





# Analysis and prediction of welding deformations of ship panels in prefabrication process

Master Student: Huggo Sena Batista  
Professor: PhD. Tadeusz Graczyk


Nantes, France 15/February/2012




# Outlines



Topics

- Introduction
- Initial Analysis
- Modeling
- Result
- Conclusion




Huggo Sena Batista 

EMship  
Advanced Design



# Introduction



Huggo Sena Batista 3

EMship  
Advanced Design

## Introduction



◇ Shipbuilding Industry

Different process, machinery and technology



Huggo Sena Batista 4


EMship  
Advanced Design

# Introduction

◇ **Shipbuilding Industry**

Improvements:

- New technologies: raw material, strength, corrosion etc.;
- Reduction of problem and rework after process;
- Reduction of the warm-up (process);
- New welding technologies;
- Layout;
- Reduction of the welding problems



Huggo Sena Batista 5

EMship  
Advanced Design

# Introduction

◇ **Shipbuilding Industry**

Improvements:



**Welding-induced deformation**



Huggo Sena Batista 5

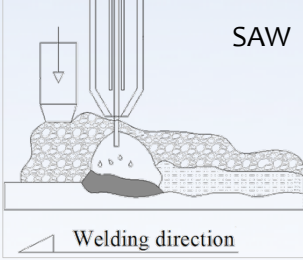
EMship  
Advanced Design

# Introduction

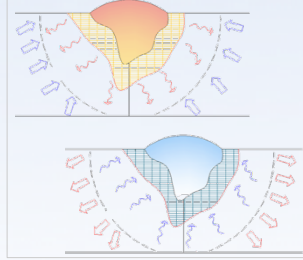
◇ **Problem**  
Welding-induced deformation due to residual stress

Welding parameter  
+  
Initial imperfection  
+  
Pressure (Gantry)  
+  
...


**Factors**



**Process**



**Heating-cooling cycles**

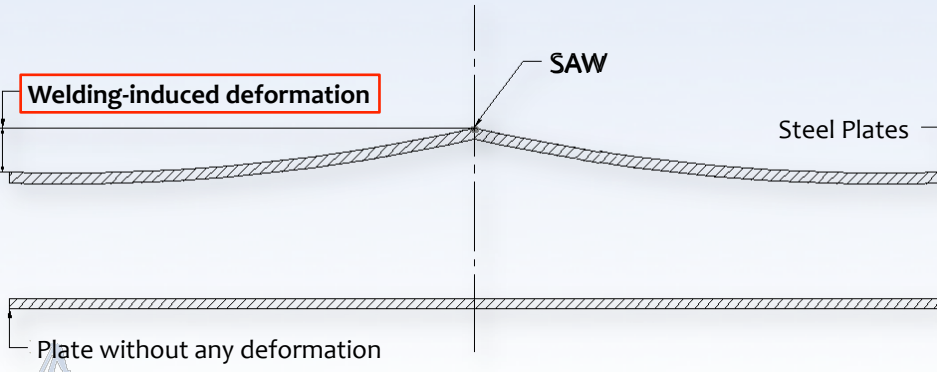



Huggo Sena Batista 6

EMship  
Advanced Design

# Introduction

◇ **Problem**  
Welding-induced deformation due to residual stress





Huggo Sena Batista 6

EMship  
Advanced Design

# Introduction

◇ Proposed solution

**Initial Analysis**

Current situation Analysis

↓

DoE – Planning and data collection

**Modeling**

Statistical Analysis

↓

DoE – Numerical equation

**Results**

Prediction of welding-induced deformation

Huggo Sena Batista 7

EMship  
Advanced Design


# Initial Analysis

Huggo Sena Batista 8

EMship  
Advanced Design

## Initial Analysis

◇ **Current situation analysis**  
Process evaluation



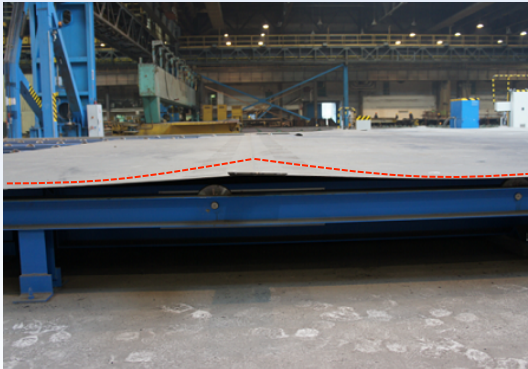
- Edge preparation (butt joint)
- Tack welding
- Submerged Arc Welding (SAW)
- Plate transportation
- Turn-over unit
- Submerged Arc Welding (SAW)

