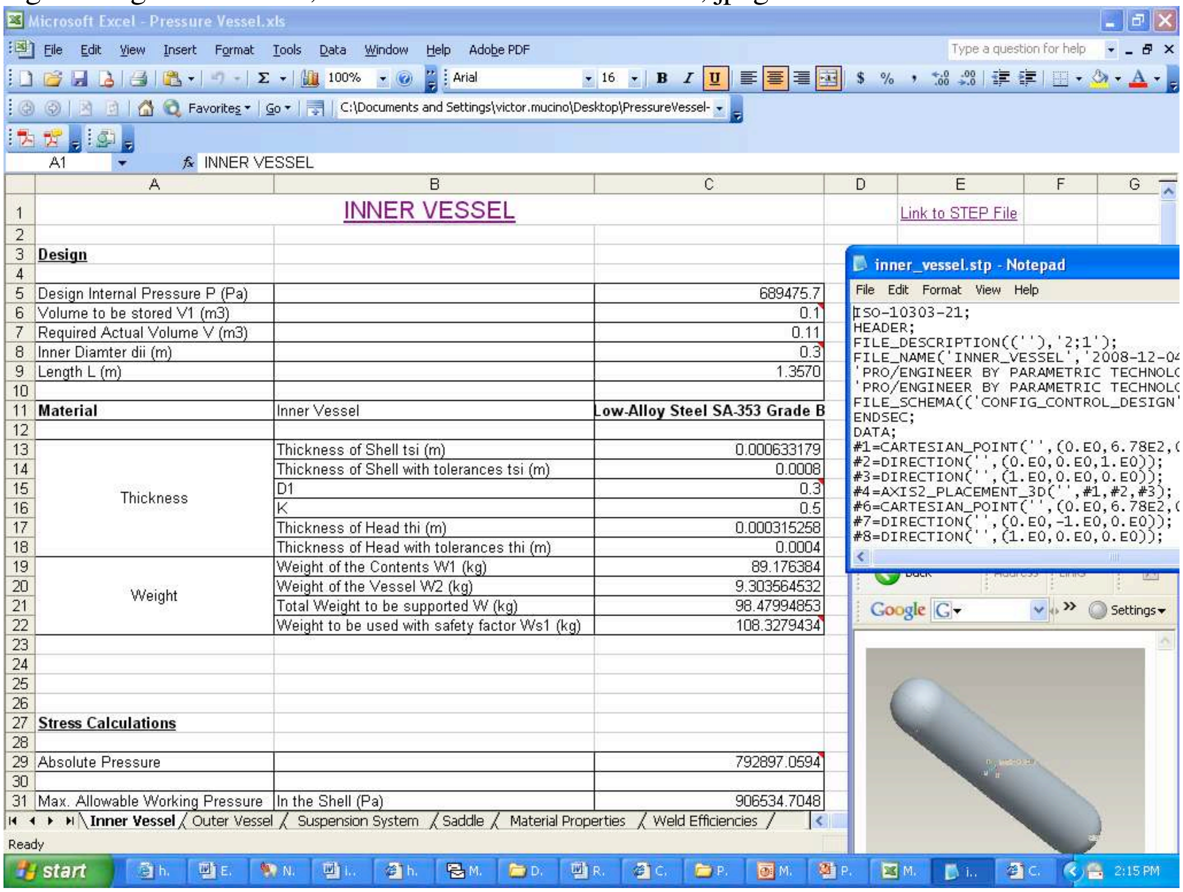


Fig. 3. Worksheet hyperlinked to the engineering scenario used for engineering calculations with reference to STEP and jpeg files.

The material designation cell in the above spread sheet for example leads to another worksheet (Fig 4) with relevant properties for the design and a link to the source of information, which is a table hosted on a public site. The table can be added as yet another hyperlink document (a picture here for illustration) is shown in Fig 5 below.

	A	B	C	D	E	F
1	Material Property Chart					
2						
3	**Material Property**	**Modulus of Elasticity (Pa)**	**Tensile Strength (Pa)**	**Poissons Ratio**	**Allowable Stress (Pa)**	**Density (kg/m3)**
4	Aluminium SB 209(1100-0)	6.89E+10	75842330.22	0.33	16202679.63890	2710
5	Aluminium SB 209(5083-0)	7.03E+10	275790291.7	0.33	68947572.93100	2660
6	Aluminium SB 209(6061-T4)	6.89E+10	206842718.8	0.33	51710679.69880	2700
7	Carbon Steel SA-129 Grade A	1.99E+11	275790291.7	0.26	68947572.93100	7850
8	Carbon Steel SA-285 Grade C	1.99E+11	379211651.1	0.26	94802912.78120	7850
9	Carbon Steel SA-299	1.99E+11	517106797	0.26	129276699.24709	7850
10	Carbon Steel SA-30 Firebox A	1.99E+11	379211651.1	0.26	94802912.78000	7850
11	Copper SB-11	1.10E+11	206842718.8	0.35	46194873.86400	8960
12	Low-Alloy Steel SA-202 Grade B	2.20E+11	586054369.9	0.29	146513592.48000	7800
13	Low-Alloy Steel SA-353 Grade B	2.20E+11	655001942.9	0.29	163750485.71200	7800
14	Low-Alloy Steel SA-410	2.20E+11	413685437.6	0.29	103421359.39767	7800
15	Monel SB-127(annealed)	1.69E+11	482633010.5	0.295	120658252.63000	8800
16	Stainless Steel SS304	1.93E+11	517106797	0.29	129276699.24709	7916.452
17	Stainless Steel SS304L	1.93E+11	482633010.5	0.29	120658252.63000	8000
18	Stainless Steel SS316	1.93E+11	517106797	0.29	198224272.17888	8000
19	Stainless Steel SS410	2.00E+11	448159224.1	0.29	112039806.01410	7800

Fig 4. Material relevant property table

From: www.matweb.com

304 Stainless Steel

Categories: Metal; Ferrous Metal; Heat Resisting; Stainless Steel; T 300 Series Stainless Steel

Material Notes: Austenitic Cr-Ni stainless steel. Better corrosion resistance than Type 302. High ductility, excellent drawing, forming, and spinning properties. Essentially non-magnetic, becomes slightly magnetic when cold worked. Low carbon content means less carbide precipitation in the heat-affected zone during welding and a lower susceptibility to intergranular corrosion.

Applications: beer kegs, bellows, chemical equipment, coal hopper linings, cooking equipment, cooling coils, cryogenic vessels, dairy equipment, evaporators, flatware utensils, feedwater tubing, flexible metal hose, food processing equipment, hospital surgical equipment, hypodermic needles, kitchen sinks, marine equipment and fasteners, nuclear vessels, oil well filter screens, refrigeration equipment, paper industry, pots and pans, pressure vessels, sanitary fittings, valves, shipping drums, spinning, still tubes, textile dyeing equipment, tubing.

Corrosion Resistance: resists most oxidizing acids and salt spray.

UNS S30400; AMS 5501, 5513, 5560, 5565; ASME SA182, SA194 (8), SA213, SA240; ASTM A167, A182, A193, A194

Key Words: aisi304, aisi 304, T304, T 304, SUS304, SS304, 304SS, 304 SS, UNS S30400, AMS 5501, AMS 5513, AMS 5560, AMS 5565, AMS 5566, AMS 5567, AMS 5639, AMS 5697, ASME SA182, ASME SA194 (8), ASME SA213, ASME SA240, ASME SA249, ASME SA312, ASME SA320 (B8), ASME SA358, ASME SA376, ASME SA403, ASME SA409, ASME SA430, ASME SA479, ASME SA688, ASTM A167, ASTM A182, ASTM A193, ASTM A194, ASTM A666, FED QQ-S-763, MILSPEC MIL-S-5059, SAE 30304, DIN 1.4301, X5CrNi189, B.S. 304 S 15, EN 58E, PN 86020 (Poland), OH18N9, ISO 4954 X5CrNi189E, ISO 683/13 11, 18-8

Vendors: **Click here to view all available suppliers for this material.**

Please click here if you are a supplier and would like information on how to add your listing to this material.

Physical Properties	Metric	English	Comments
Density	8.00 g/cc	0.289 lb/in³	

Mechanical Properties	Metric	English	Comments
Hardness, Brinell	123	123	Converted from Rockwell B hardness.
Hardness, Knoop	138	138	Converted from Rockwell B hardness.
Hardness, Rockwell B	70.0	70.0	
Hardness, Vickers	129	129	Converted from Rockwell B hardness.
Tensile Strength, Ultimate	505 MPa	73200 psi	
Modulus of Elasticity	193 - 200 GPa	28000 - 29000 ksi	
Poissons Ratio	0.290	0.290	
Charpy Impact	325 J	240 ft-lb	
Shear Modulus	86.0 GPa	12500 ksi	

Electrical Properties	Metric	English	Comments
Electrical Resistivity	0.0000720 ohm-cm	0.0000720 ohm-cm	at 20°C (68°F); 1.16E-04 at 650°C (1200°F)
Magnetic Permeability	1.008	1.008	at RT

Thermal Properties	Metric	English	Comments
CTE, linear	17.3 µm/m-°C @Temperature 0.000 - 100 °C	9.61 µin/in-°F @Temperature 32.0 - 212 °F	
	17.8 µm/m-°C @Temperature 0.000 - 315 °C	9.89 µin/in-°F @Temperature 32.0 - 599 °F	
	18.7 µm/m-°C @Temperature 0.000 - 650 °C	10.4 µin/in-°F @Temperature 32.0 - 1200 °F	
Specific Heat Capacity	0.500 J/g-°C	0.120 BTU/lb-°F	from 0-100°C (32-212°F)
Thermal Conductivity	16.2 W/m-K	112 BTU-in/hr-ft²-°F	at 0-100°C, 21.5 W/m°C at 500°C
Melting Point	1400 - 1455 °C	2550 - 2651 °F	
Solidus	1400 °C	2550 °F	
Liquidus	1455 °C	2651 °F	

Material Components Properties	Metric	English	Comments
Carbon, C	<= 0.0800 %	<= 0.0800 %	
Chromium, Cr	18.0 - 20.0 %	18.0 - 20.0 %	
Iron, Fe	66.345 - 74.0 %	66.345 - 74.0 %	
Manganese, Mn	<= 2.00 %	<= 2.00 %	
Nickel, Ni	8.00 - 10.5 %	8.00 - 10.5 %	
Phosphorous, P	<= 0.0450 %	<= 0.0450 %	
Silicon, Si	<= 1.00 %	<= 1.00 %	
Sulfur, S	<= 0.0300 %	<= 0.0300 %	

References for this datasheet.

Internet

Fig.5. Table of material properties from a material database site.

All the information contained in the previously described documents together with the data flow diagram of Fig 2 above describing the "Engineering Scenario" can actually be documented with tools that can be applied for this purpose.

Under the assumption that the work done in this project will be "reviewed", "inspected" or simply "browsed" in the future (30/40 years or more), as long as it is possible to recreate the worksheet, the block diagrams, the jpegs, the text files, and the STEP files, not only the geometry will be retrievable but also in large measure the context of the development. The geometry picture (Fig 5) illustrates the "end result", but all the documents described above provide an engineering context to the design.

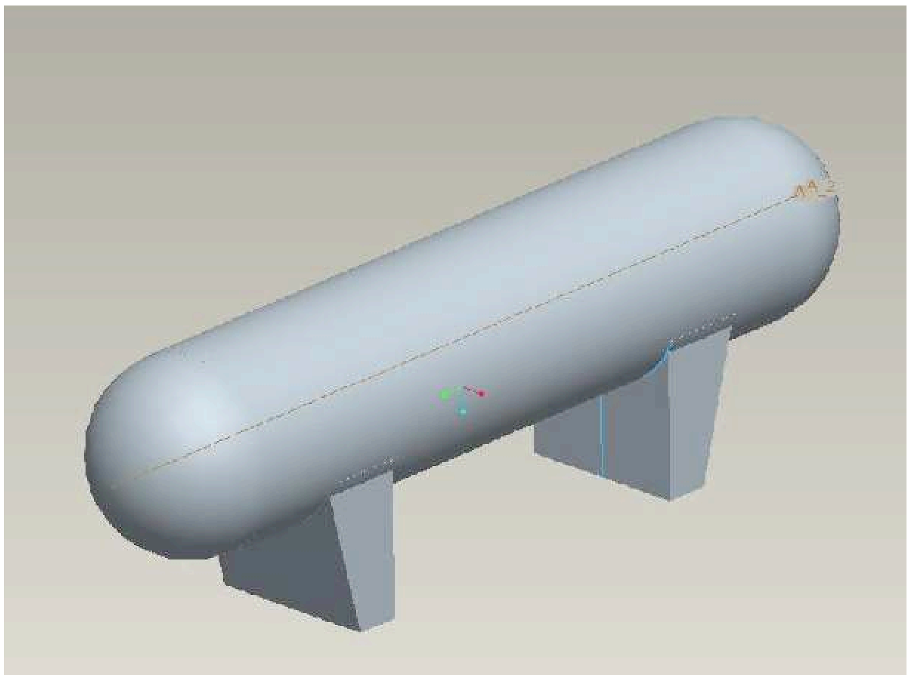


Fig 6. Final design picture of the cryogenic tank with supports

In this cases study currently being developed by our WVU team, the design tasks will continue to iterate until all the components are properly integrated to the design, specifically the fittings for the inlet and manifold outlets. These elements are called bayonets and are to be designed and reported in subsequent reports. The bayonets are intended to supply a steady flow of liquid nitrogen to a superconductor application. The fabrication and manufacturing tasks (like forming and welding sequences) will be integrated through tasks that are yet to be described and will be part of future reports.

