

**The Reconstruction and FEA Analysis of the Decommissioned WWII Era Destroyer USS Cassin Young in the SolidWorks Environment**

by

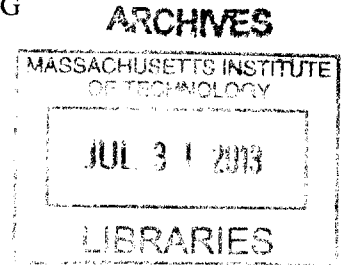
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SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING  
AT THE  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2013

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Submitted to the Department of Mechanical Engineering on May 17, 1994 in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Mechanical Engineering

**ABSTRACT**

An attempt was made at reconstructing the now decommissioned World War II era destroyer USS Cassin Young using blueprints on file at the Hart Nautical Museum . After the electronic model was constructed, an attempt was made to run an FEA analysis to determine stress levels in the ship's hull.

The ship was made using the various Solidworks tools available including surfacing and extrusion tools while using the available blueprints for recreation accuracy. The FEA was not completed due to problems encountered in the meshing and analysis of the complex geometry of the ship hull.

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## **Acknowledgements**

This project proved to be more challenging than anything I have undertaken in a Computer Aided Design environment. I would like to thank my thesis advisor Jerod Ketcham for his patience and understanding as well as his guidance. When I got to a particularly challenging area, he always had sound suggestions or would provide an idea that I did not think about in my bid to build a ship from the blueprints. I can honestly say that without his help I would not have gotten nearly as far as I was able to in this endeavor. Thank you sir, my only wish is that I could have done it even better.

I would also like to thank Kurt Hasselbach and the staff at the MIT Museum for scanning the Fletcher Class destroyer structural drawings and making them available to me electronically. Without their help, this attempt would not have been able to happen.

Secondly, I would like to thank the many veteran Solidworks users on the online forums who always seemed to have a clever solution to most of the problems I faced. It is good to have such a great community out there to siphon useful knowledge from!

Finally, a big thanks to my buddy Phillip Daniel. Even though the analysis failed in the end, your suggestions allowed me to get closer than ever to being able to successfully run it. I wish you the best of luck my friend, and I hope that whatever you do, your awesome qualities as an engineer and a person will be recognized.

## List of Figures

- 1-1 An example of self-intersecting geometry
- 1-2 Showing the parts of the hull deleted in order to successfully thicken.
- 2-1 An idea of the size of the average blueprint drawings
- 2-2 Frame sketch example
- 2-3 Extruded frame example
- 3-1 Sketch technique for lofting longitudinals
- 3-2 End result of loft of longitudinal
- 3-3 All the longitudinals after reflection
- 4-1 Platform sketch
- 5 Deck picture with sketch and final result
- 6-1 The ship before attempted meshing
- A- 1 Dimensions of an I-beam profile

## **List of Tables**

- B-1 List of referenced drawings used in constructing the USS Cassin Young
- B-2 List of plate thicknesses used in build
- B-3 Longitudinal cross-sections used in build

# Nomenclature

## Symbols

' - Designation for foot

" - Designation for inch

# - For the longitudinals, pounds per linear foot, for plates, pounds per square foot. Allows the determination of cross sectional dimensions using a steel structures reference for the longitudinal beams and the thickness for all of the plates.

## Useful Definitions

Aft                    Going toward the stern of the ship.

Bow                    The front of the ship

CPU                    Allows a program to interpret and execute program instructions

Fore                    Going toward the bow of the ship

I-Beam                A structural beam with a cross-section reminiscent of a capital I

Keel                    The longitudinal structure along the centerline at the bottom of a vessel's hull.

Longitudinal        Running the length of the ship

RAM                    Random Access Memory allowing a program to complete a task it is given

Stern                    The back of the ship

T-Beam                A structural beam with a cross-section reminiscent of a capital T.

Transverse            Running the width of the ship





## **Introduction**

USS Cassin Young (DD-793), a Fletcher-class destroyer, was a ship of the United States Navy named for Captain Cassin Young (1894–1942), who was awarded the Medal of Honor for his heroism at Pearl Harbor and killed in the Naval Battle of Guadalcanal. Cassin Young (DD-793) was launched 12 September 1943 by Bethlehem Steel Corp., San Pedro, California; sponsored by Mrs. C. Young; and commissioned 31 December 1943 with Commander E. T. Schrieber in command. After serving in World War II, including the Battle of Leyte and the Battle of Okinawa, Cassin Young continued in active service until 1960. She is preserved today as a memorial ship, berthed at Boston Navy Yard in Boston, Massachusetts, across from USS Constitution. ("USS Cassin Young")

The Cassin Young is an important piece of U.S. history and it is important to preserve it to ensure people do not forget the sacrifices made by the men and women of the armed forces during World War II. May this particular piece of history stick around for years to come and continue to remind us of our persistence in the face of adversity.

### **1. Hull Surfacing and thickening**

This thesis will lay out the process by which the USS Cassin Young was built. For this build, Solidworks 2012-2013 Student Edition was used on a laptop computer sporting Windows 7 64-bit operating system, an Intel Core i7 processor with each core operating at 2.20 GHz, 8 Gigabytes of RAM, and an NVIDIA GeForce GT 540M Graphics Card with 1 GB of dedicated memory for rendering. Checking CPU and RAM usage when solid works was at the height of its use confirmed that the CPU and RAM was sufficient for Solidworks to operate normally. The hull was originally a surface constructed in a different CAD software known as Rhinoceros Version 4.0. The hull would be the main entity to which all of the other ship features, including the transverse frames and longitudinal beams, would be attached. The surface was constructed by two individuals who did previous work on the USS Cassin Young named Kyle Miller and Adam Jones. A quick check was made to verify that the hull dimensions matched those of the USS Cassin Young. The overall height and length of the destroyer hull surface checked out.

## 1.2 Self-Intersecting Geometry

There were a few issues that need to be taken care of at first. Initially, the bow had some self intersecting geometry that was preventing Solidworks from allowing the manipulation of the hull surface to proceed with the construction of the other ship features.

