Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 3, March-2016

HEAT TREATMENT STUDY OF 2205 DUPLEX STAINLESS STEEL

Rohitkumar Talaviya[1],Krupeshkumar Talaviya[2], SagarKumar Hirpara[3], Amit Dudhat[4]

[1]B.E.Metallurgy – GEC, Gandhinagar

[2]B.E.Metallurgy – GEC, Gandhinagar

[3]B.E.Mechanical – LDRP-ITR, Gandhinagar

[4]B.E.Mechanical – LDRP-ITR, Gandhinagar

Abstract- *Duplex stainless steels were originally developed for the manufacture of pumps and impellers housing in the fertilizer industry. However, the growing demand for casting components of these materials has led to the application of a largely developed for this forming process technology. After having undergone heat treatment solution treatment, these materials become thermodynamically metastable systems, as the concentration of solid solution of solute atoms is so high that they become saturated, causing them to look for a free energy state lower when exposed to different temperatures. These systems achieve a stable thermodynamic state by the precipitation of different intermetallic phases, depending on the temperatures to which they are exposed. Thermal energy is the catalyst to "overcome" the energy barrier separating the metastable and stable phases. The objective of this study was to determine the influence of various heat treatment temperatures on the microstructure and mechanical properties of stainless steel and duplex.*

Keywords- *Heat Treatment, Duplex Stainless Steel, Solution Annealing, Liquid Carbonitriding, Tensile Testing, Metallography.*

I. INTRODUCTION

Stainless steels are generally heat treated according to the stainless steel type, and implementation patterns of treatment. Heat treatment methods, such as relieving stress, curing and annealing, enhance ductility and corrosion resistance of the metal that is modified during production, or generate hard structures able to tolerate the abrasion and high mechanical stresses. Heat treatment of stainless steel is most often carried out under controlled conditions to prevent carburization, decarburization and scaling on the metal surface.

2205 is a second generation duplex stainless steel having a nominal composition of 0.03% carbon, 22% chromium, 5.5% nickel, 3% molybdenum and 0.14% nitrogen. This composition results in a stable microstructure containing about 45% ferrite and 55% austenite. Austenitic stainless steels generally exhibit excellent corrosion resistance in most environments corrosion, but may fail by stress corrosion in warm chloride solutions in certain circumstances. Ferritic stainless steels are generally resistant to cracking under these conditions. However, the use of ferritic stainless steels is limited due to constraints of weld ability in the above section thickness of about 2 mm. It is believed that the presence of ferrite in duplex stainless steels inhibits crack propagation.

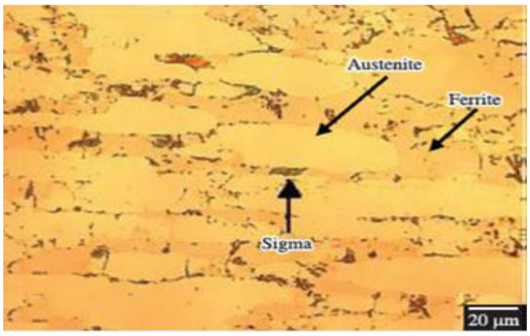

Figure 1. Microstructure of Duplex Stainless Steel without Heat Treatment

We are introducing new method of Heat Treatment of duplex stainless steel (2205) which will provide more ductility and toughness to steel than method of liquid carbonitriding. Liquid carbonitriding method of Heat treatment provides only case hardening and high wear resistance and resistance against friction. Although our method of heat treatment is less expensive compared to liquid carbonitriding.

II. RECENT SCENARIO ABOUT HEAT TREATMENT STUDY OF DUPLEX STAINLESS STEEL

Generally we are using Liquid Carburizing Process for improving mechanical properties of Duplex Stainless Steel. Carburizing is a thermochemical processes. During this process, the work piece is enriched with a mixture of carbon and nitrogen (carbonitriding) to improve the mechanical properties of the work piece edge layer. It was originally developed as an alternative to the gas nitriding which produce a more uniform case through the contact surface between the substrate and the liquid salt. When steel pieces are placed in a preheated liquid salt, there is enough energy localized near the surface due to chemical potential differences which in turn allows the nitrogen and carbon species diffuses from the salt in the steel substrate. The process is conducted at 750-1050 ° C, making it faster as gas nitriding. Lower temperature cycles produce a broadened case S-phase / austenite in stainless steels. Post-oxidation after nitriding combined with polishing produces coatings with an outstanding appearance (black) and high resistance to corrosion (electrolytic upper chromium plating). To ensure the quality of the part, our salt baths are constantly monitored, with chemistry adjustments made if necessary.