Huggo Sena Batista 9

EMship  
Advanced Design


## Initial Analysis

◇ **Current situation analysis**  
Problem – welding-induced deformation




- After 1<sup>st</sup> butt-welding
  - **Heat Input**
    - Welding Current
    - + Welding Speed
    - + Voltage
    - + Efficiency factor (SAW)
  - **Copper Bar**
  - **Magnetics**

Huggo Sena Batista 10



# Initial Analysis



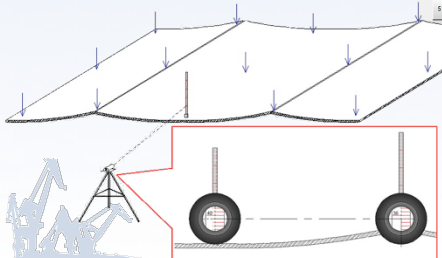
---

## ◇ DoE – Planning and data collection

- Design of Experiment
- Factors, level, restrictions etc
- Data collection (measurement)

**2-Level Factorial Design**  
Design for 2 to 21 factors where each factor is varied over 2 levels. Useful for estimating main effects and interactions. Fractional factorials can be used for screening. The color coding represents the design resolution: Green = Res V or higher, Yellow = Res IV, and Red = Res III.


	Number of Factors														
Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	2 <sup>1</sup>														
2		2 <sup>2</sup>													
3			2 <sup>3</sup>												
4				2 <sup>4</sup>											
5					2 <sup>5</sup>										
6						2 <sup>6</sup>									
7							2 <sup>7</sup>								
8								2 <sup>8</sup>							
9									2 <sup>9</sup>						
10										2 <sup>10</sup>					
11											2 <sup>11</sup>				
12												2 <sup>12</sup>			
13													2 <sup>13</sup>		
14														2 <sup>14</sup>	
15															2 <sup>15</sup>




Level	Heat Input [kJ/cm]	Magnetic Pressure [bar]	Copper Bar Pressure [bar]
Minimum	10.4	1.0	0.35
Central	10.9	1.5	0.40
Maximum	11.8	2.0	0.45

27 different welding condition!