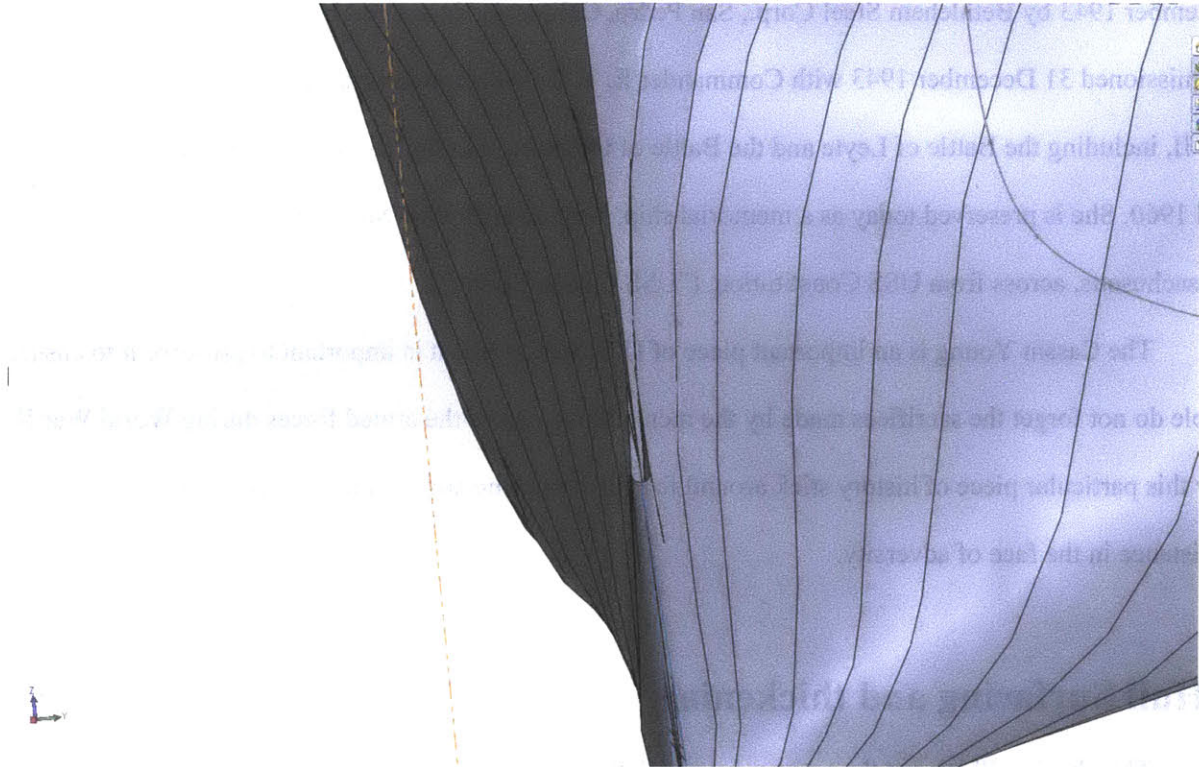


Figure 1-1: A picture showing the initial self intersecting geometry that needed to be corrected in order to proceed

## 1.3 Thickening

Thickening the hull using the Solidworks thicken tool was also a bit of challenge but ultimately a successful endeavor. The way the thickening tool works in Solidworks is that it actually offsets the surface a certain distance corresponding to the thickness of the resulting solid you specified. The potential problem, however, is the fact that if there are any sharp corners or sharp surface features, Solidworks cannot offset the surface. This is likely due to the fact that trying to offset the surface could result in what's called zero thickness geometry. As a result, in order to get the hull to thicken, parts of the hull had to be deleted and patched later. The deleted parts are shown in figure 1-2. Another issue to note is that the

hull varied in thickness from 7# (.171") to 20# (.49"). Solidworks thickening tool is a uniform thickening tool so a median thickness of 12# (.293") plate was chosen.