Heating temperature: 9200C
Soaking time: 3-3: 00 pm
Media Quench Tempering oil temperature: 2100C
Furnace: Furnace salt bath
Salt: Nitrogen/Cyanide salt with liquid

III. PROCESS PLANNING

In our experimental work in the industry, we worked on the basis of heat treatment processing 2205 Duplex stainless steel. Various stage performed on this steel like, hardness test, tensile test and metallography. We first took the sample of 2205 duplex stainless steel.

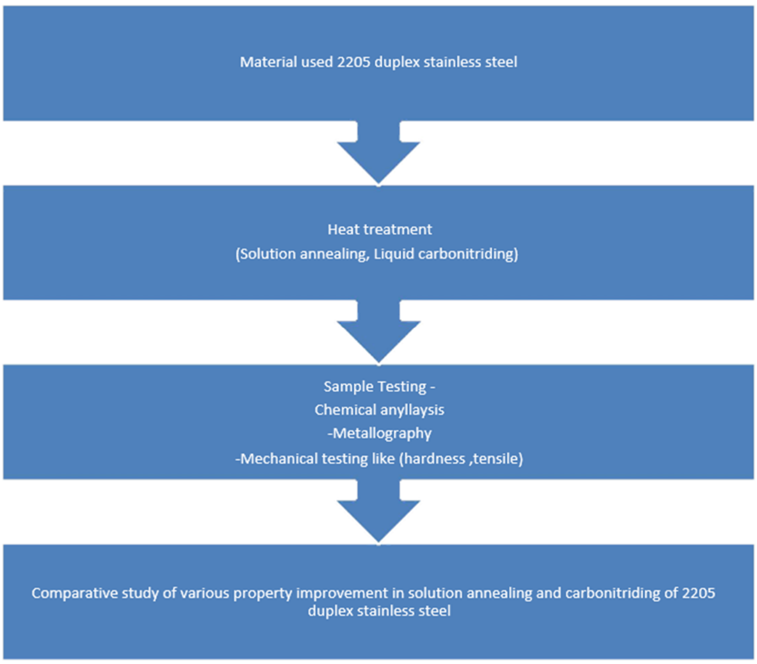

Figure 1. Process planning of Heat treatment of 2205 Duplex Stainless Steel

IV. EXPERIMENTAL PROCEDURE

4.1 Solution Annealing

Solution Annealing is a process carried out on the steels. Heat slowly and steadily to 10400 C. Then hold at this temperature for 10 minutes. Quench in an agitated water bath down to room temperature.

It is extremely important that the recommended cooling cycle has been respected as a cool air or cool the oven will result in the precipitation and formation sigma brittle intermetallic phase which will negatively affect the mechanical properties, particularly the cold formability and toughness of the material.

Figure 2. Solution Annealing

4.1.1 Cycle 1 :

Heating up to Temperature: 1040 ^{0}C
Holding Time: 120 min
Quench Media: Water
Final Temperature: Room Temperature
Furnace: Muffle Furnace

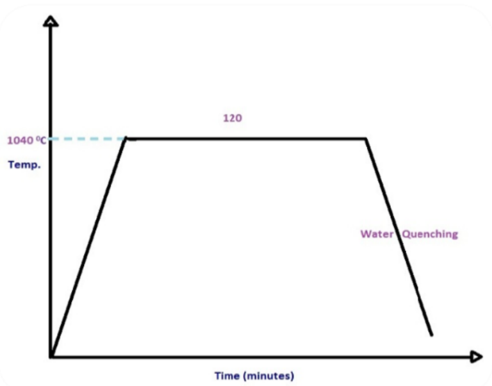

Figure 3. Cycle 1

4.1.2 Cycle 2 :

Heating up to Temperature: 1040 ^{0}C
Holding Time: 120 min
Quench Media: Water
Final Temperature: Room Temperature
Furnace: Muffle Furnace