It should be noted that in this scenario, several important documents are being interconnected through "hyperlinks", which include: the flowchart (which is a MS power-point document), a multi-page worksheet tabulation (a MS Excell document), STEP files with geometry of various components (ASCII Notepad documents), picture files of various types (jpeg's and postscript documents). Future scenarios will also include clips and other visualization elements like PDF3D. All of this will provide "engineering context" in the documentation of the vessel.

12. Subsystem replacement with design improvement (Case of 120’ retriever rudder redesign).

In this case it is assumed that a system exists (120’ Torpedo Retriever) of which a large number of units require a subsystem to be replaced. The reason for the replacement could be a faulty design, damaged subsystem due to accidents, or simply a replacement due to “old age”, but if a replacement is to be conducted, a design improvement is in order. In this case, all the information is “available” through “blue prints”, which have actually been provided to our team in the form of high resolution scans of hand-made blue prints for the vessel.

The rudder subassembly is available in the form of STEP files, which can be used with existing CAD tools (ProE, CATIAV, Workbench etc.) and pictures describing the geometric features, which can be extracted and verified against the blueprints. In redesigning a rudder, several functions are necessary that can also be clustered un groups similar to what has been done in the case of the leaky transmission or in the case of the cryogenic pressure vessel. The diagram of Fig 7 below illustrates the generic “engineering Scenario.”

This case study is still under development and is using the material provided in the repositories, but in neither repository however, engineering context is provided to understand the driving issues that resulted in the final configuration. For instance, some questions need to be asked and resolved in order to “redesign” and improve the rudder, such as what is the size of the propellers, what is the power of the engines, what are the expected speeds of the ship, what is the rated Reynolds number for the flow to be diverted, what are the pressures to which the rudder is exposed….. Should a flat plate be used? Should an airfoil be used?... are there specific performance requirements for the rudder?... All these questions (among others) provide the “engineering context” necessary to develop an appropriate (effective) redesign improvement and replacement of the rudder.

It is entirely possible that the current design is near optimum and thus no major changes be put forward for the replacement. But this should be a conclusion arrived at through analysis and rational design practice, as opposed to simply anecdotal references (something like “based on my experience, this looks good enough” or “this rudder works fine in another application so it should be ok here”)

The block diagram shown below, again is a representation of the various engineering task clusters that need to take place in order to generate an improved redesign (or a verification that the current design is appropriate). The tasks illustrated below (and interconnected through hyperlinks to working documents) represent the roadmap to recreate the “engineering context” which will lead to the redesign of the rudder, but most importantly to identify the information, data and working documents that can possibly be stored through STEP application protocols (some of them currently being used (green) , some of them available but not widely applied (blue) , some of them yet to be developed(red)).
Further detail of the tasks in this scenario are provided in Appendix 2 at the end of this report

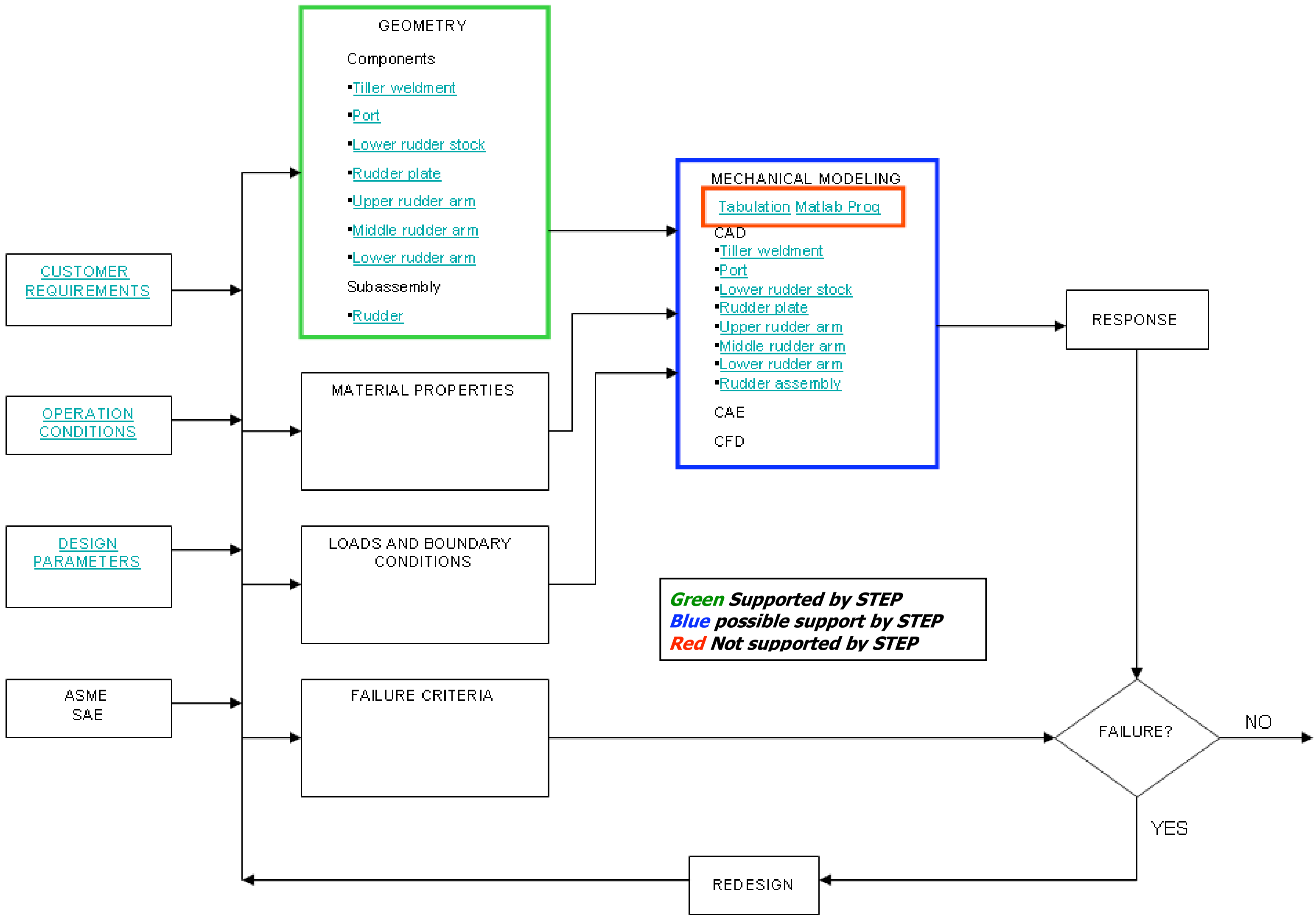


Fig 7. Rudder redesign for the 120' Retriever scenario

As in the previous case (the cryogenic pressure vessel), the task involving the geometric definition of the rudder, provides hyperlinks to jpegs and step files with the actual geometry taken from blue prints. Fig 8 below shows the subassembly of the rudder.

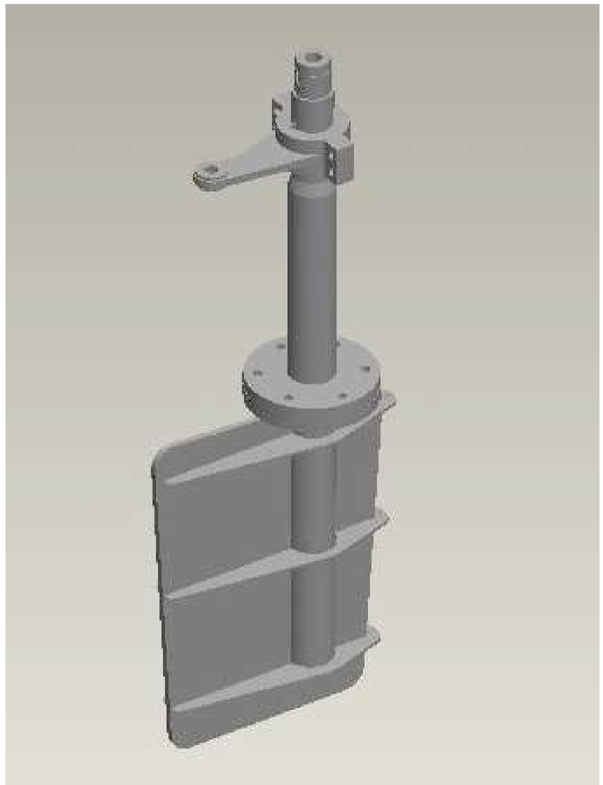


Fig 8. Rudder for the 120' Retriever

In this case, no context exists, other than the blue print. But it is assumed that a design procedure took place which took into account the type of ship, large or small, fast or slow, power-train with engine, transmission, drive-shaft and propeller. All of this information including the extreme conditions of operation of this ship (for example can this ship be used in artic waters or in the midst of an oil spill etc.). In the process engineering calculations will be necessary to produce performance characteristics of the rudder in terms of the specific application.

The tabulation (in red frame) in this case is conducted using a Matlab subroutine, which produces performance plots as illustrated in Figure 9 below. The text of Fig 10 is part of the actual Matlab routine used in producing the performance plots.

Each of the other tasks (still under development by our group) invokes certain parameters, certain information yet to be deployed and applied to produce not only a redesign, but also to capture the engineering procedure that leads to it.

For illustration purposes only and with the objective of "capturing context" the various documents are hyperlinked to the flowchart of the engineering scenario.