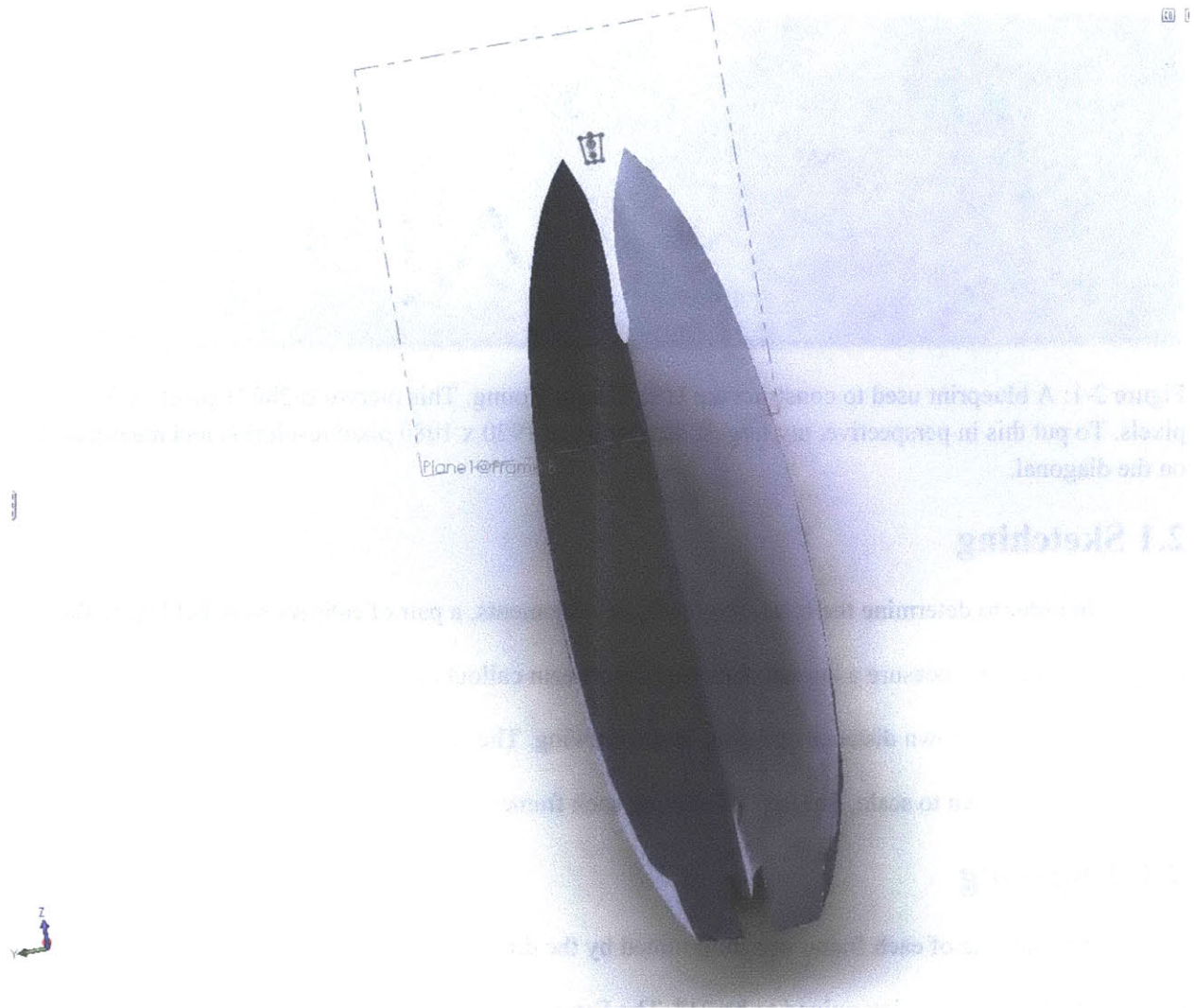


Figure 1-2 : Showing the thickened hull with the parts that needed to be deleted in order for the surface to thicken successfully. The deleted parts include the bow, the back panel at the stern of the ship, and the panel leading from the fin to the back panel.

## 2 Frames

The transverse frames were perhaps the single most time consuming set of features to construct in Solidworks by virtue of the fact that there are so many of them. There were at least 45 individual frames that needed to be done. For the frames, the various blueprints that were pulled from the Hart Nautical Museum were used. Table B-1 in appendix B has the complete list of drawings that were used. The

drawings are in .tiff form and thus highly detailed and take up a good bit of memory storage. The tradeoff is that initial loading time upon opening could vary anywhere from 20 seconds to a minute.

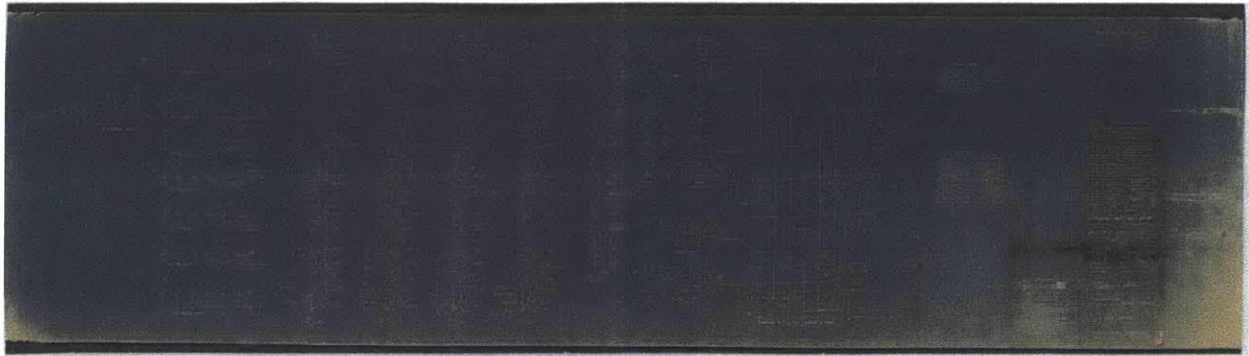


Figure 2-1: A blueprint used to construct the USS Cassin Young. This picture is 28071 pixels x 7934 pixels. To put this in perspective, my largest display has a 1920 x 1080 pixel resolution and measures 23" on the diagonal.

## 2.1 Sketching

In order to determine the location of structural elements, a pair of calipers were held up to the computer display to measure a known distance (say a beam callout on the blueprint) and use that distance to determine an unknown distance or radius in the drawing. The reason this was possible was that the drawings were drawn to scale. For ease of editing, each frame was done as an independent sketch.

### 2.1.2 Spacing

The spacing of each frame was determined by the drawing titled bow framing. The spacing between each frame was determined to be 21". The Frames started at Frame B at the bow to Frame A to Frame F.P. and then went into the numbered frames proceeding aft. The actual numbered frames were located by multiplying their frame number by 21" to get their distance from frame F.P. A plane was put at the location that the frame was supposed to reside and a sketch was made. The outer contours were splines in order for the frames to best fit the contours of the hull. Sub features such as holes were added after the shape was determined.