Huggo Sena Batista 11



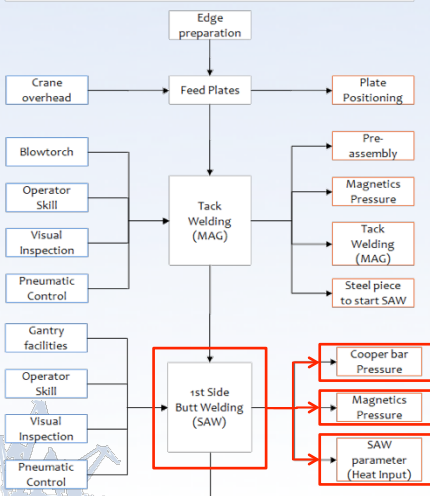
# Initial Analysis

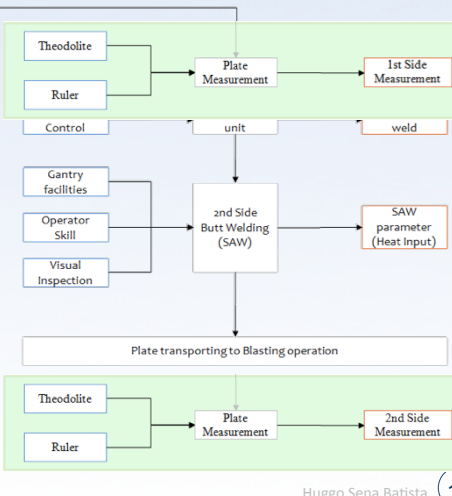


---

## ◇ Current situation analysis – Summary



1st Stage of Weld Panel: Feeding, Tack welding and SAW






Huggo Sena Batista 12

EMship  
Advanced Design





# Modeling



Huggo Sena Batista 13

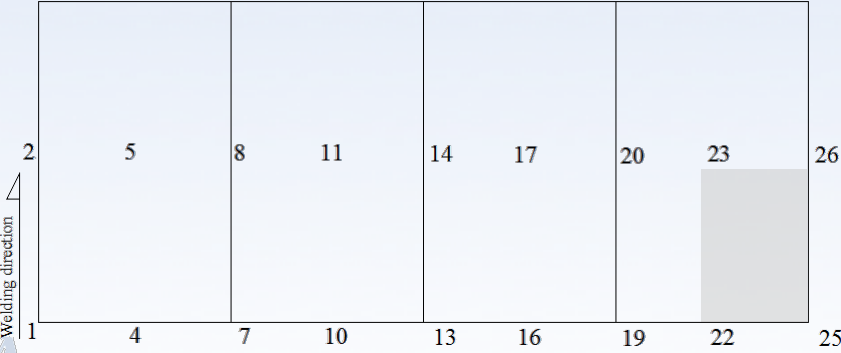
EMship  
Advanced Design




# Modeling

◇ Statistical analysis

Assumptions – Data processing




	3	6	9	12	15	18	21	24	27
3									
2		5	8	11	14	17	20	23	26
1		4	7	10	13	16	19	22	25




Huggo Sena Batista 14







# Modeling





---

◇ **Statistical analysis**  
 After data collection → Data processing (Assumption)





- Only data from 1<sup>st</sup> side butt welding (SAW)
- Only real data


Huggo Sena Batista 15

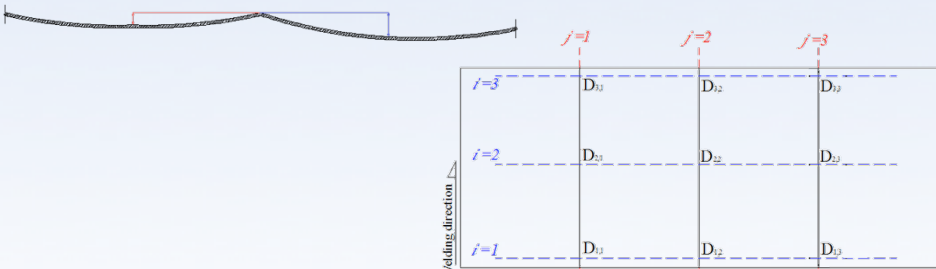


# Modeling




---

◇ **Statistical analysis**  
 Data processing – data input



$$D_{i,j} = \text{Max} \left( \left| P_{(i+3)+6(j-1)} - P_{(i+6)+6(j-1)} \right|, \left| P_{(i+9)+6(j-1)} - P_{(i+6)+6(j-1)} \right| \right)$$

$$D_{seam_j} = \frac{1}{3} \sum_{i=1}^3 (D_{i,j})$$


Huggo Sena Batista 16

EMship Advanced Design **Modeling**

◇ **Statistical analysis**  
Data processing – data input

**Trials (DoE)**

19  
8

Done  
Outstanding

19 Trials = 50 measured points

**Data input (DoE)**

17  
2

Modeling  
Verification

- 17 trials to modeling the numerical equation
- 2 trials for verification

Huggo Sena Batista 17


EMship Advanced Design **Modeling**

◇ **Statistical analysis**  
Data processing – outcomes  
Characteristics considered:


- Terms of the model
- P-values of the model
- Residual
- F-value
- Lack of fit of the model
- Standard deviation

Design Expert

Huggo Sena Batista 18



# Modeling




◇ **Statistical analysis**

Data processing – ANOVA (Analyze of Variance)


Item	Specification	ANOVA				
Terms of the Model	-	Q	CB	M	Q*CB	Q*M
P-value – Terms	<0.05	0.91	0.54	0.26	0.04	0.0
P-value – Model	<0.05	0.0				
Residual Mean Square	-	22.48				
F value – Model	-	4.44				
F value – Terms	-	0.01	0.38	1.31	4.28	15.26
Lack of Fit	>0.05	0.1				
Standard Deviation	-	4.7				

All the values were analyzed based on statistical fundamentals.  
These values might be different, depend on the data arrangement.

Huggo Sena Batista 19



# Modeling



◇ **DoE Numerical equation**

Data processing – Numerical equation

$$D = +422.45083$$

$$-35.87045 \cdot Q \quad \leftarrow \text{Heat Input}$$

$$-574.07631 \cdot CB \quad \leftarrow \text{Copper bar pressure}$$



$$-113.80114 \cdot M \quad \leftarrow \text{Magnetic pressure}$$

$$+52.41132 \cdot Q \cdot CB$$


$$+10.01348 \cdot Q \cdot M$$

Huggo Sena Batista 20

EMship  
Advanced Design






# Results



Huggo Sena Batista 21

EMship  
Advanced Design

## Results

◇ Prediction of welding-induced deformation  
Using the equation – residual calculation