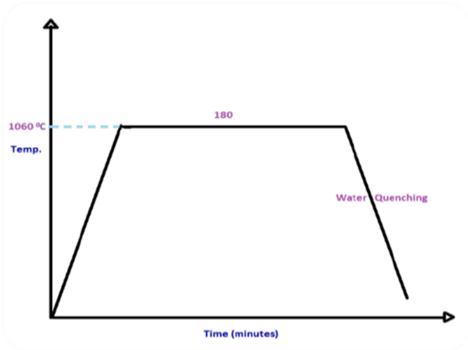

Figure 4. Cycle 2

4.2 Tensile Testing

The tensile test, also known as tensile test is a test of science base materials in which a sample is subjected to a controlled tension until failure. The test results are routinely used to select a material for an application, for quality control and to predict how a material will react in other types of forces. Properties that are directly measured by a tensile test are tensile strength, maximum elongation and reduction of area. From these measurements, the following properties may also be determined: Young's modulus, Poisson's ratio, elastic limit, and the stress-curing characteristics. Uniaxial tensile test is most commonly used to get the mechanical properties of isotropic materials. For anisotropic materials, such as composite materials and textiles, uniaxial tensile testing is necessary. In accordance with ASTM standards (ASTM E8), the ratio of the diameter of the gauge to measure the length should be 1: 5. Thus turning was done to obtain the required specifications.

I. Gauge Length: 50 mm
II. Gauge Diameter: 50 mm
III. Total Length: 165 mm
IV. Grip Diameter : 18 mm

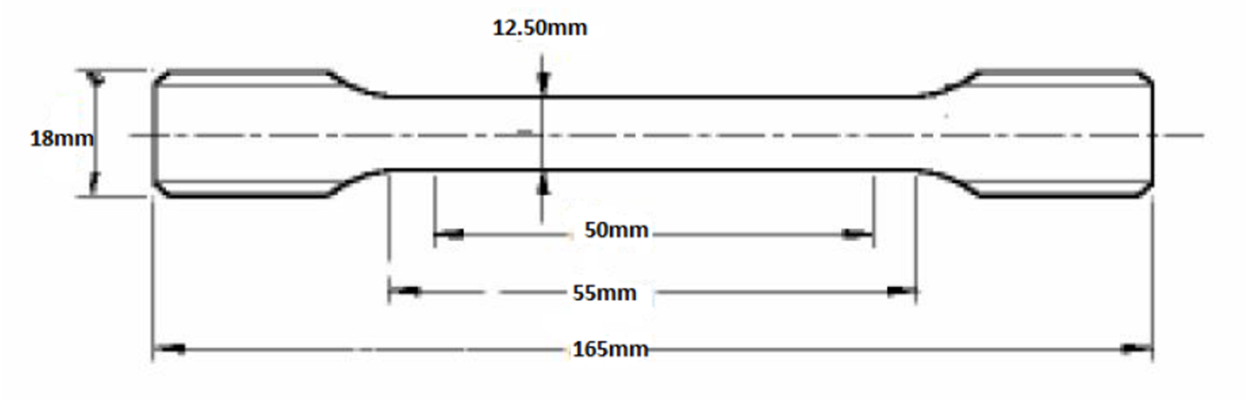

Figure 5. Tensile Testing Specimen

4.2.1 Procedure of Tensile Testing :

ASTM A536 (1563) was used for the tensile tests.
The prepared sample into the sample preparation step was performed according to ASTM A536 specification standard and therefore was used directly.
The process is as follows:
1. The dimensions of the test piece (thickness / gauge length / total length in mm, etc.) have been accurately measured with an electronic caliper.
2. Data were introduced into the testing machine.
3. The distance between the jaws was set according to the reference length of the sample.
4. The sample was inserted into the machine and gripped by the jaws.
5. Maximum load was set at 150KN and loading was done until the specimen failed.
6. The corresponding readings generated for the yield strength, % elongation and breaking strength was noted.

4.3 Brinell Hardness Testing

The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material specimen. It is one of several definitions of hardness in materials science.

Proposed by the Swedish engineer Johan August Brinell in 1900, he was the first test widely used and standardized hardness in engineering and metallurgy. The large size of indentation and possible damage to test limits its usefulness.