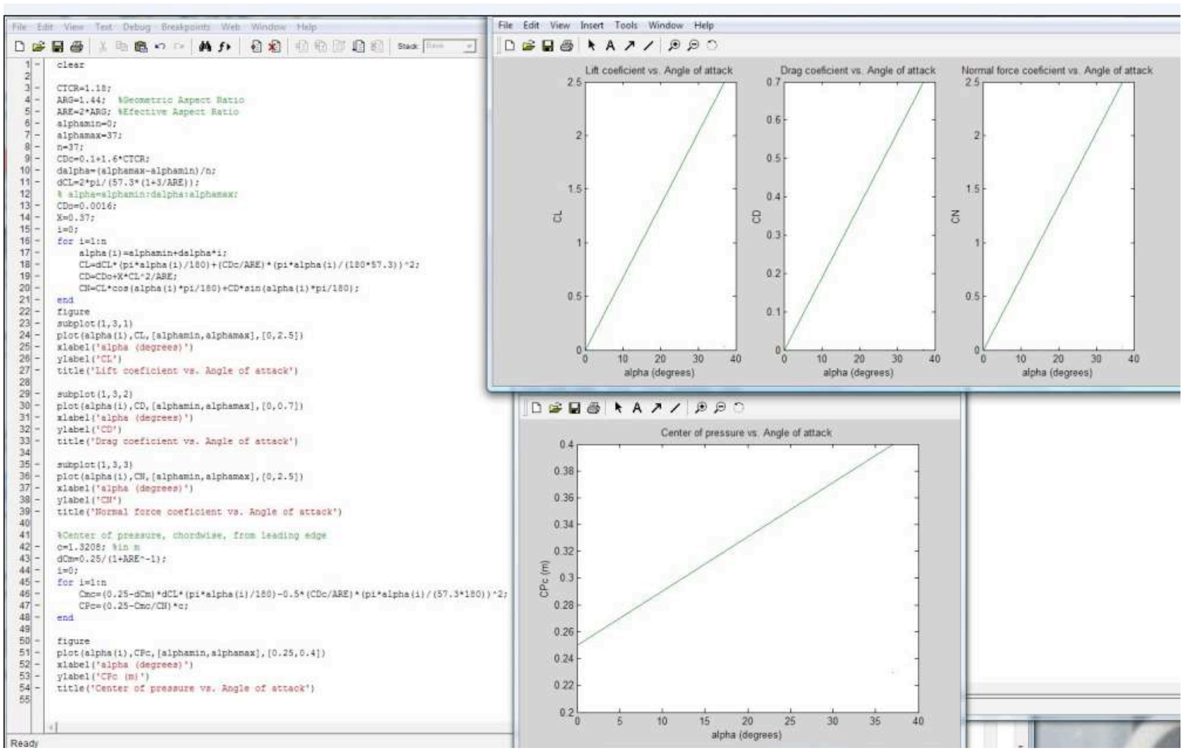


Fig 9. Matlab subroutine used as a mechanistic model with rudder performance plots

```
CTCR=1.18;
ARG=1.44;  %Geometric Aspect Ratio
ARE=2*ARG; %Efective Aspect Ratio
alphamin=0;
alphamax=37;
n=37;
CDc=0.1+1.6*CTCR;
dalpha=(alphamax-alphamin)/n;
dCL=2*pi/(57.3*(1+3/ARE));
% alpha=alphamin:dalpha:alphamax;
CDo=0.0016;
X=0.37;
i=0;
for i=1:n
    alpha(i)=alphamin+dalpha*i;
    CL=dCL*(pi*alpha(i)/180)+(CDc/ARE)*(pi*alpha(i)/(180*57.3))^2;
    CD=CDo+X*CL^2/ARE;
    CN=CL*cos(alpha(i)*pi/180)+CD*sin(alpha(i)*pi/180);
end
figure
subplot(1,3,1)
plot(alpha(i),CL,[alphamin,alphamax],[0,2.5])
xlabel('alpha (degrees)')
ylabel('CL')
title('Lift coeficient vs. Angle of attack')

subplot(1,3,2)
plot(alpha(i),CD,[alphamin,alphamax],[0,0.7])
xlabel('alpha (degrees)')
ylabel('CD')
title('Drag coeficient vs. Angle of attack')

subplot(1,3,3)
plot(alpha(i),CN,[alphamin,alphamax],[0,2.5])
xlabel('alpha (degrees)')
ylabel('CN')
title('Normal force coeficient vs. Angle of attack')

%Center of pressure, chordwise, from leading edge
c=1.3208; %in m
dCm=0.25/(1+ARE^-1);
i=0;
for i=1:n
    Cmc=(0.25-dCm)*dCL*(pi*alpha(i)/180)-0.5*(CDc/ARE)*(pi*alpha(i)/(57.3*180))^2;
    CPc=(0.25-Cmc/CN)*c;
end

figure
plot(alpha(i),CPc,[alphamin,alphamax],[0.25,0.4])
xlabel('alpha (degrees)')
ylabel('CPc (m)')
```

Fig 10. Matlab code used in the process of conducting engineering calculations to redesign the rudder

13. Adaptation of existing designs to different operating conditions. This case is yet to be developed, but in general, similar tasks will be required to take an existing mechanical system and adapt it for a new application of simply for different operational requirement ranges. An example would be to change the power source technology in the 120' Retriever, assuming that the new power sources (engine) and drive-train should be able to operate with alternate fuels or even multi-fuel possibilities.

14. Repairs of damaged subsystems. This case is a typical case of repairs due to unforeseen circumstances that result in damages due to collisions, accidents, and other severe or catastrophic conditions which were not anticipated. In this cases, it would be necessary to recreate the context of the specific subsystem design.

CONCLUSIONS: CONNECTION WITH STEP PROTOCOLS

The above scenarios and task clusters have been illustrated in previous reports in this program. The connection with STEP Application protocols is that by being able to describe a diagrammatic description of engineering tasks and functions into what has been called "Engineering Scenarios" or roadmaps, it is possible to identify information documents and data, which can be used to document specific technology in a contextual manner (what was produced, why , how and when). Some of the data typically produced (mainly geometry) can be supported by STEP Application Protocols (AP203, 204, 214), and few other data sets can also be supported by STEP application protocols, although these protocols may not be easily available. But most importantly, some data that contain engineering procedural information (contextual) are not currently supported by STEP application protocols.

At this point, it is felt that contextual engineering scenarios can be captured as long as three conditions are met:

1. Engineers document engineering tasks with references to sources of information and prospective function for which data and information are produced.
2. Document worksheet tabulations, engineering calculation procedures and mechanistic modeling functions (physical and computational) that produce performance measures of the system.
3. Engineering scenarios as can be constructed through functional block diagrams which can provide a roadmap of engineering tasks and data transactions with a sequential dimension, in order to establish an inferential frame on the context of the system design.

Note: a Federal Information Processing Standard (FIPS) exists that invokes a tool called (IDEF0) for Function Modeling. This standard permits the construction of models comprising system functions (activities, actions, processes, operations), functional relationships, and data (information or objects) that support systems integration. This product is being assessed as an alternative for flowcharting engineering scenarios in the future, but the connection of this standard and STEP is yet to be explored in earnest.

Appendix 1
Cryogenic Pressure Vessel Design

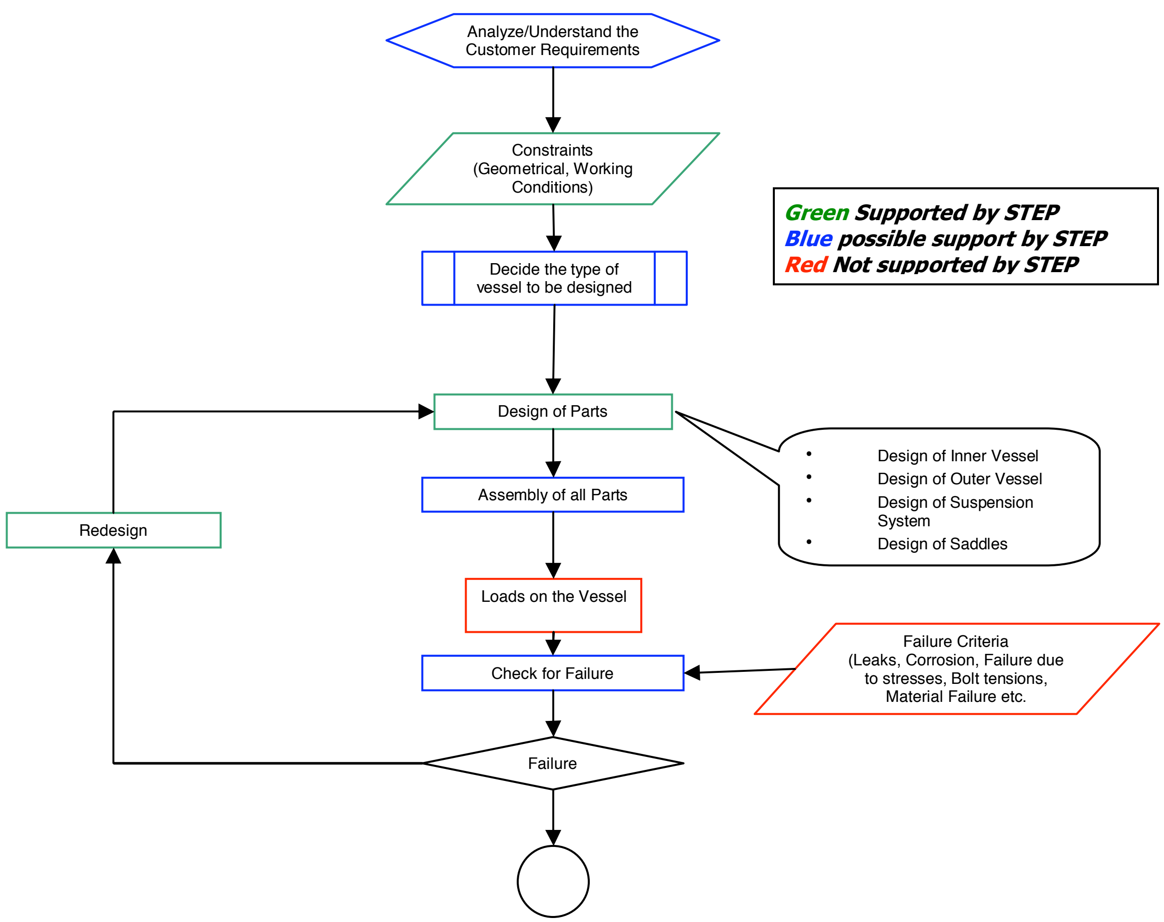
By Sam Sarovar

We look at a case study, which is the design of a cryogenic pressure vessel, used to supply liquid nitrogen for a super conductor application. The vessel operated at sub zero temperatures, and there are a few requirements in the flow of fluid through this vessel.

"The pressure vessel must be under extremely high vacuum external pressures to provide adiabatic insulation. One inlet and three outlets at equal pressure and flow rate are the performance measures in addition to the structural soundness."

The first step is to design the structure of the vessel, keeping in mind the performance requirements.

Design of Pressure Vessel:



The main tasks are still 'Building Geometry', 'Loads and Boundary Conditions', 'Material Selection', and 'Failure Criterion'. Thus, this acts as the very general overview, whereas at each step, there are many other tasks involved in completion of the design.

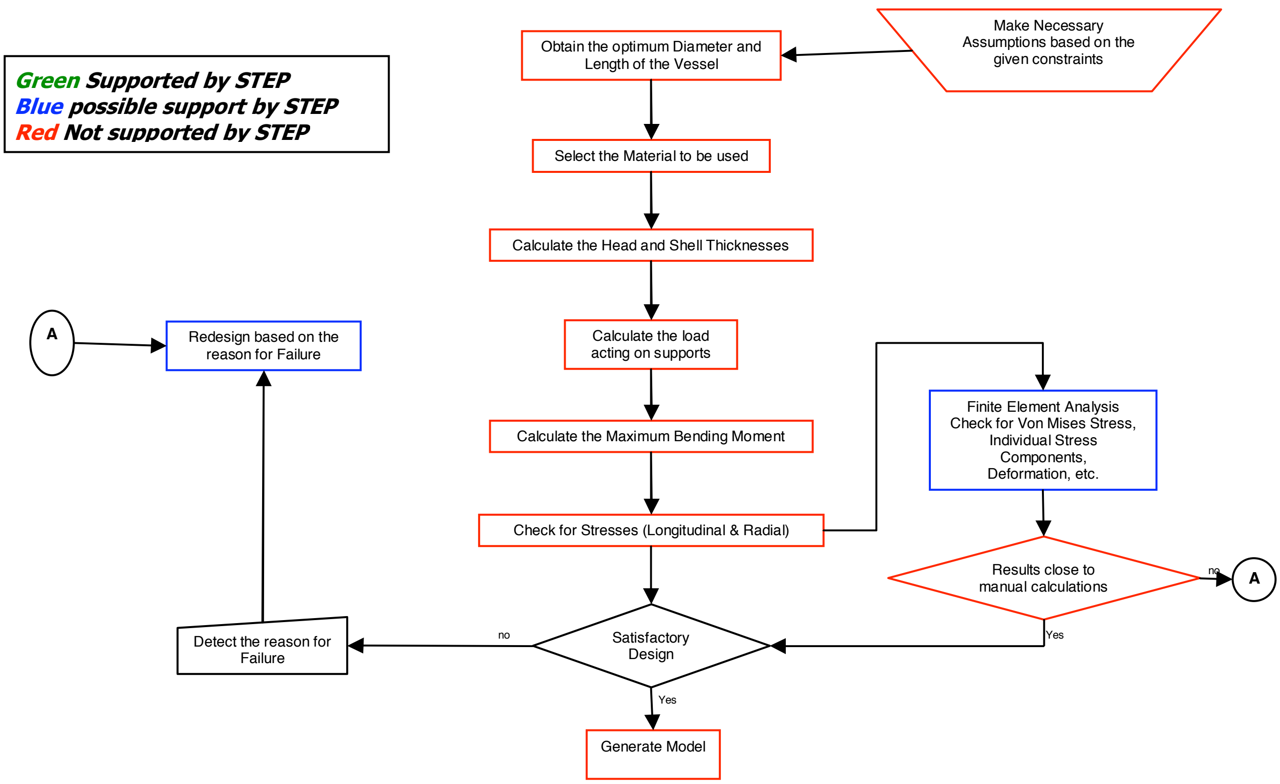
The Design of Parts indicates the various parts that need to be designed and assembled in order to build the vessel. Once the vessel has been built, the model is analyzed and deemed ready for use. The process is iterative, and is carried out until the optimum design is obtained.