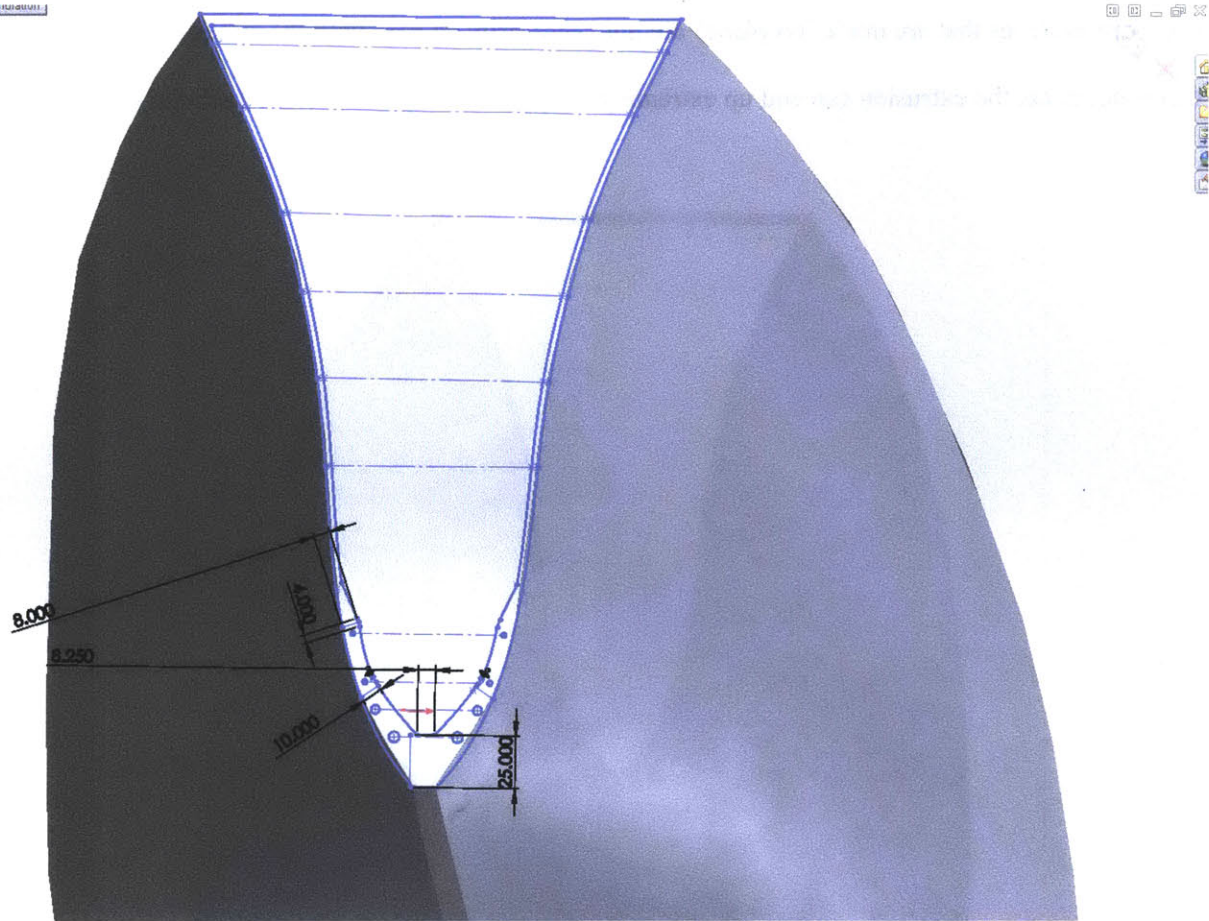


Figure 2-2: An example of the sketch technique employed in making all of the frames (Cut away view for ease of comprehension).

## 2.2 Extruding

Extrusion was done using the plate thickness callouts on each frame. The prevailing plate thickness was 7#. The thicknesses were determined by using the density of steel ( $490 \text{ lbs/ft}^3$ ). The # callout on the blueprints are pounds per square foot plating designations i.e. the weight of the plate per square foot. To get the thickness, divide the plate number call out by the density of steel. Table B-2 in Appendix B tells the thicknesses used in the construction of the USS Cassin Young. The way the frames were extruded were by using Solidworks extrusion property manager and selecting the required contours. The distance to extrude was determined by the plate thickness callouts on each frame. It was important to make sure the sketch that was made was on the plane of the sketch. The reason this is important is because Solidworks uses the 3D sketch feature when putting 2D sketches on a 3D surface. If this is the

case then sketches that are made "on plane" are not necessarily on plan until the relationship is verified. If this is not done, the extrusion can end up extremely warped and may even return a rebuild error.

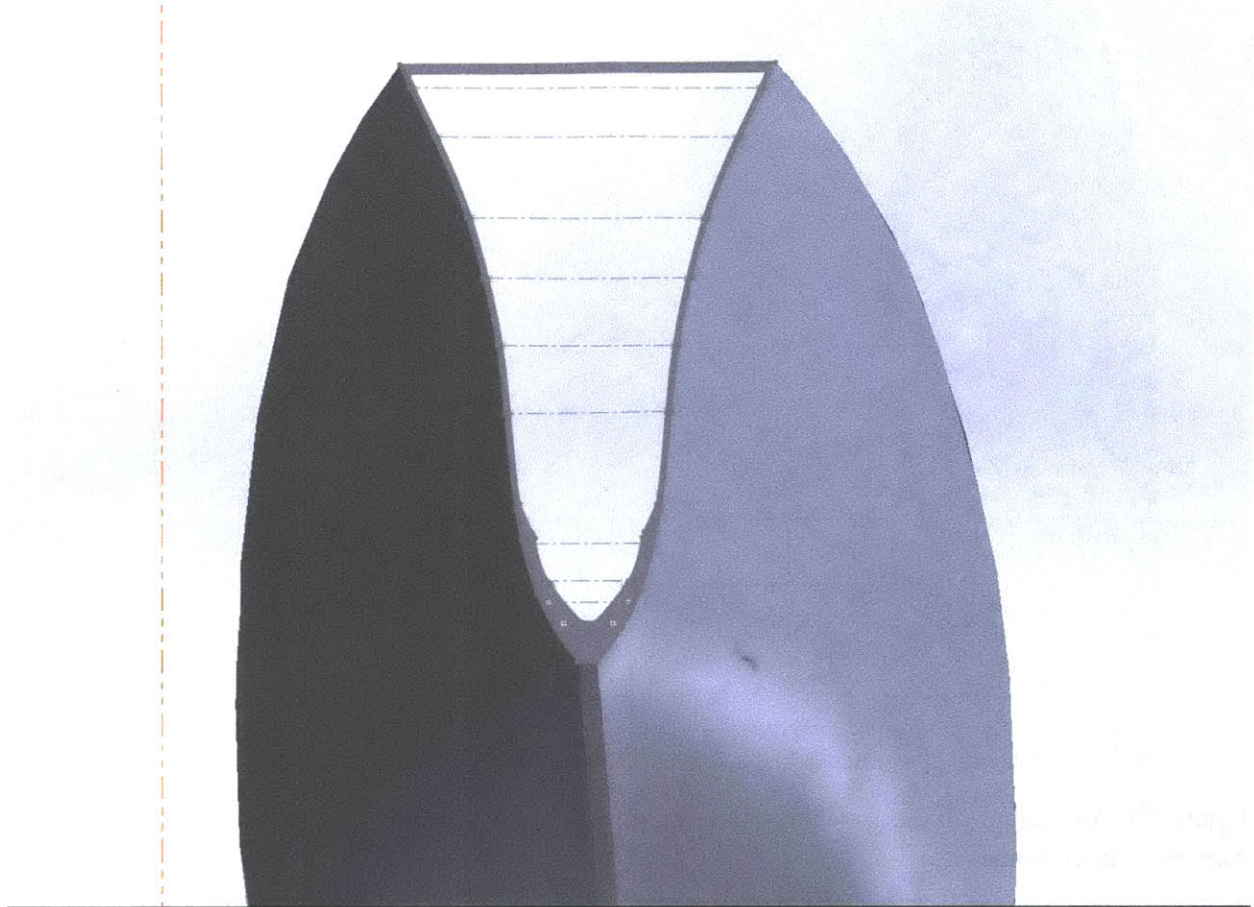


Figure 2-3 - A picture of the very same frame depicted in figure 2.2 now extruded.

### 3 Longitudinals

The longitudinal stiffeners are a bunch of I-beams and T-Beams that run the length of the ship. The blueprints of the frames also had the location of the major longitudinals. There were also two dedicated longitudinal drawings that allowed the relative horizontal or vertical distances from the centerline of the ship to be determined.