The typical test uses a 10 mm (0.39 in) diameter steel ball as a penetrator with 3,000 kgf (29 kN 6,600 lbf) of force. For softer materials, a smaller force is used; for harder materials, a tungsten carbide ball is replaced by the steel ball. The indentation is measured and hardness calculated as follows:

$$\mathrm{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where,
P = applied force (kgf)
D = diameter of indenter (mm)
d = diameter of indentation (mm)

4.3.1 Procedure of Hardness Testing

The method utilized for hardness testing was Brinell Hardness Testing. In this process:
1. The specimen was put on the specimen holder.
2. The minor load of 100kg was applied by rotating the axle.

When the reading on the display became zero the rotating was stopped and final loading was applied by pressing the loading button.

4.4 Metallography

Metallography is the study of the physical structure and components of metals, typically using microscopy.

4.4.1 Procedure of Hardness Testing

1. The surface of a metallographic specimen is prepared by various methods of grinding, polishing, and etching.
2. Etching with 40% NaOH solution.
3. After preparation, it is often analyzed using optical or electron microscopy.
4. Observation at 500X.

V. EXPERIMENTAL DATA

5.1 Tensile Testing

5.1.1 Solution Annealing

5.1.1.1 Cycle 1

Table 1. Cycle 1 of Solution Annealing For Tensile Testing

Parameters	Original	Solution annealed
Original Diameter mm	9.87	9.77
Original G.l mm	50.08	49.90
Original Area	76.54	75.00
Ultimate Load N	56820	59820
UTS N/mm^2	742.34	797.61
Yield Strees N/mm^2	639.65	662.81
Yield Load N	48960	49710
Final G.l mm	63.58	64.45
Elongation%	26.96	29.16
Reduction Area%	74.64	68.65
Location of Fracture	WGL	WGL

5.1.1.2 Cycle 2

Table 2. Cycle 2 of Solution Annealing For Tensile Testing

Parameters	Original	Solution Annealing
Original Diameter mm	9.87	9.95
Original G.l mm	50.08	50.06
Original Area	76.54	77.79
Ultimate Load N	56820	46320
UTS N/mm^2	742.34	595.47
Yield Strees N/mm^2	639.65	413.05
Yield Load N	48960	32130
Final G.l mm	63.58	64.75
Elongation%	26.96	29.35
Reduction Area%	74.64	73
Location of Fracture	WGL	WGL

5.1.2 Liquid Carbonitriding

Table 3.Liquid Carbonitriding for Tensile Testing

Parameters	Original	Liquid Nitrocarburising
Original Diameter mm	9.87	9.90
Original G.I mm	50.08	49.90
Original Area	76.54	77.01
Ultimate Load N	56820	62070
UTS N/mm^2	742.34	806.02
Yield Strees N/mm^2	639.65	647.47
Yield Load N	48960	49860
Final G.I mm	63.58	58.85
Elongation%	26.96	17.94
Reduction Area%	74.64	27.15
Location of Fracture	WGL	WGL

5.2 Hardness Testing

5.2.1 Solution Annealing

5.2.1.1 Cycle 1

Table 4. Cycle 1 of Solution Annealing for Hardness Testing

Ball Diameter	Load In (Kg)	Room Temp.	1	2	3	Avg
10	3000	30	223	224	223	223

5.2.1.2 Cycle 2

Table 5. Cycle 2 of Solution Annealing for Hardness Testing

Ball Diameter	Load In (Kg)	Room Temp.	1	2	3	Avg
10	3000	30	222	223	224	223

5.2.2 Liquid Carbonitriding

Table 6. Liquid Carbonitriding for Hardness Testing

Ball Diameter	Load In (Kg)	Room Temp.	1	2	3	Avg
10	3000	30	235	232	232	233

5.3 Chemical Composition

5.3.1 Solution Annealing

5.3.1.1 Cycle 1

Table 7. Cycle 1 of Solution Annealing for Chemical Composition

Elements (wt%)	Original	Solution Annealed
C	Nil	0.009
Cr	23.510	23.480
Mo	2.930	3.100
Ni	2.800	3.680
Cu	0.350	0.330
P	0.022	0.0270
S	0.007	0.008

5.3.1.2 Cycle 2

Table 8. Cycle 2 of Solution Annealing for Chemical Composition

Elements (wt%)	Original	Solution Annealed
C	Nil	0.009
Cr	23.510	23.430
Mo	2.930	3.100
Ni	2.800	3.690
Cu	0.350	0.350
P	0.022	0.0250
S	0.007	0.007