Tasks:

1. Analyze/Understand the requirements from the pressure vessel [may also be customer requirements].
2. Understand the Constraints on the vessel. Most often, they are constraints on capacity, dimensions, and usage. In this case, we assume the capacity and dimensions as constraints.
3. Based on the usage, and the previously assumed constraints, we decide the specifics of the pressure vessel. Since the Vessel has to hold Liquid Nitrogen, we know that heat loss is an important cause of failure and that temperature stresses are predominant. Hence, we decide that *there has to an inner vessel and an outer vessel, and a vacuum chamber between the two, to reduce heat loss*. Since the usage is for a superconductor application, the *vessel has to be of a lower capacity*.
4. All parts other vessel are designed. [Discussed later on in the document]
5. Assembly of the parts.
6. The Vessel is then subjected to the loads as it would in actuality. *The vessel is placed in STP conditions*.
7. The vessel is then checked for possible failure due to various reasons. *Manual Calculations and Simulations provide good means of analyses. Failure in this case can occur due to heat loss, leakage in cylinder, thermal stresses, freezing of parts, etc.*
8. If the analyses provide satisfactory results, the vessel is sent to the next step of operations. If not, then the reason is found, and the model is sent for redesign.

Design of the parts once again is basically the same procedure, with a few added processes and tasks. Here, the pressure vessel consists of an Inner Vessel, an Outer Vessel, a Suspension System for the inner vessel, Saddles to support the outer vessel, Nozzles, etc. Some of the design processes are described as follows:

Design of Inner Vessel:



Tasks:

1. Obtain the Optimum Diameter and Length of the Vessel. We assume the capacity of the vessel, and we just have information about the geometrical constraints. Hence we assume a certain diameter and calculate the length of the vessel. Care is taken to see that they are in some proportion, and the vessel is practically feasible. This is an iterative process.

2. Select the Material to be used. Since the vessel is to be used in cryogenic applications, the material should have the strength to withstand extreme conditions. Stainless Steel is chosen based on the material properties under various conditions. [All material properties and data obtained from ASME code].

3. Calculate the Head and Shell Thickness. One of the major steps in this design; we calculate the thickness of the shell and head using the equations given in the ASME Pressure Vessel and Boiler Code. The Equation is selected based on the vessel conditions.

4. Calculate the load acting on the supports. The effect of fluid pressure is not very significant when compared to the effect of weight of the vessel and the fluid itself. This load once calculated is used in determining the stress on the walls of the vessel and subsequently, used to determine whther or not stiffness rings are required in the vessel.

5. Calculate the Maximum Bending Moment. Due to its geometry and the loading conditions, any pressure vessel will have bending stresses in the walls. The maximum bending stresses occur at the point of maximum bending moment. The location of the maximum bending moment is given to us through ASME Pressure Vessel code in the forms of a chart. We assume the position of supports based on that value. If the Maximum Bending Moment(actual) is greater than the Maximum Bending Moment(allowed), then there is a need for stiffness rings. This follows into the design of stiffness rings using the ASME Pressure Vessel code.

6. Check for Stresses. Once we have the basic design ready, we check the vessel for stresses. Manual calculations are carried out, and also a Finite Element Model is generated. Comparison of the two analyses results in the model being accepted. If the design is not satisfactory due to any reason, it is sent for redesign.

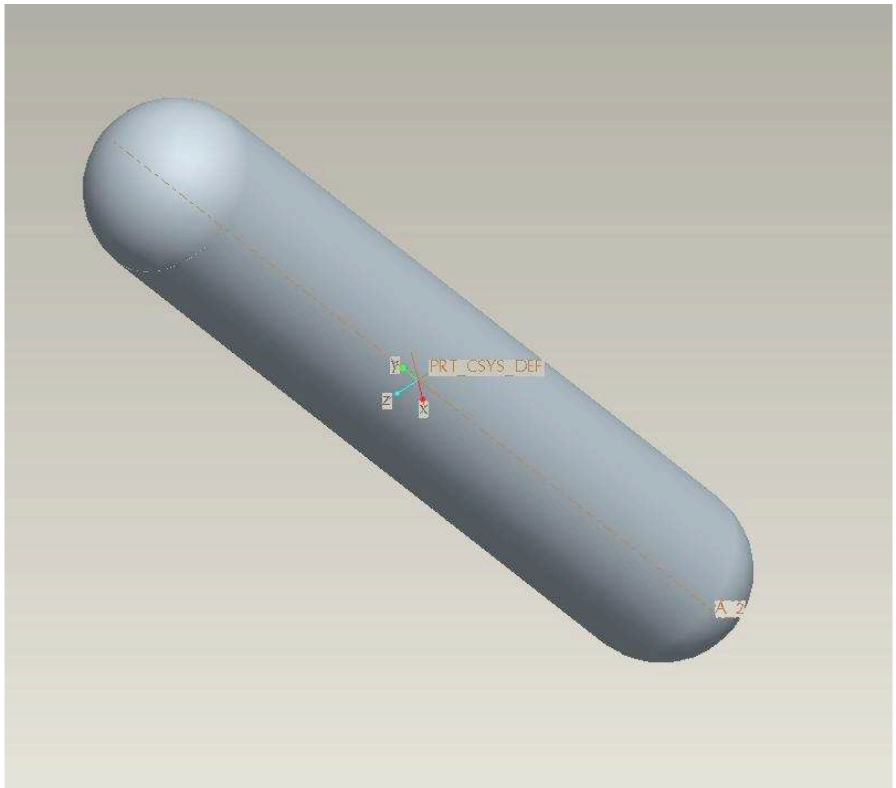


Figure 1 - PRO-E Model of the Inner Vessel

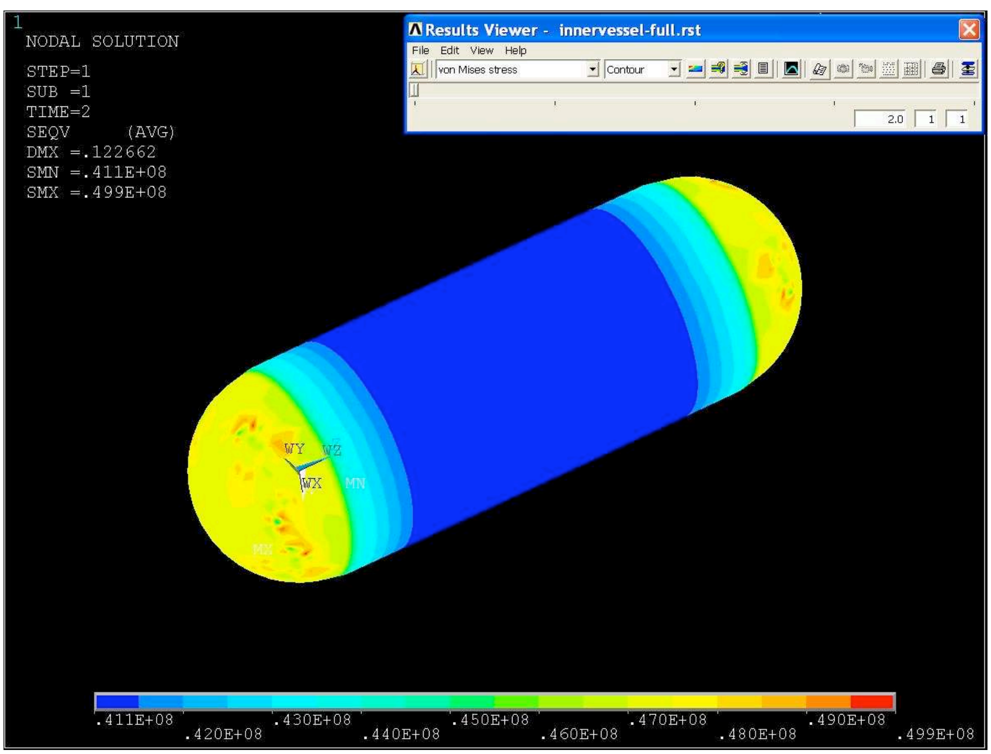
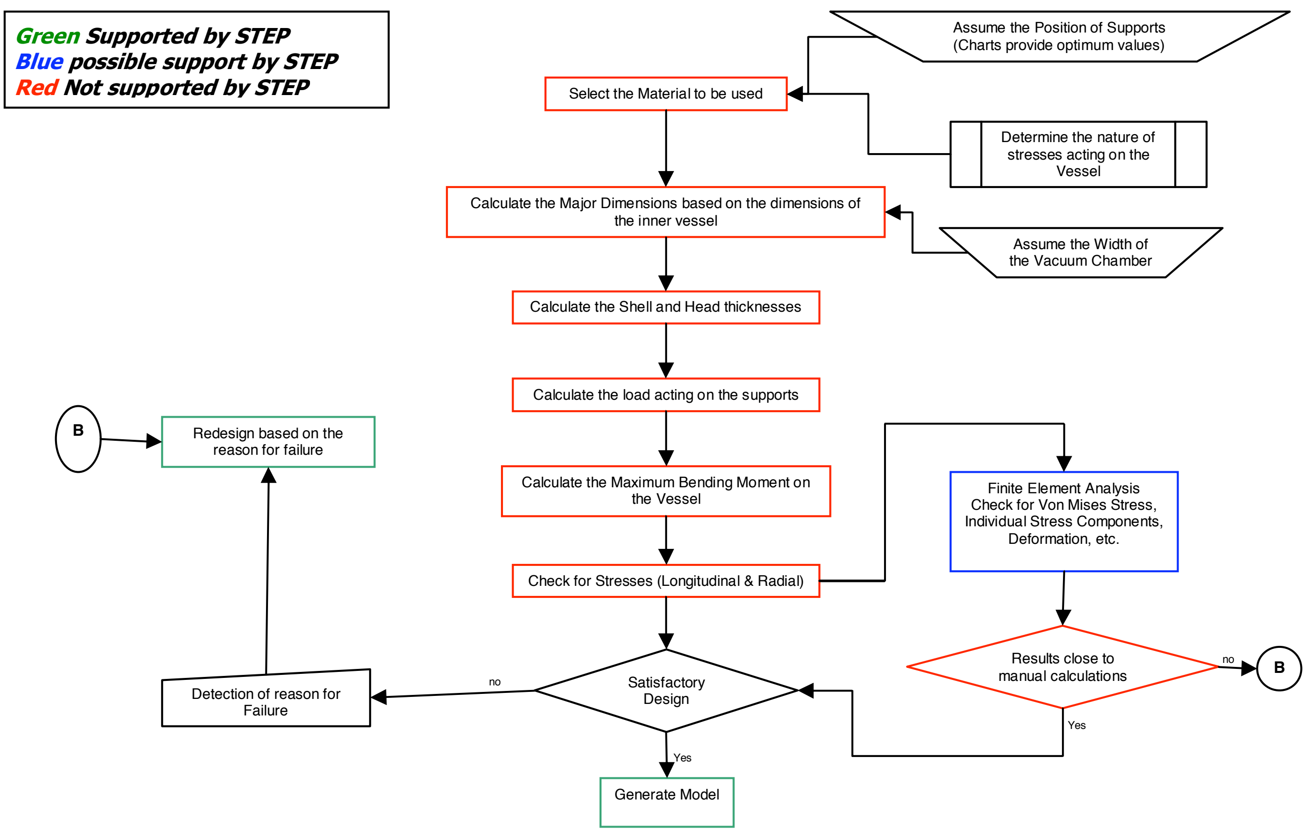


Figure 2 - ANSYS Simulation of Inner Vessel

Design of Outer Vessel



Tasks:

1. Assume the Position of supports. We select the optimum position based on charts provided in the ASME Pressure Vessel code.

2. Select the Material to be used. The outer vessel fails possibly due to elastic instability as it is placed in atmospheric conditions.

3. Calculate the major dimensions of the vessel. Assume the width of the vacuum chamber, and based on the inner vessel dimensions, we calculate the dimensions of the outer vessel.

4. Calculate the Shell and Head thickness. We use the ASME Pressure Vessel code to select the equations based on the conditions we have for the vessel. The important factors here are the Length-Diameter ratio, & Thickness-Diameter ratio. Based on these values we check if the cylinder is long/short. Then we use the respective equation. The other point to be noted is that all the governing factors here are assumed. Hence it is an iterative process, and we take collapsing pressure as the decisive factor.

5. Calculate the load on the supports. Once again, weight of the vessel is the most significant load on the supports. Also, the weight of the inner vessel and the fluid inside add on to the weight of the vessel.

6. Calculate the Maximum Bending Moment. This is the same as we did for the inner vessel.

7. Check for Stresses. The basic model is then checked for stresses using manual calculations and finite element analyses.