Initially, sketches were made with the sweep technique in Solidworks in mind. The sweep feature works by taking a profile and projecting it along a curve of your choosing as long as the profile and curve have what is called a pierce relation, which is when the guide curve literally pierces the profile. Initial attempts with this feature proved it to be very processor intensive and time consuming to the point that

the wait time would be around an hour just to sweep one longitudinal. The end result was also not satisfactory with the bottom edge of the longitudinal rendering as if it was jagged and not adhering well to the profile. The loft alternative proved much faster and also satisfactory. The way a loft works is that you make a number of profiles and use the loft property manager to select the number of profiles in order that a loft is created. The process of lofting had to be done for one half of the ship, roughly 11 longitudinals as well as the keel. The other half was done through mirroring the longitudinals (section 3.3).

### **3.1 Sketching**

To successfully loft, there needs to be a sufficient number of profiles for accuracy. The technique used involved finding the horizontal or vertical distance of the longitudinal from the top edge of the hull at a specific frame. It was also required to find the overall length of the longitudinal by looking at the frames that it traversed through. The resulting sketch, depicted in figure 3.1, shows what the longitudinal sketch looks like before the loft is carried out. Note that each profile has its own plane in order to be positioned correctly. In order for the profile to sit on the hull correctly, a line was drawn through each point and then the endpoints of the line were given on surface relations. The profiles were then rotated so that their bottom lines were coincident with the line that had the on surface relation. The profiles of each longitudinal were determined by their callouts. Table B.3 has a list of the beam call outs and their dimensions. Longitudinals 3, 7, and 13, which are listed in Table B.3, were omitted from the CAD model due to their absence in the available structural drawings drawings.

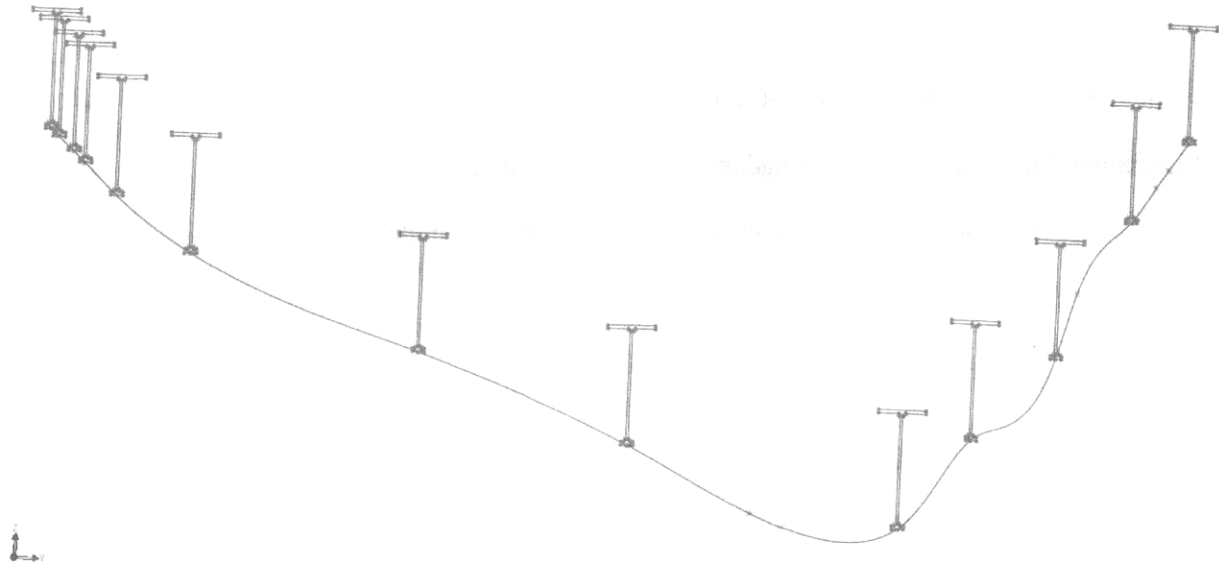
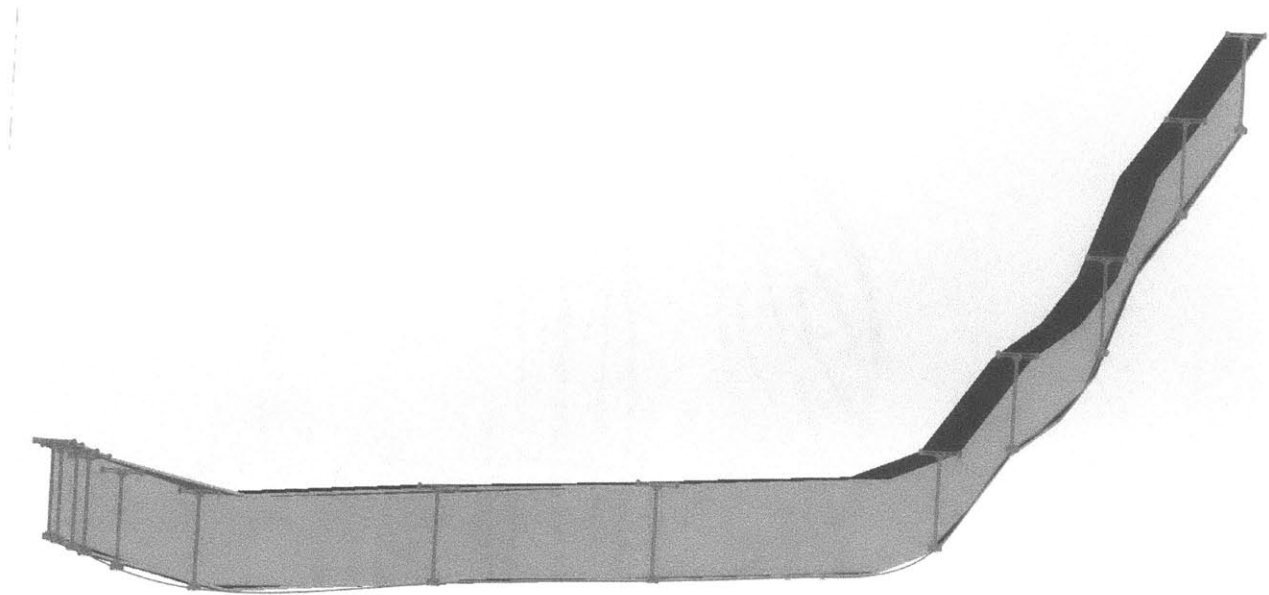


Figure 3-1- A picture showing the 3D sketch of the Keel of the USS Cassin Young before lofting. A spline guide curve runs through the bottom middle of each profile to aid in accurate lofting. The guide curve adheres to the hull surface which is why it has the seemingly weird shape.

