Outline

• Introduction

• Thin Steel Design and Construction Difficulties

• Preferred Construction Methods

• Distortion Mitigation Techniques

• Proper Administration of Correction Techniques
  – Flame Straightening, Reduced Heat

• Summary
Introduction to Thin Steel Design

• Thin steel hulls have become a current trend in Naval Surface Combatant designs
  – Incorporates thinner and higher strength steel panels and structures
  – Designs increasingly becoming more light weight to increase mission capabilities
  – Meet operational objectives and improve vessel performance
  – Counteracts increase in weight due to automated equipment and weaponry
  – Naval vessels will increasingly trend toward use of thinner, light weight/high strength steel designs

• Thin steel designs cause significant fabrication difficulties
  – Distortion due to high heat input on thin steel
  – Panel shrinkage and dimensional control issues
  – Workforce unfamiliar with techniques needed to mitigate thin steel construction difficulties
  – Reluctance of changing to newer unfamiliar technology that can drastically aid in reducing the difficulties of thin steel fabrication
Design Effects on Optimal Construction Effort

Eliminate Unnecessary Welding

Distortion Prior to Butt Welding

Additional Transverse Seams on Thin Plate (3/16”)

The “best practice” for eliminating overwelding is not welding at all.

With the ongoing effort to reduce distortion in thin plates and implementation of “best practices,” design engineers need to be conscious of distortion and eliminate designs that create problems for controlling distortion on the production side.
Craft is doing their part to implement distortion reducing “best practices” by reducing weld size and increasing restraints during butt welding, but the “best practice” of all would be to eliminate unnecessary welds altogether.
Design Effects on Optimal Construction Effort
Reduce Thick to Thin Transitions

LIDAR distortion scan of panel with insert

LIDAR distortion scan of panel without insert

Designs which create seams with differing plate thicknesses cause numerous distortional difficulties.

- Fit-up issues (Forced fit which locks in residual stress, enlarged gap which causes overwelding)
- Although these concerns are being addressed by production, cases where inserts can be eliminated, or moved away from plate edge will greatly reduce distortion
Identical Inserts on port and starboard sides. The size of weld and amount of heat required to weld these insert plates caused major distortion throughout unit

- All alternative designs that eliminate the need for inserts on thin steel panels should be exhausted before adding these inserts to the design

- It is evident from the picture on the right that these inserts, being so close the panel edge, caused significant and symmetrical unstable distortion on this unit
Design Effects on Optimal Construction Effort

*Increased Construction Difficulties with Inserts*

Several same thickness inserts were put in the design on this unit to account for manholes which intersect a longitudinal butt seam

- Because of the increased heat from a weld size of 1”+ (as shown above) this unit has severe unstable distortion throughout

- Welding to the manhole cutout (similar to the partial penetration shown on the insert) should be used to eliminate these inserts and the resulting distortion
Typical Construction Problems - An Actual Thin Plate Production Panel

6.5” MAX Distortion

Panel complexity and welding methods, combined with material condition prior to welding caused excessive distortion throughout panel.

Stiffeners fit “top-down” and resulted in significantly more distortion than “center-out” method.
Comparison of Plastic Zone Weld Sizing Effect: 5mm versus 7mm Fillet Weld

2mm increase in weld size causes DOUBLE the heat input and distortion

Leg: 5mm

\[ A_1 = \frac{5 \times 5}{2} = 12.5 \]

Leg: 7mm

\[ A_2 = \frac{7 \times 7}{2} = 24.5 \]
Optimal Construction Techniques

*Improve Fit-Up / Reduce Root Gap*

Welders should be challenged to be conscious of the effect enlarged back-gouging and fit-up have on weld size

- Optimal root gap is 1-2mm to achieve proper weld sizing on thin plate, the example above shows a back gouge of 12 mm.

- Reducing heat input by limiting root gap (without force fitting inserts), back gouge size, etc. are key to reducing the negative effects that inserts cause on distortion.
Optimal Construction Techniques

Minimize Tack Size

Tack size often drives an increase in weld size to cover tacks

- Fitters/Welders should limit tack size to at least 1/16” less than design weld size
- When tacks are too large, welders should grind them down in order to avoid overwelding and inducing unnecessary heat
- Using a smaller weld wire (3/32”) is another affective way to further reduce tack size.
Optimal Construction Techniques

Optimize Fit/Weld Sequence

Optimizing stiffener fit and weld sequence is a key ship construction process.

Fit/Weld from center out – Eliminates locking distortion into panel.

Proper sequencing counteracts distortion caused from inserts, weld size, etc.
Optimal Construction Techniques

Use Back-Step Weld Sequence

Using Back-Step Weld Sequence – Reduces Rotational Distortion

Reduces Out-of-Plane Distortion Caused by Inserts

Radius Should be left Unwelded until Properly Reinforced with Structuralss
Units should be tacked flat to the jig in order to hold the deck plate flat while transverse members are welded.