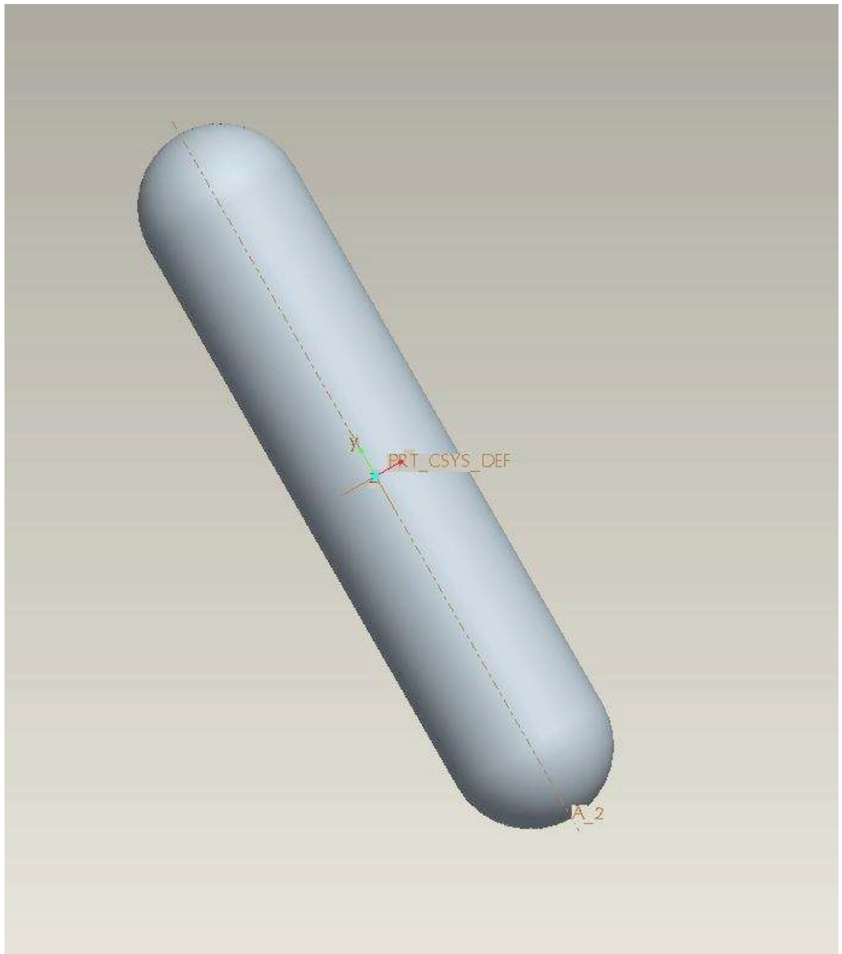


Figure 3 - PRO-E Model of the Outer Vessel

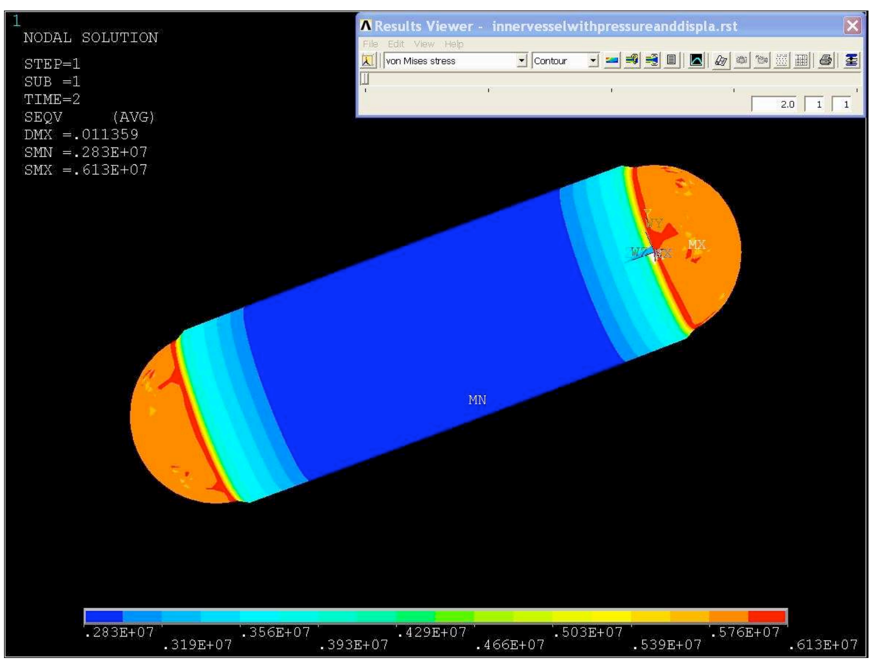
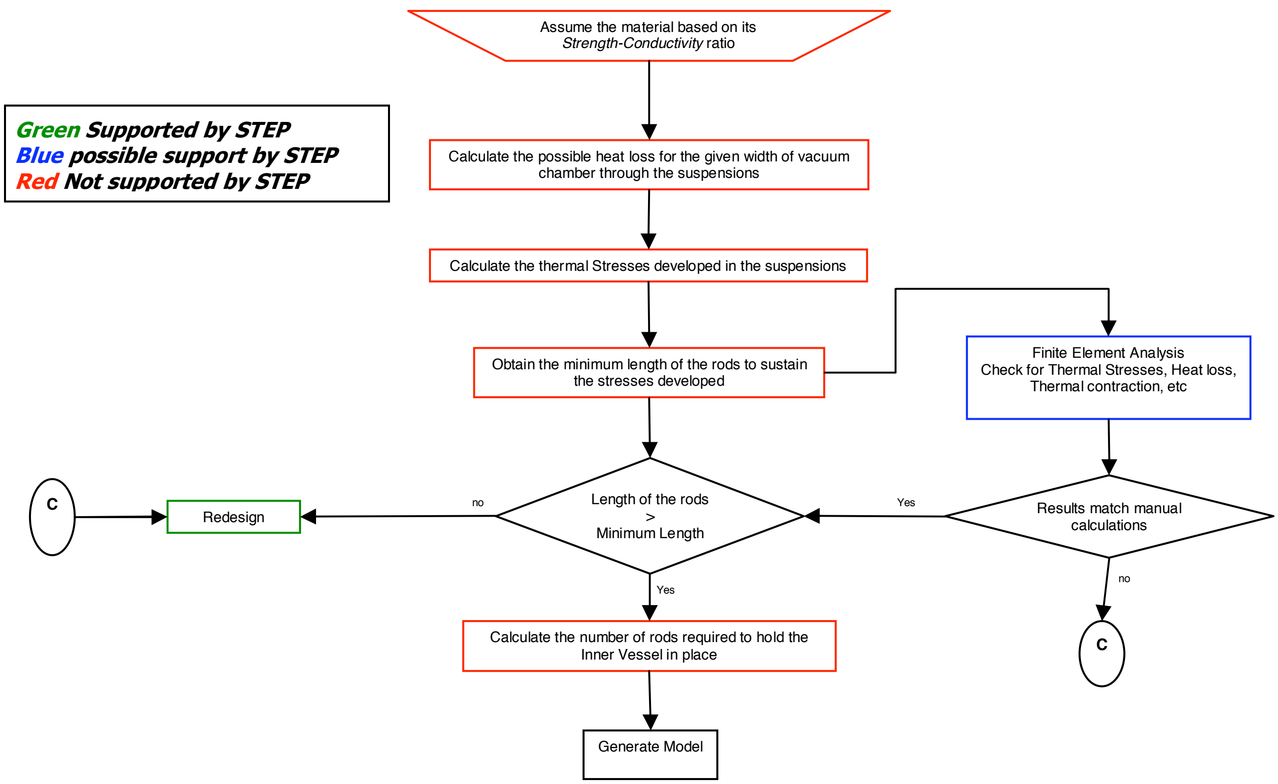


Figure 4 - ANSYS Simulation of the Outer Vessel

Design of Suspension Systems



Tasks:

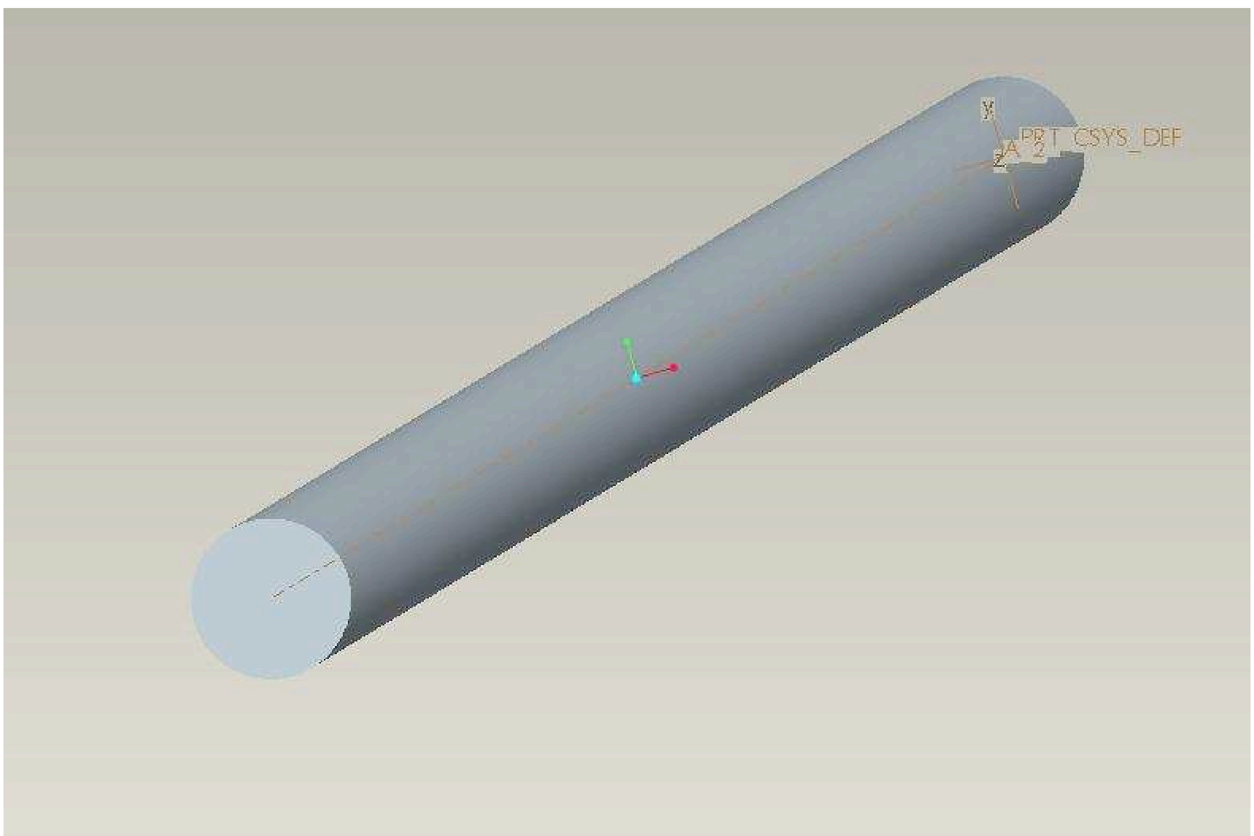
1. Assume the Material to be used: The material used should have low thermal conductivity. We choose the material with the highest strength-conductivity ratio.

2. Calculate the possible heat loss: For the width of the vacuum chamber, we calculate the possible heat loss through the member.