## 3.2 Loft

Lofting the longitudinals was simple after the sketches were painstakingly made. A spline was run through each profile at the same point on the profile so that it could act as a guide curve. Tangency control and spine points were used to ensure the guide curve fit to the contour of the ship. To run the curve through any other profile point is to invite an error. Once the loft is done, a longitudinal such as the one shown in figure 3.2 results. It is important to note that selecting each profile in a logical order. That is, select only profiles immediately after the preceding profile. Never skip a profile and then select it later down the line. To select profiles out of order is to cause self intersecting geometry and very long processing time.





Model: Motion Study.1

Figure 3-2: A picture showing the keel of the ship after it has been lofted. Note that all other features have been hidden for ease of viewing. The funny looking shape is likely due to imperfections in Solidworks rendering.

### 3.3 Mirror

Once all the longitudinals were made for one side of the ship, it was time to reflect it across the longitudinal center axis. This was accomplished by simply reflecting the longitudinals about the X-Z plane. The result is depicted in figure 3.3. With that, the frames and longitudinals were done.

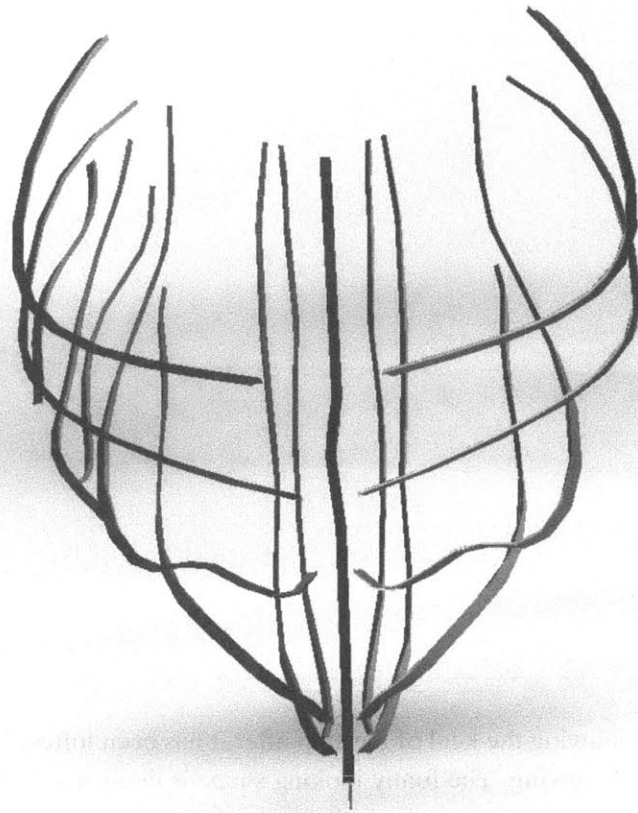


Figure 3-3 : The result of reflecting the longitudinal about the X Z plane.

## 4 Platforms

The height of and extent of the platforms were determined from the drawings. The transverse frame drawings had lines denoting the various platforms. There were 3 platforms for and 2 platforms aft. There may have been platforms that proceeded from frames 72 - 93 and 110 - 131 but there was no data available as to their location or thickness.

### 4.1 Sketching

The sketching for the platforms was extremely similar to the longitudinals because of the fact that it was also a loft. The sketch for each platform consisted of two profiles with two guide curves to ensure

adherence to the ship. It was in the profiles that the thickness of the platform was considered. The profile was made so that the platforms would be 7# plates as called for in the drawings.

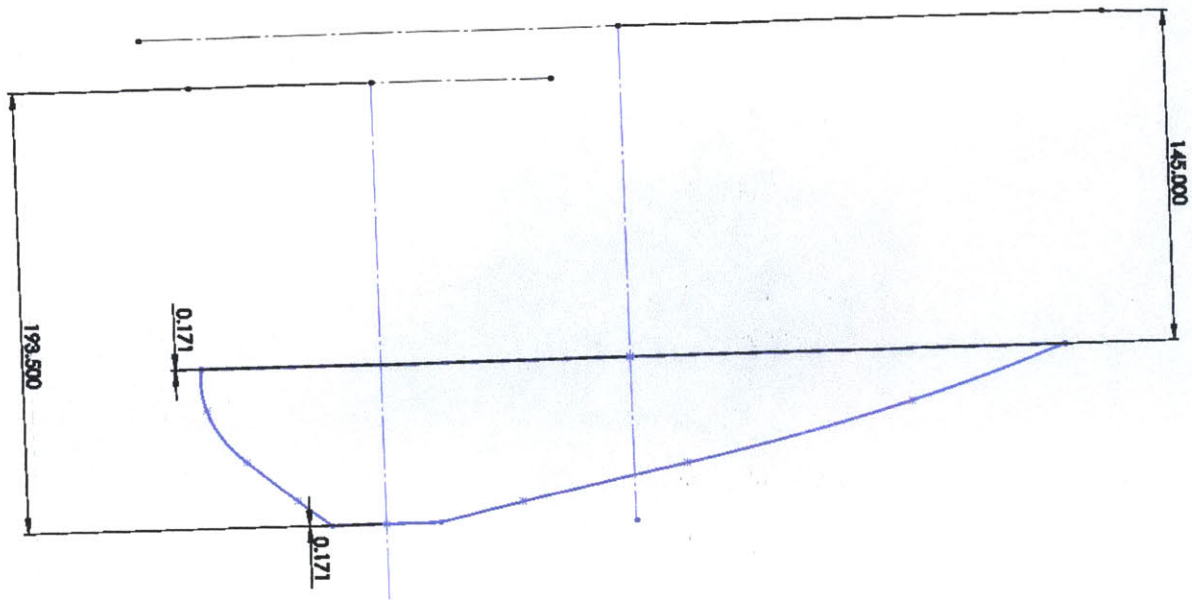


Figure 4-1: The sketch of the platform with the splines on the left and right being the guide curves. The broken lines are what allowed for the proper height of the platform to be reflected in the model.

## 4.2 Lofting

Lofting these parts was much easier than the longitudinals due to the fact that there were much fewer profiles and not as much rotation as in the longitudinal sketches.

## 5 Deck

The deck was the final feature of the ship to complete before attempting an analysis.