Tacking large plates flat to jig keeps units flat while welding transverse stiffeners and bulkheads, less spring-back & distortion when turned shipshape.
Optimal Construction Techniques

Use Weights w/ Large Footprint

Beams replace keel blocks as weight restraints for thin plate butt welding

- Keel blocks concentrate too much weight on a small surface area preventing out of plane distortion and natural plate shrinkage in the area it contacts only

- Beams spread out weight over larger surface area and allow for consistent shrinkage while still restraining plate from buckling distortion
Single Most Important Procedure to Resist Buckling Distortion

Clamping Plate Edges Significantly Reduces Buckling Distortion

Thin Panels Need to Have Edges & Cutouts Clamped Prior to ANY Welding

Cutouts should be left tabbed while seams and stiffeners are welded

- Tabs should be spaced every 12-18" depending on cutout size/type
Fillet Weld Panel Comparison (3/16” base plate)
Restraint Comparison on Unstable Distortion

P1: Clamps/Weights During Butts & Fillets (Var = 0.069)

Summary for Var
Survey = Fillet Welder

Anderson-Darling Normality Test
A-Squared: 0.40
P-Value: 0.206

Mean: 0.18160
StDev: 0.24219
Variance: 0.05805
Skewness: -0.17444
Kurtosis: -0.49547
N: 60

Minimum: -0.38668
1st Quartile: -0.59569
Median: 0.18069
3rd Quartile: 0.34604
Maximum: 0.75060

95% Confidence Interval for Mean
Lower Limit: 0.29177
Upper Limit: 0.22723

95% Confidence Interval for Median
Lower Limit: 0.18069
Upper Limit: 0.18069

95% Confidence Interval for StDev
Lower Limit: 0.22204
Upper Limit: 0.31579

P2: Weights for Butts, Nothing for Fillets (Var = 0.171)

Summary for Var
Survey = Fillet Welder

Anderson-Darling Normality Test
A-Squared: 0.54
P-Value: 0.05

Mean: 0.24442
StDev: 0.41471
Variance: 0.17541
Skewness: 1.35936
Kurtosis: 3.91642
N: 44

Minimum: -0.26800
1st Quartile: 0.06600
Median: 0.24370
3rd Quartile: 0.29500
Maximum: 1.75000

95% Confidence Interval for Mean
Lower Limit: 0.18362
Upper Limit: 0.29622

95% Confidence Interval for Median
Lower Limit: 0.24370
Upper Limit: 0.24370

95% Confidence Interval for StDev
Lower Limit: 0.30144
Upper Limit: 0.52467

P3: Unrestrained During Butts and Fillets (Var = 0.500)

Summary for Var
Survey = Fillet Welder

Anderson-Darling Normality Test
A-Squared: 5.10
P-Value: 0.006

Mean: 0.38950
StDev: 0.67011
Variance: 0.44966
Skewness: 2.9625
Kurtosis: 11.6930
N: 50

Minimum: -0.82680
1st Quartile: -0.18750
Median: 0.29000
3rd Quartile: 0.39103
Maximum: 2.62500

95% Confidence Interval for Mean
Lower Limit: 0.30954
Upper Limit: 0.52222

95% Confidence Interval for Median
Lower Limit: 0.29000
Upper Limit: 0.29000

95% Confidence Interval for StDev
Lower Limit: 0.26635
Upper Limit: 0.85928

P1 vs. P2 vs. P3

Panel Variation Comparison (Fillet Welds)

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Distortion from Insufficient Support

Panel Line

• When space is limited, thin panels MUST take optimal storage priority

• Extra effort to reduce distortion in manufacturing practices nullified when panels are not staged properly

• Unlike thicker panels, stiffener and panel weight cause a bending moment that permanently distorts thinner panels
Grinding and Jig Construction Issues

Excessive Grinding, Proper Jig Use

- Shell plate not welded prior to turning for paint
- Noticeable panel distortion between tacked sections on jig
- Excessive paint grinding for weld prep
Construction Difficulties – Material Handling
Improper Handling of Stiffeners

Improper handling puts bending moment on beam

Permanent plastic deformation in beam

Deck pulled up to curvature of stiffener and locks in distortion
Material Handling Damage
Fabrication Shop

• Longer panels are often staged overlapping shorter panels. When forklifts and other machinery run over these panels significant permanent distortion is noticed.

• Simple fix that eliminates adding additional distortion in panels before welding heat is even introduced.
Achieving Design Specified Weld Size
Shipyard Wide Culture Change

- Small welds obtainable with proper tooling (smaller weld wire, utilizing bug-o whenever possible, increased weld speed)

- Our engineering group has made great efforts to address the overwelding issues that presently exist in our shipyard
  - Welders have a tendency to “overweld” to cover QA inspections
  - Proper weld tooling and training is critical to achieving weld design size

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Reduce Damage from Flame Straightening

• Thin material is often over-corrected due to excessive heat during flame straightening.

• Over-heating thin material can cause severe disruption to compartment completion schedule
  • Tripped members
  • Shrinking unit out of dimensional tolerances
  • Burning up paint and creating extensive rework

Setting Flame Straightening Guidelines

• Parameters were established for material \( \frac{1}{4} \)” and below and are as follows:
  • 1-1.25” spot pattern
  • 900-1000 degree heat spots
  • Staggered pattern along stiffener with spots every 2”
Summary

• The trend of thin steel in today’s ship designs
• The issues thin steel designs bring to production
• Key design factors that affect thin steel producibility
• Key construction techniques used to mitigate distortion
• Preferred manufacturing processes and administration of correction methods to avoid creating additional production problems in order to reduce construction costs
Thank You

Questions?