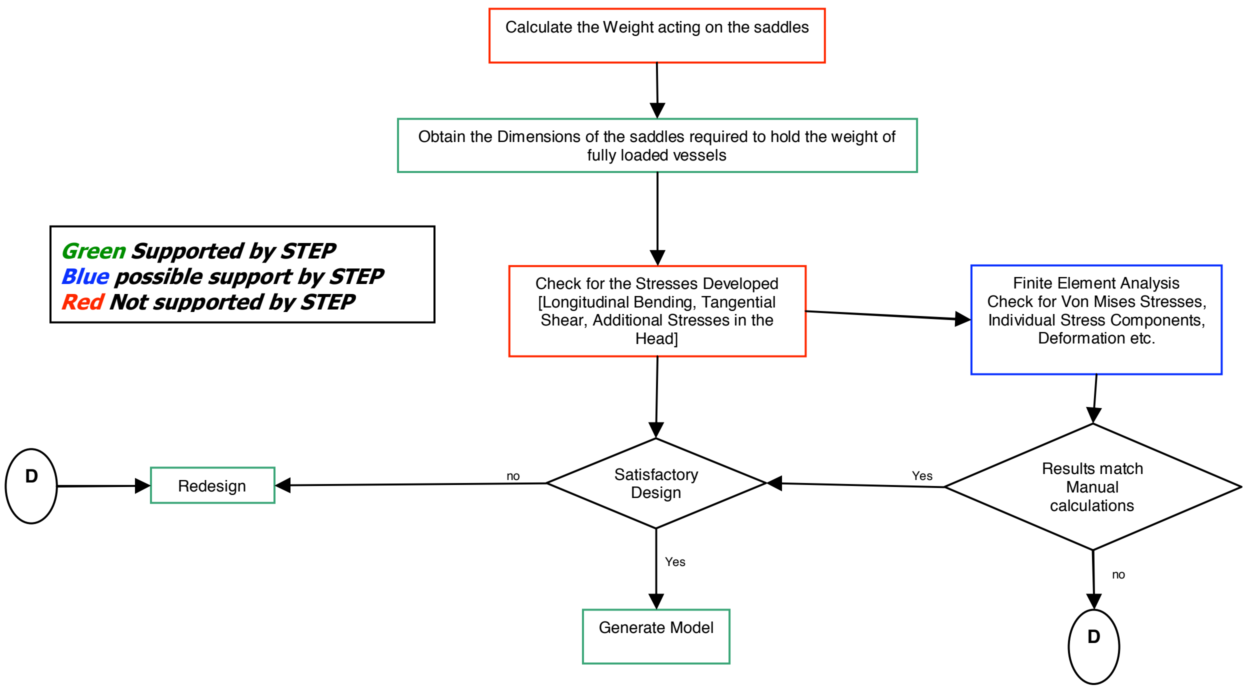
3. Calculate the thermal stresses developed. The suspension system is connected to both the outer and inner vessels. These connections constraint its contraction due to the temperature difference observed, which gives rise to thermal stresses.

4. Obtain the minimum length required. The thermal stresses developed may be more than the allowable stress values for the material. Thus we use the reverse method, and find out the length of the rods that will produce stress values lesser than the acceptable stress values.

5. Calculate the number of members. Calculate the number of member required to hold the inner vessel in place.



Design of Saddles

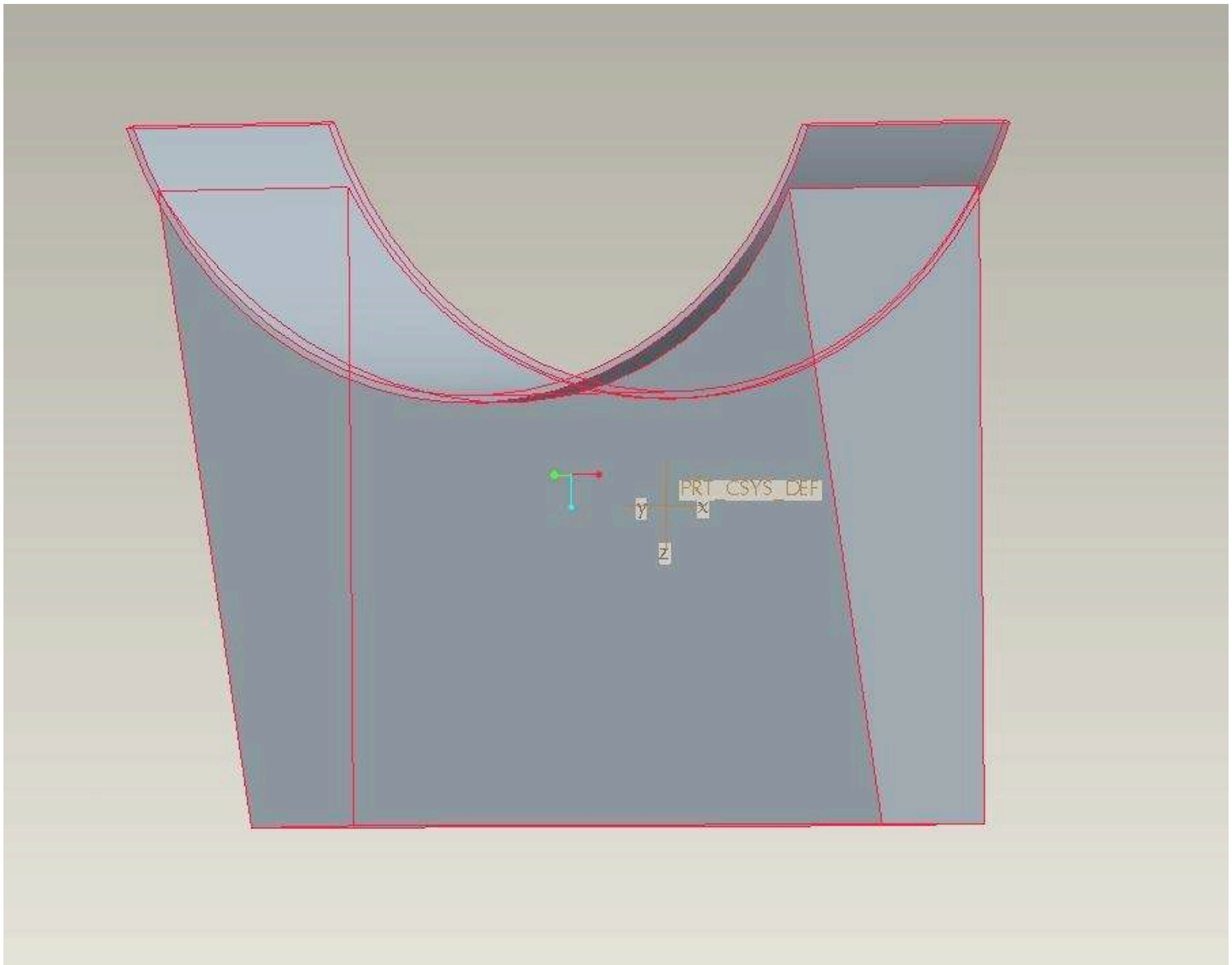


Tasks:

1. Calculate the weight acting on the saddles. The weight acting on the saddle is the sum of weights of all the other components.

2. Obtain the Dimensions of the Saddles. Dimensions of saddles are specified by ASME code, based on the dimensions of the pressure vessel. They are in the form of equations.

3. Check for the Stresses. Due to the weight acting, the stresses developed are Longitudinal bending, Tangential shear, and some other additional stresses in the head. All of these can be calculated using the equations provided in the ASME code.


PRT_CSYS_DEF
Y
X
Z

Appnedix 2

120’ Retriever Durred Redesign

By Aaron F. Montejo

Introduction

As it was mentioned in previous work done by the Engineering Team of WVU, engineering projects have many different ways to be started.

There are four tasks to be done: geometric characterization, material properties characterization, operating loads and boundary conditions; and failure criteria. The variation of the design process depends on the information we have on each of them.

It is also possible to talk about different engineering scenarios, which can be used to begin the process of design. Among of them we have: design from scratch, design from a previous design, design trouble shooting and reconstruction of an engineering context from archival data.

The discussion of this report is going to be focused on the last one.

To do this, it has been chosen one component of the archival repository: **the rudder.**

It is intended to make changes to this part of the boat assuming that it has to be improved for some reasons.

In the development of this task, it is necessary to have some information and requirements to achieve our goal. The intention here is to point out what part of the context reconstruction process can be stored by STEP and which one needs to be implemented among the STEP application protocols.
Next diagram shows the scenario developed to build the context in which the rudder was designed. Or at least it is trying to explain the procedure to understand the design of the rudder and after that make possible improvements.

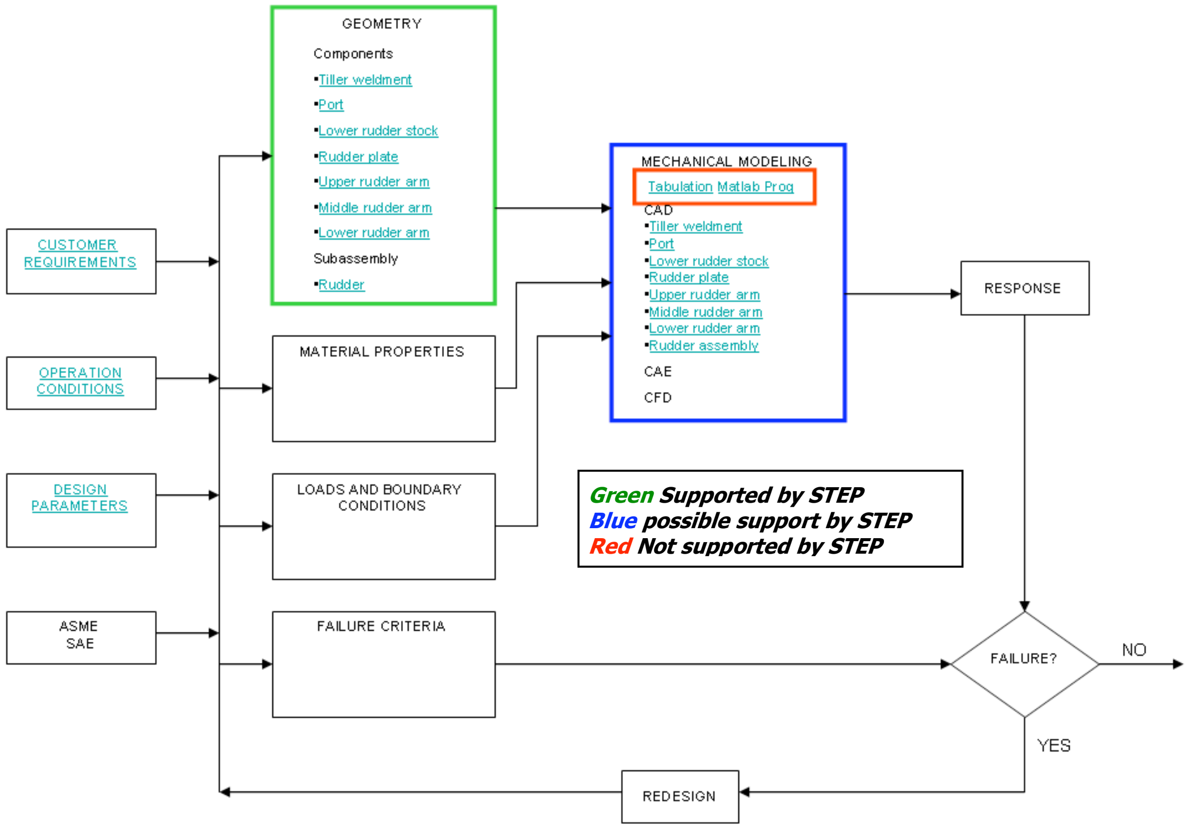


Fig. 1 Diagram showing the procedure to design a rudder (still under development)

Looking for Information

Searching among all the information contained in the repository, anybody can come across with some pictures, blueprints and files shaved in different CAD software.

Fig. 2 through 8 show the parts of the rudder found in the repository. These images were found as JPG files. Also, it is possible to find their respective CAD files and STEP files.

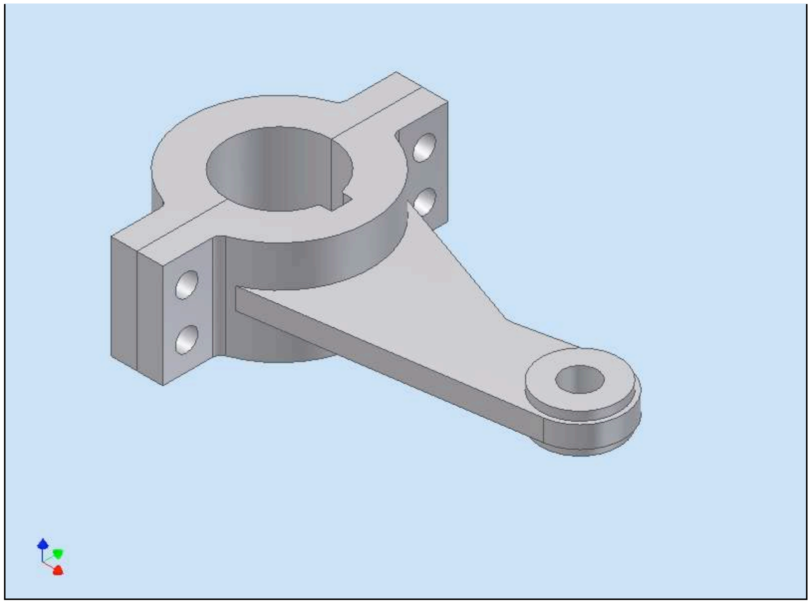


Fig. 2 Tiller weldment. From the repository at http://unbox.org/data4ever/trunk/nara_data_april08/Examples/2007_08_28/Archieve_data_samples/Rudder/TILLER%20WELDMENT.jpg