### 5.1 Surfacing and thickening

The surface was what was called a lofted surface. Basically, a series of lines were drawn across the transverse section of the ship with a spline that was coincident with the center of these transverse lines that would act as a guide curve. The surface was then built using the lines and the guide curve ensured that it had the right curvature. The surface was then thickened to the thickness specified in the drawings, which was 7# plate.

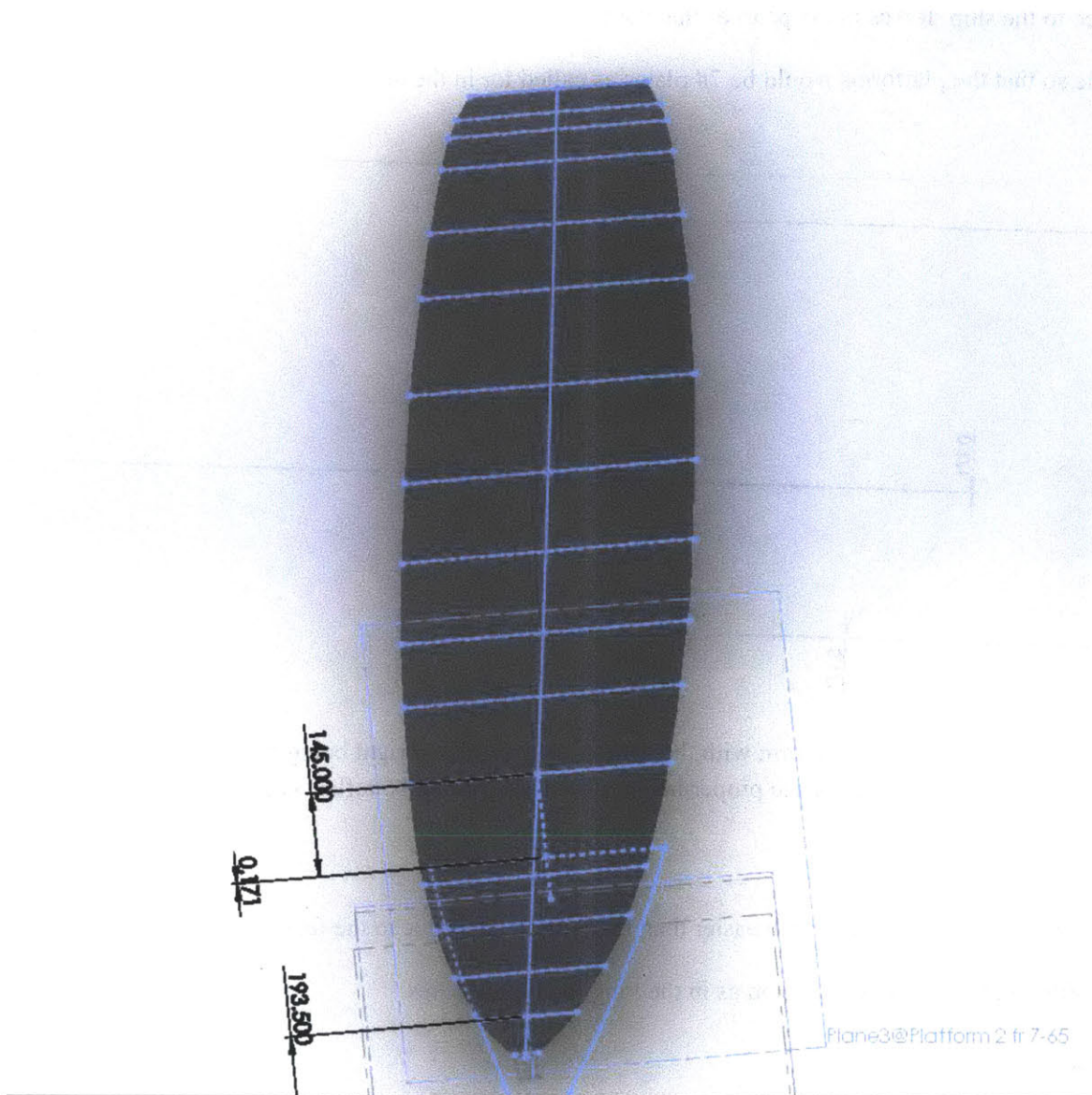


Figure 5-1: Showing the deck after thickening and

## 6 Finite Element Analysis

### 6.1 Setup

The objective of the FEA analysis was to see if any dangerous stresses would result from the corrosion of the Cassin Young's Hull since it has been a floating museum for years. This would have been accomplished by applying a pressure on the outside of the hull. Since the tonnage of a Fletcher Class

Destroyer was 2050 tons, a distributed pressure was applied that would have been equivalent to that roughly  $8126 \text{ N/m}^2$ .

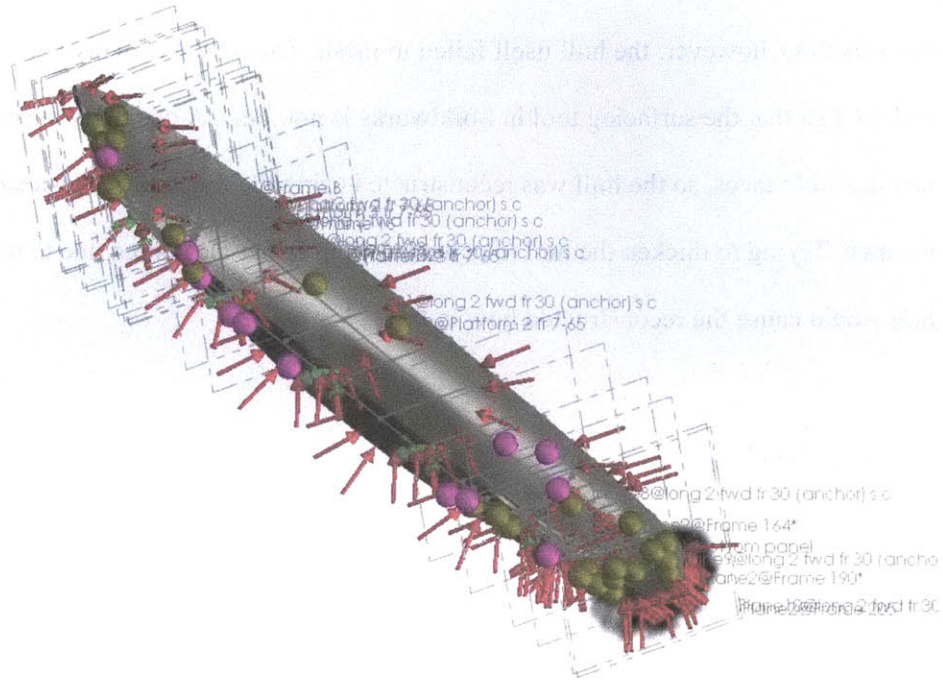


Figure 6-1: The ship with all longitudinals modeled as beams, and the pressure force applied. This was before the mesh was attempted and after the interferences were taken care of.