**Residual (Actual x Predicted)**

Residual [mm]

+3  $\sigma$

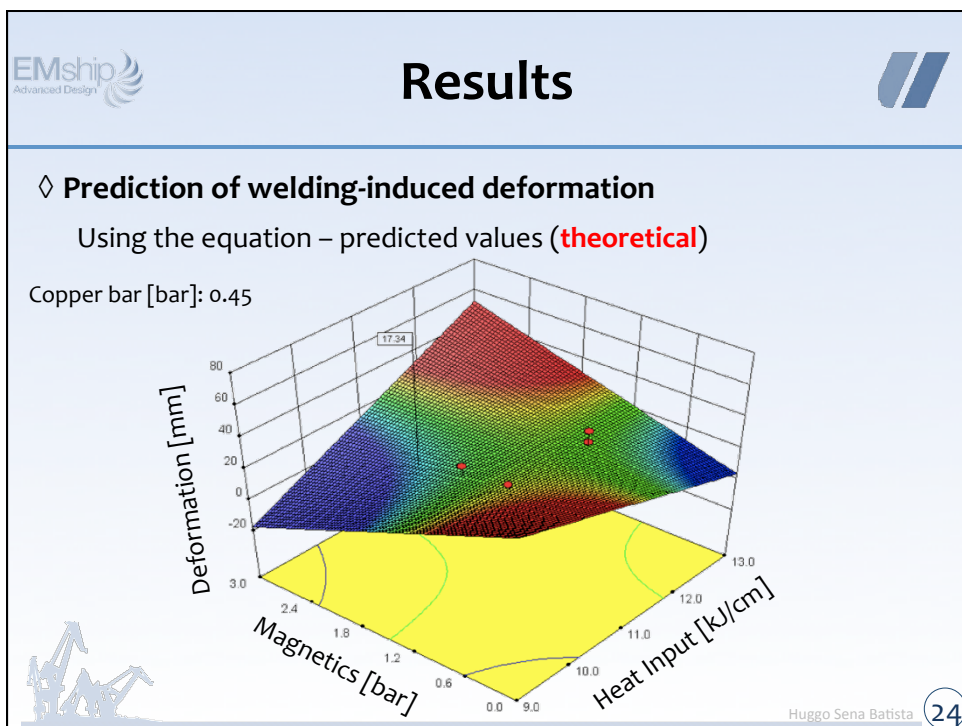
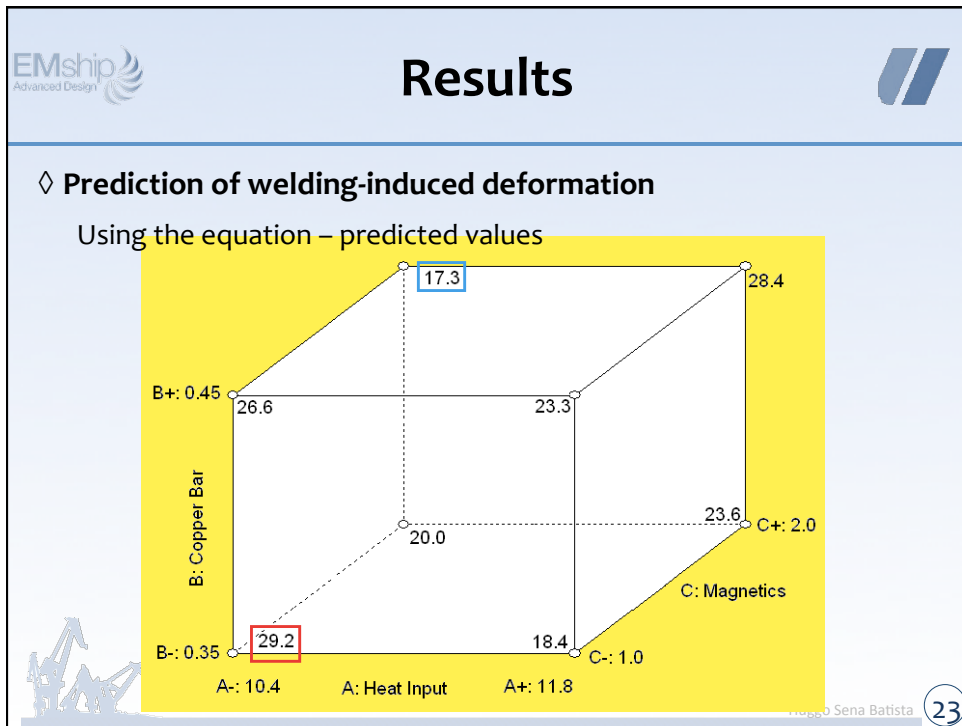
-3  $\sigma$