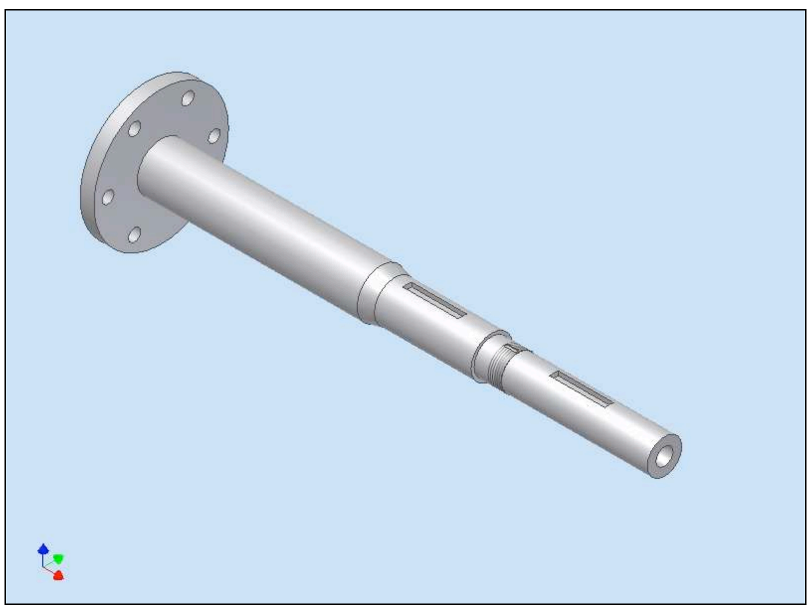


Fig. 3 Port. From the repository at http://unbox.org/data4ever/trunk/nara_data_april08/Examples/2007_08_28/Archieve_data_samples/Rudder/PORT-FINAL.jpg

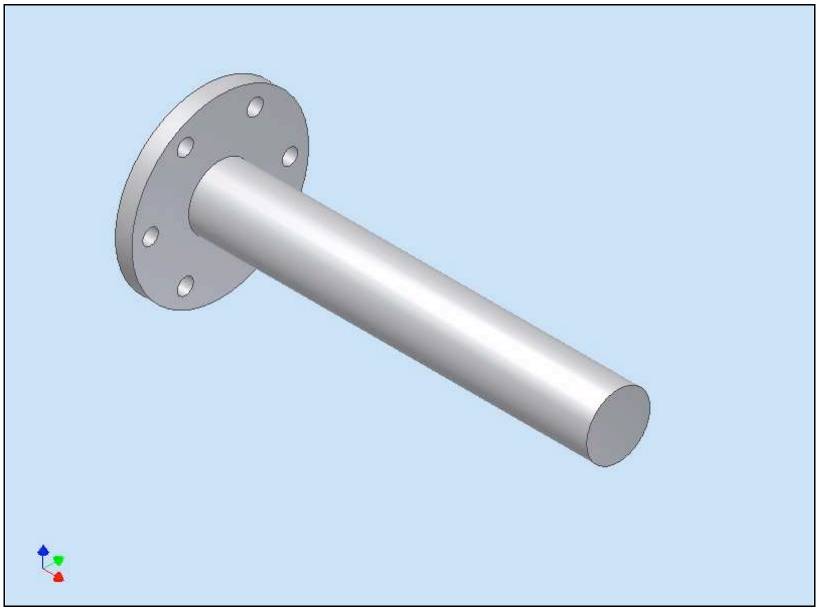


Fig. 4 Lower rudder stock. From the repository at
http://unbox.org/data4ever/trunk/nara_data_april08/Examples/2007_08_28/Archieve_data_samples/Rudder/LOWER%20RUDDER%20STOCK-FINAL.jpg

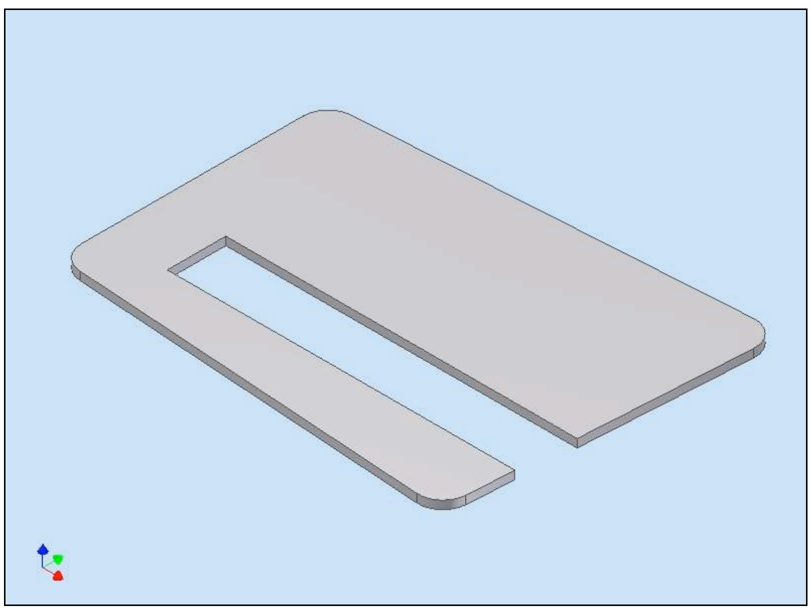


Fig. 5 Rudder plate. From the repository at
http://unbox.org/data4ever/trunk/nara_data_april08/Examples/2007_08_28/Archieve_data_samples/Rudder/RUDDER%20PLATE.jpg

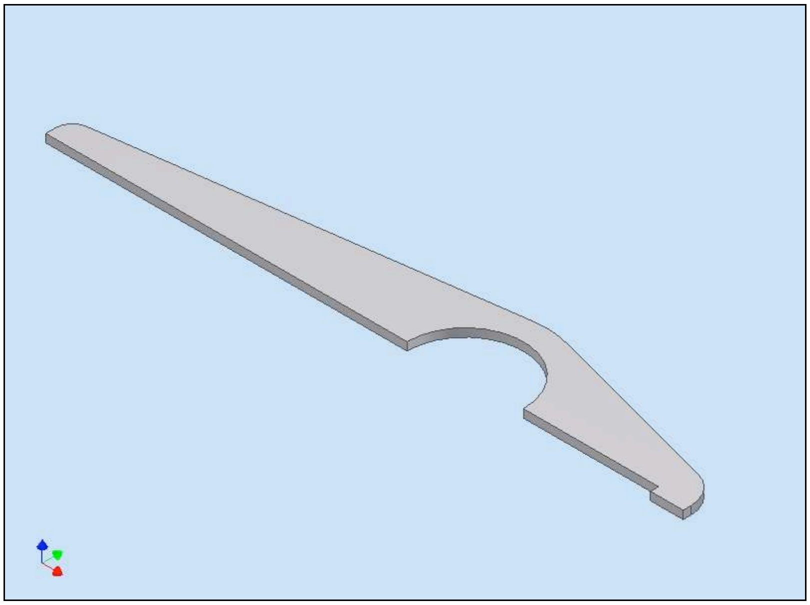


Fig. 6 Upper rudder arm. From the repository at http://unbox.org/data4ever/trunk/nara_data_april08/Examples/2007_08_28/Archieve_data_samples/Rudder/UPPER%20RUDDER%20ARM.jpg

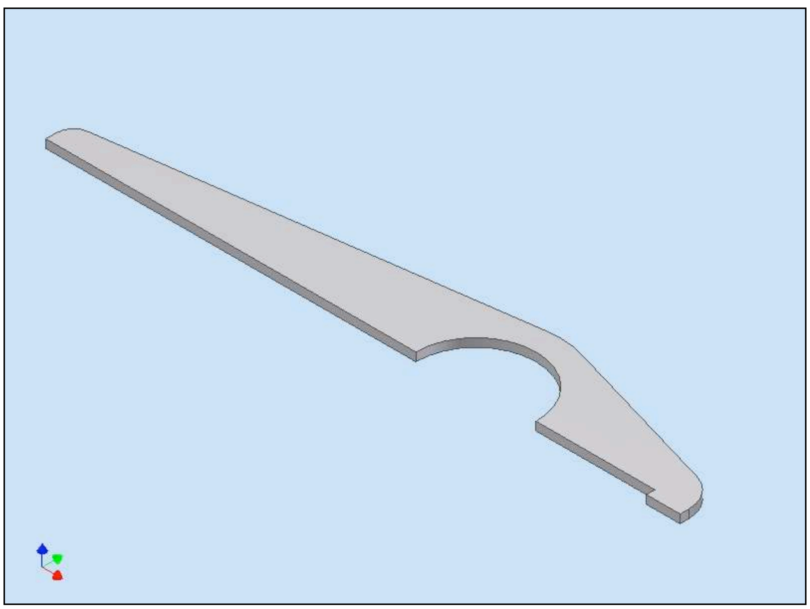


Fig. 7 Middle rudder arm, from the repository at http://unbox.org/data4ever/trunk/nara_data_april08/Examples/2007_08_28/Archieve_data_samples/Rudder/MIDDLE%20RUDDER%20ARM.jpg

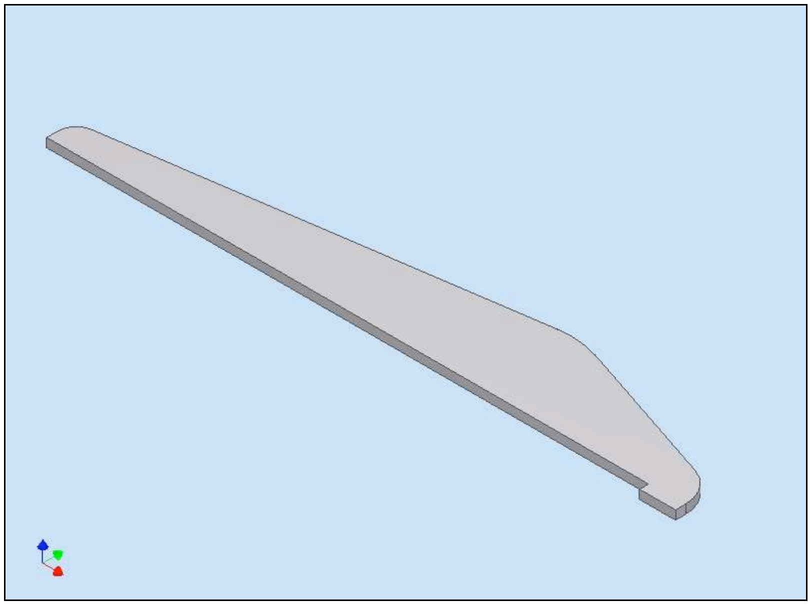


Fig. 8 Lower rudder arm from the repository at
http://unbox.org/data4ever/trunk/nara_data_april08/Examples/2007_08_28/Archieve_data_samples/Rudder/LOWER%20RUDDER%20ARM.jpg