## 6.2 Challenges

The Finite Element Analysis of the ship proved unsuccessful. At first, the primary mode of failure was due to the interferences caused by the transverse frames and other elements of the ship. Initially, there were over roughly 3500 interferences, but suppressing all but the most basic of features (the hull and longitudinals) helped tremendously. A slight scaling of the hull rid the model of the rest of the interferences. The reason that the interferences of objects had to be cleared was that If there were interferences in the model, Solidworks would not complete the analysis because it would lead to improper meshing of the features and likely very inaccurate results. If one tried to force solve it (i.e. continuing

despite Solidworks recommendation to abort analysis), then it is likely Solidworks will be solving for a very long time.

Once the interference issue was solved, it was time to mesh the solids, and this is where the process ran into a snag. All of the longitudinals were successfully modeled as beams, greatly reducing analysis time, however, the hull itself failed to mesh. The reason is likely because of how thin the hull is and the fact that the surfacing tool in Solidworks is not ideal. A geometry check of the hull revealed incompatible faces, so the hull was reconstructed using the frame edges instead. The same problem resulted. Trying to thicken the hull to make meshing easier also failed due to the fact that thickening the hull would cause the reconstructed bow to fail.

## **7 Conclusion**

While the construction of the USS Cassin Young was accomplished in the Solidworks environment, the FEA was not. The only real way to avoid this problem would be to reconstruct the ship and find as well as fix all of the problems associated with surfacing in Solidworks. The main issue is that Solidworks will say that something fails, but it currently does not have a good utility for locating the failure mode easily. In a model as big as a ship, combing each frame and longitudinal is difficult and extremely time consuming. In addition, splines are not the ideal item to use in CAD software in general, but it was the only way to make the frames without the process being prohibitively time consuming. If I had more time, I would have tried making the ship into an assembly, by making each frame and longitudinal an individual part and putting them into the hull with a series of mates so that they would stay in the desired positions. It would likely have gotten around the zero thickness issues I encountered. Splines seem to be a necessary evil, though the tool "fit spline" might have allowed Solidworks to be more accepting of the frame features.

The fact that ships like these were built in the 1940s without the aid of computers is astounding. where it takes months to accurately construct a model in the computer environment, it took weeks at the height of the war effort to build one of these ships. It is amazing and humbling and I feel that the efforts

of every man and woman involved in the construction of destroyers like the USS Cassin Young should not be overlooked.

# **Appendix A**

## **Figures**



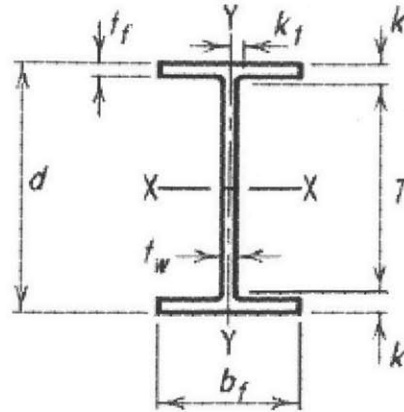


Figure A.1: A picture showing what each dimension in a standard I-beam profile is.

# **Appendix B**

## **Tables**

**Table B.1: List of Referenced Drawings in Build**

<b>BuShips Designation</b>	<b>Description</b>	<b>Structural Details</b>
445-S110005 ALT 1	Trans WT Bulkheads 38.8, 42 and 54	Detailed structural drawings of watertight bulkheads w/ measurements
445-S100005 ALT 2	Trans OT BHD 71	Same as above
445-S110005 ALT 3	LONG OT BHD FRS 148-182, OT BHD 148-152	Same as above
445 S110009 ALT 1	Stanchions Fwd FR 42 Below Main Deck	Same as above
445-S110011 ALT 2	Sections Fwd	General section structural drwgs w/ measurements
445-S110011 ALT 1	Midship Sections	Same as above
445-SS110011 ALT 3	Sections Aft	Same as above
445-S110001	Outside plating stem to FR 72	Detailed drwgs of plating
445-S110003	Transverse framing FRS. 7-29	Detailed drwgs of frames
445-S110003	Transverses 95.5 and 99.5	Detailed drwgs of frames
445-S110003	transverses 199, 202, 206, 208, & Stern framing	Same as above
445-S110004	Long's FWD of Fr 30 & Details	Same as above
445-S110004	Long's Fr. 148-Stern and details	Same as above
445-S110013	Bow framing	Detailed drwg of bow frames

**Table B.2: List of Plate thickness callouts used**

<b>#</b>	<b>Thickness (in.)</b>
7	.171
7.65	.187
8	.196
9	.220
12	.293
15	.37
20	.49

**Table B.3 List of Longitudinal Cross Sectional Profiles**

Designation	Depth	Web	Flange		Distance	Longitudinal that uses it
			Thickness $t_w$ (in)	Width $b_f$ (in)		
<b>8 x 13</b>	<b>7.99</b>	<b>.23</b>	<b>4</b>	<b>.255</b>	<b>.6875</b>	<b>8,9,10,11</b>
<b>8 x 21</b>	<b>8.28</b>	<b>.25</b>	<b>5.27</b>	<b>.4</b>	<b>.8125</b>	<b>14</b>
<b>10 x 17</b>	<b>10.11</b>	<b>.24</b>	<b>4.01</b>	<b>.33</b>	<b>.75</b>	<b>1,2,3,4,6,7</b>
<b>12 x 16</b>	<b>11.99</b>	<b>.22</b>	<b>3.99</b>	<b>.265</b>	<b>.75</b>	<b>12*</b>
<b>16 x 40</b>	<b>16.01</b>	<b>.305</b>	<b>6.995</b>	<b>.505</b>	<b>1.1875</b>	<b>5</b>

Notes- Refer to Figure A.1 for explanation of each dimension

All longitudinals are cut from this stock only bottom flange removed

\*Longitudinal is cut to a T at half of the depth of the I-beam used

Longitudinal 13 is not called out in any drawings

## References

- 1) "USS Cassin Young." *National Park Service*. National Park Service. Web. 15 May 2013. <<http://www.nps.gov/bost/historyculture/usscassinyoung.htm>>.