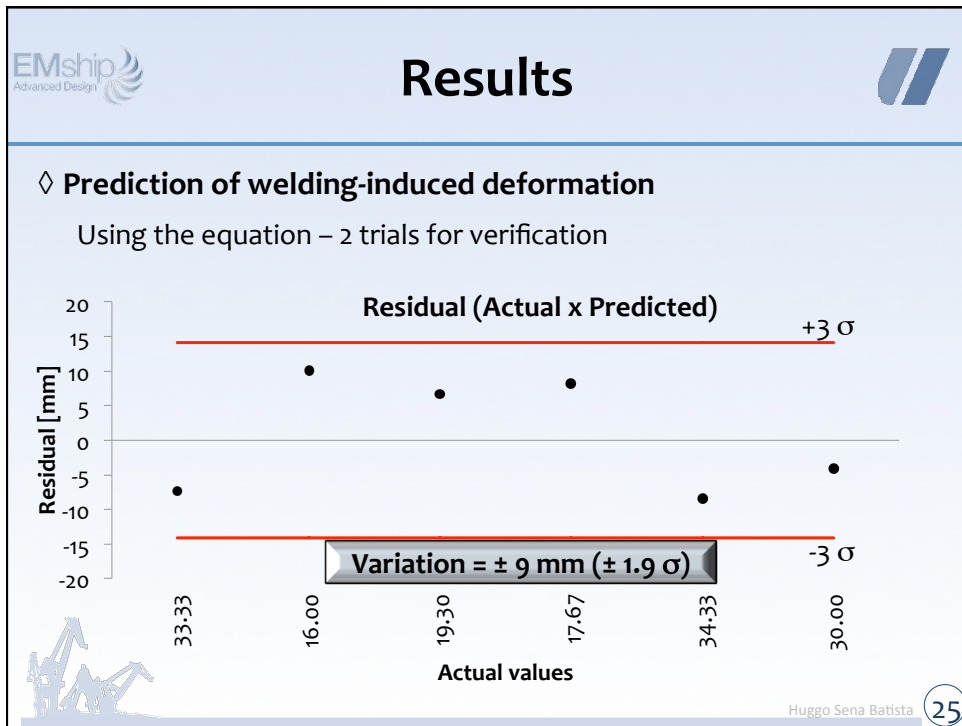
Variation =  $\pm 10 \text{ mm } (\pm 2.1 \sigma)$

Actual values

Actual values	Residual [mm]
19.33	6.5
22.67	-3.5
17.67	12.5
32	-6.5
24	-4.5
31	-2.5
31.33	-8.5
22.33	1.5
13.67	5.5
23.67	-1.5
18	-6.5
17	1.5
23	-4.5
14.67	4.5
21.33	-4.5
27.67	-3.5
13.33	8.5
21	1.5
29.33	-6.5
32	-8.5
19	5.5
28.33	1.5


Huggo Sena Batista 22






**Conclusion**


Huggo Sena Batista 26



## Conclusion



- ◇ Welding-induced deformation is possible to predict through statistical analysis;
- ◇ A initial analysis of the process to define the main factors;
- ◇ Data arrangement analyses;
- ◇ Statistical results vs sources of error;



Huggo Sena Batista 27




## Thank you!





### Analysis and prediction of welding deformations of ship panels in prefabrication process


Master Student: Huggo Sena Batista  
Professor: PhD. Tadeusz Graczyk

Nantes, France    15/February/2012








# Meaning



◇ **Statistical analysis** U

Item	Recom	Mean
F value – Model	>1	Relation between model variance with the residual (error) variance. If the model variance is bigger than the error variance, F value >1 and null hypothesis is out.
F value – Terms	> 1	
P-value – Terms	<0.05	Small probabilities reject the null hypothesis (significant). The possibility to verify F-value if the null hypothesis is true.
P-value – Model	<0.05	
Residual Mean Square	-	Square root of the sum of the residual square. It verifies if the model is close or not of the real values
Lack of Fit	>0.05	This is the variation of the data around the fitted model. Large values means that this characteristics is not significant (NOT significant LOF = the model fits the data)
Standard Deviation	$\sqrt{\text{RMS}}$	Estimate of the SD associated to the experiment

Huggo Sena Batista
29