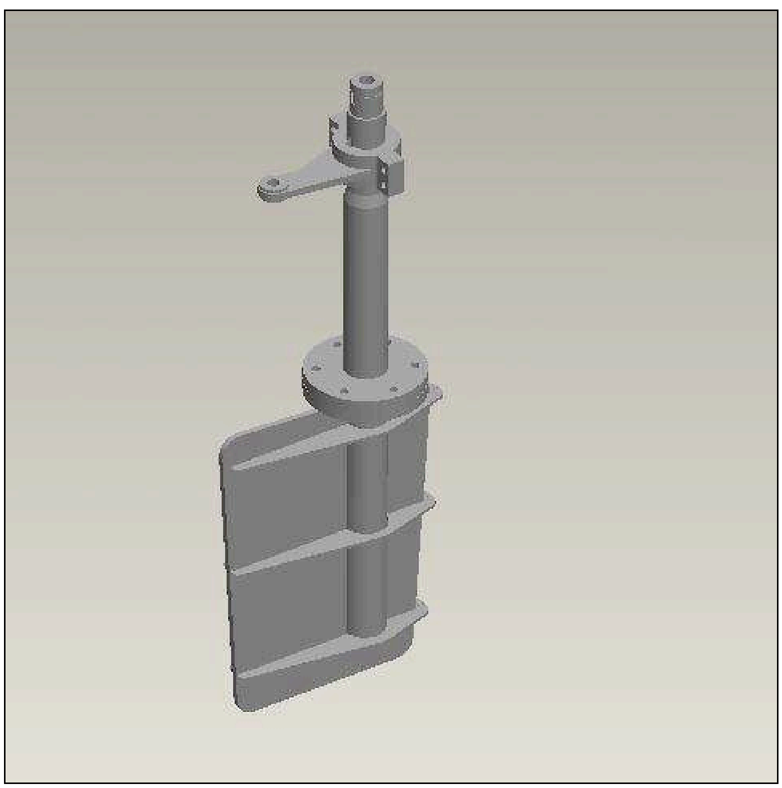
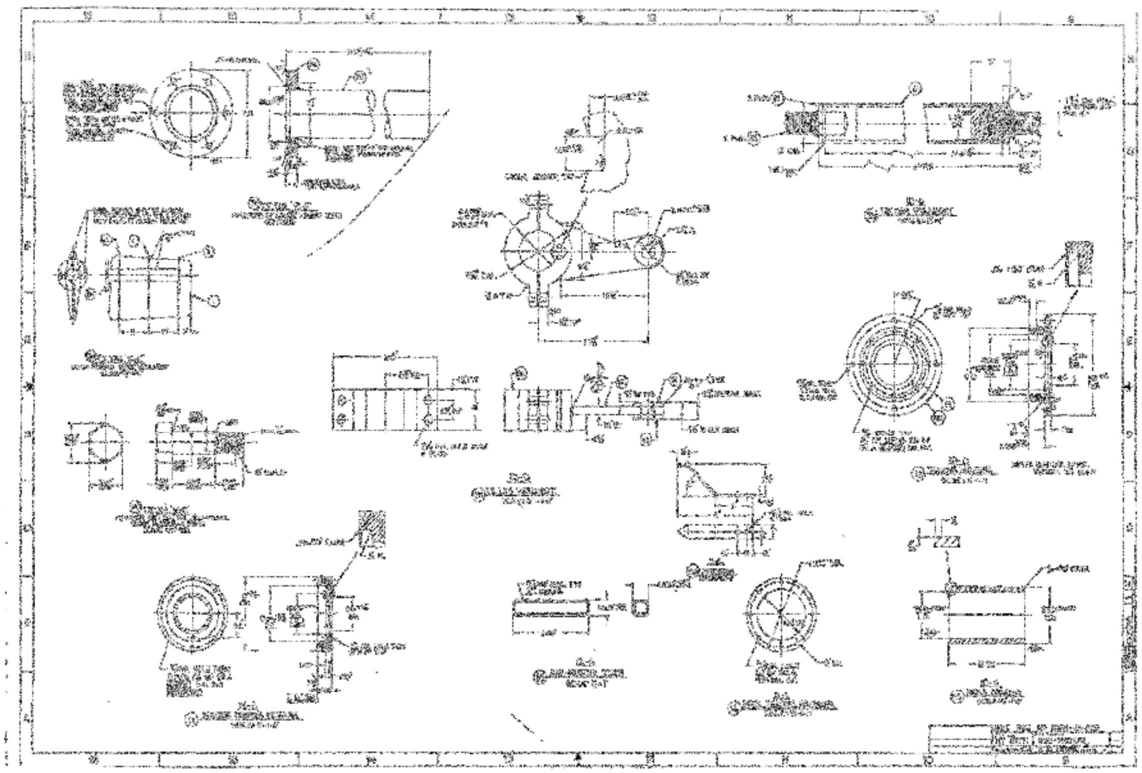


Fig. 9 Rudder sub-assembly open in ProE as a STEP file, from the repository at http://unbox.org/data4ever/trunk/nara_data_april08/Examples/2007_08_28/Rudder_data/STEP%20Files/Rudder_stp/Rudder_Assembly.stp

Fig. 9 shows the rudder sub-assembly in ProE, open as a STEP file. As the other figures, there is a CAD file of the entire rudder assembly.

In order to make improvements to this component, it is necessary to make some tests and find out its performance.

It is true that this rudder can be built any time since there are some blueprints in the repository, detailing its geometry, Fig 10.



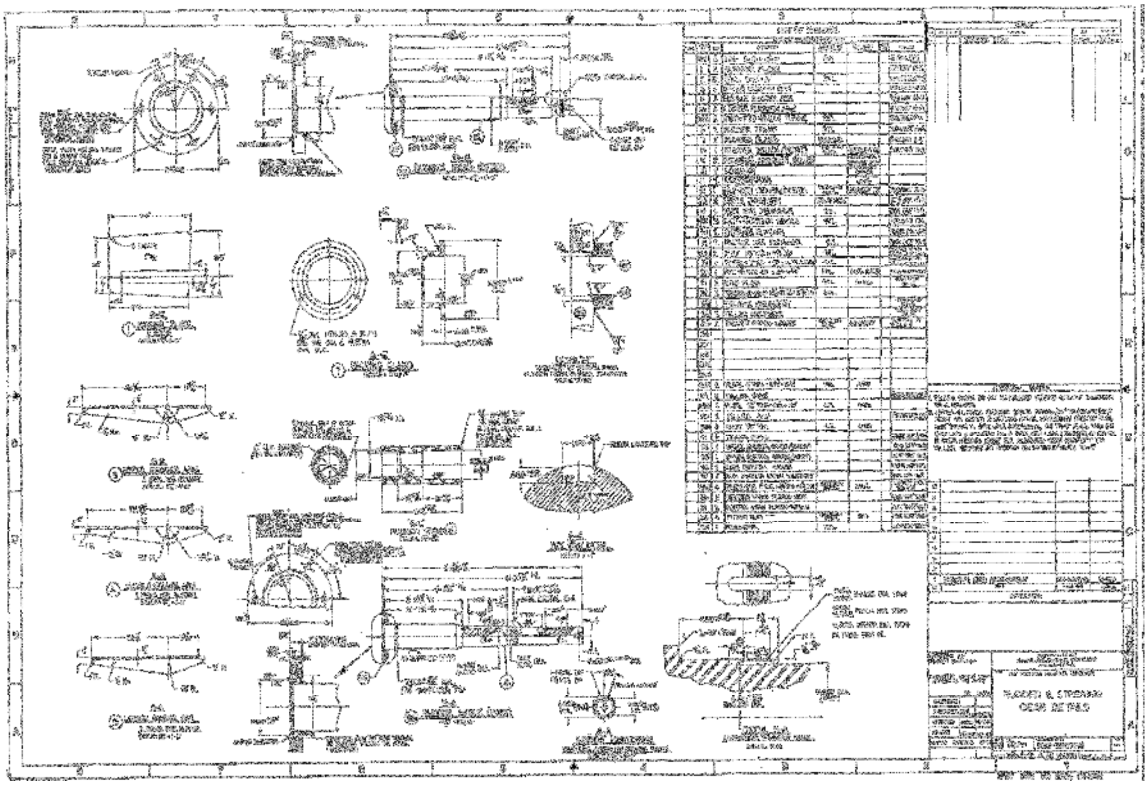


Fig. 10 Blueprints containing detailing geometry of the rudder and components. From the repository at http://rabecs.dt.navy.mil/TWR/lsSheetAll.php under drawing number 6201019-1 and 6201019-2

But the idea here is not just rebuild the component. It is to make changes using all the data available.

To start this task, it is important to know the requirements supplied by the customer and the rudder must satisfy this requirements. This requirements have to lead to the geometry of the rudder. For example, it is necessary to know the max speed of the ship in order to get an aspect ratio of the rudder. High speed requires high aspect ratio and low speed need an low aspect ratio.

Among the requirements we can mention:

- What the speed of the ship is
- What water temperatures the rudder is going to be exposed
- What turning speed is desirable

The materials to be used, the geometry of the rudder, the loads over the rudder are going to depend on the answer of these and other questions.

All this information is not contained inside the repository. The reason of the dimensions and geometry is not explained. There is no detail about the processes that were followed to build each component. There is no numerical analysis. There is no list of all the standard codes used to build a particular component.

All these aspects will be taken on count during the reconstruction of the context and improving of the rudder.

Doing some tabulations and understanding the behavior of the rudder, we came up with some results that are shown in fig 11, which describes how the drag coefficient, lift coefficient, normal force coefficient and the center of pressure moves when the angle of attack increases. The more the angle of attack is, these coefficients get higher values.

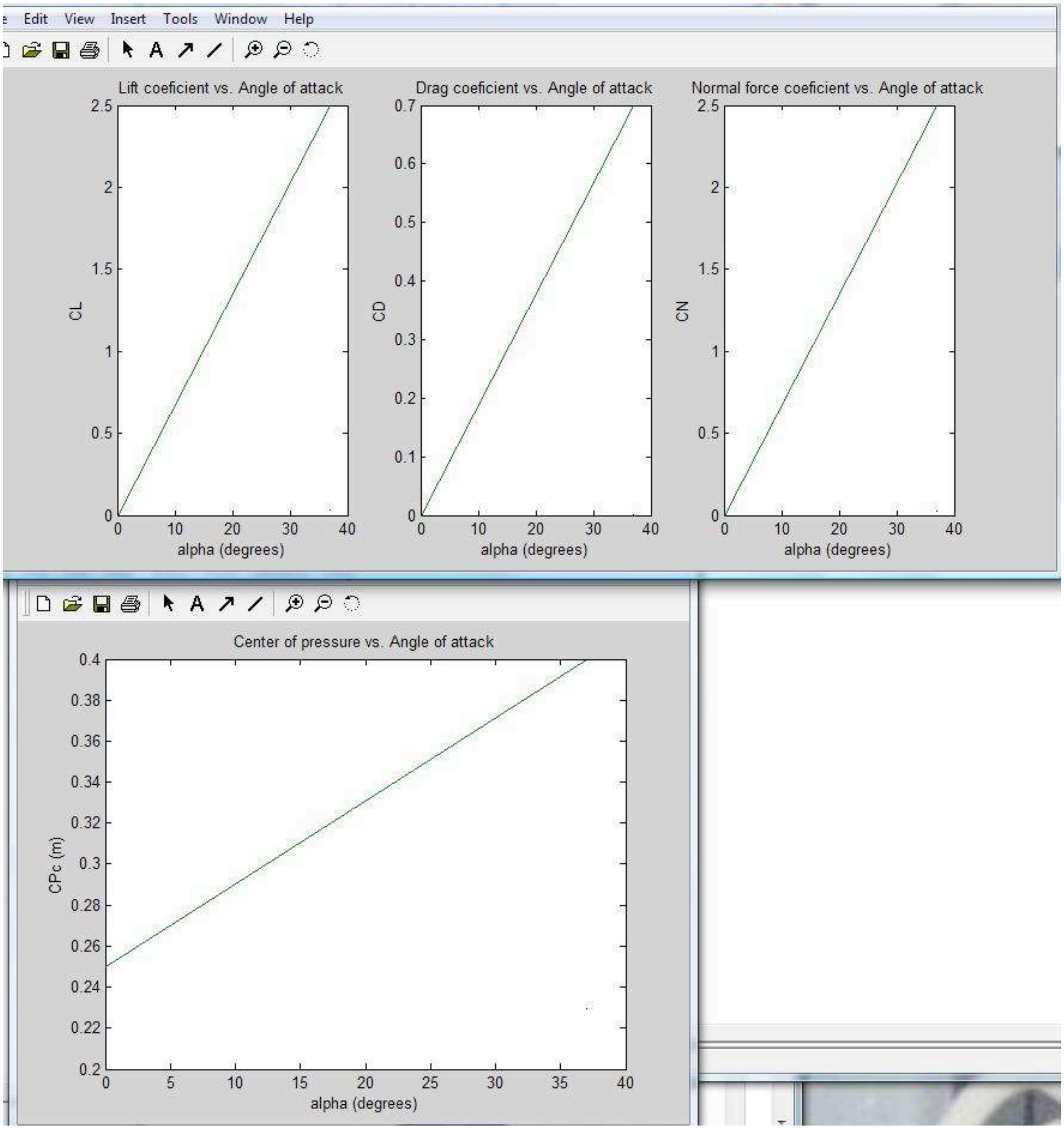


Fig. 11 Relation between the lift coefficient, drag coefficient, normal force coefficient and center of pressure and the angle of attack.

Engineering Scenarios, Creating Context: status report

Changes to this document since last submission:
This report is all addition to previous submission, with two new (not previously documented in this program) case studies:
1. The pressure Vessel for Cryogenic Applications. This is a case of Design from scratch with a series of interconnected (hyperlinked) engineering work-documents.
2. The 120' Torpedo Retriever's "Rudder Replacement" case. This is a "make believe" scenario, in which we assume that the rudder system needs to be replaced and its design improved in the process. The data we have to begin with, is the information from the repositories provided.

The emphasis is places on engineering task documentation with engineering working documents to identify what can be supported with STEP Application protocols and what is not currently supported that represents opportunity.
Resources:

Only the work of 3 students:

- Mr. Samrat Sarovar, MS Student in his second semester (Pressure Vessel)
- Mr. Aaron Montejo, MS Student in his first semester (120' Retriever's Rudder Redesign)
- Mr. Michale Lyons, Potential Ph.D. Student on semester (Documentation of STEP AP's)
- Victor Mucino unsupported during the Fall semester (Coordinate interact with other team members, direct student's work, write reports)