5.3.2 Liquid Carbonitriding

Table 9. Liquid Carbonitriding for Chemical Composition

Elements (wt%)	Original	Liquid Carbonitring:
C	Nil	0.006
Cr	23.510	23.470
Mo	2.930	3.120
Ni	2.800	3.660
Cu	0.350	0.340
P	0.022	0.0260
S	0.007	0.007

5.4 Metallography

5.4.1 Original

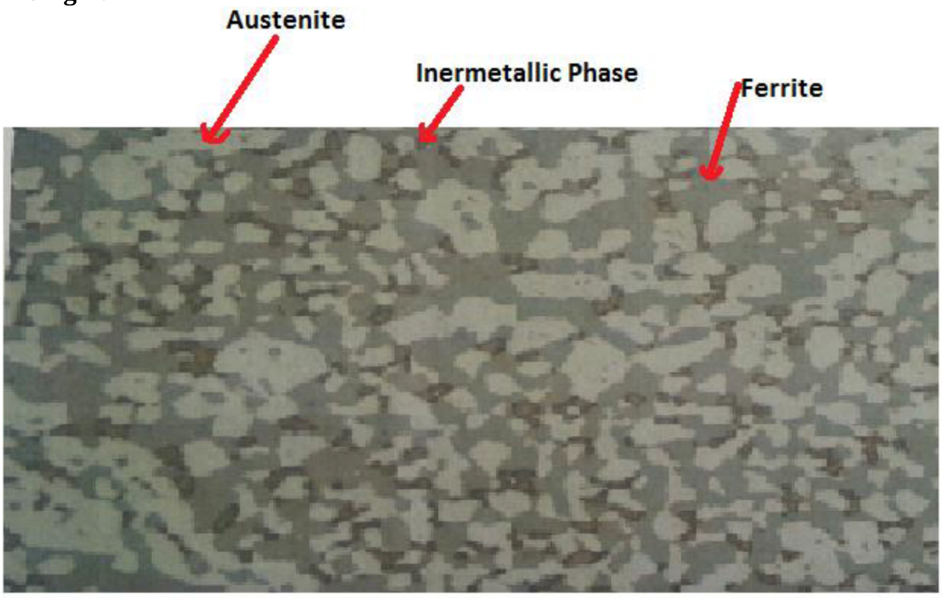

Figure 6. Duplex Stainless steel Microstructure without Heat Treatment

OBSERVATION: Figure shows that in this microstructure austenite and ferrite reveled and grain boundary reveled with inter metallic phase (magnification 500X and etchant is NAOH)

5.4.2 Solution Annealing

5.4.2.1 Cycle 1

OBSERVATION: Figure shows that in this microstructure austenite and ferrite reveled and grain boundary free from inter metallic phase (magnification 500X and etchant is NAOH).

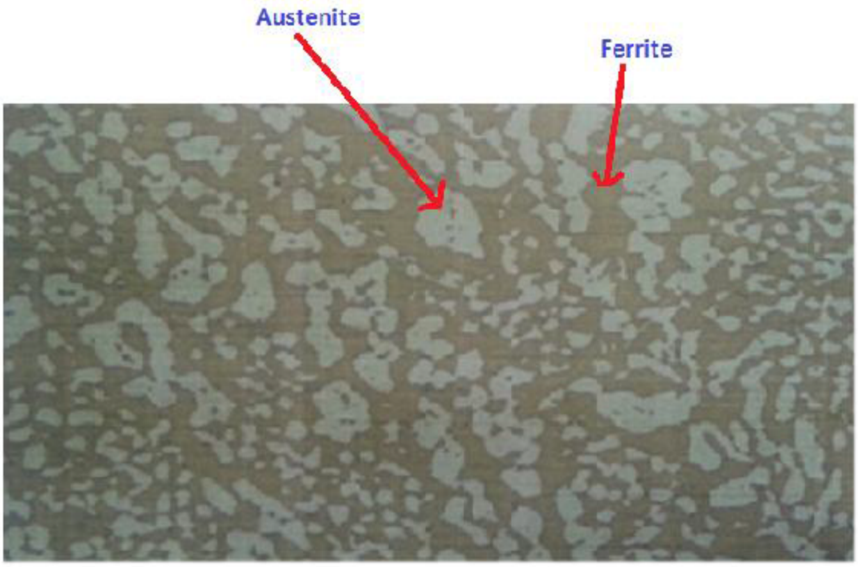

Figure 7. Duplex Stainless steel Microstructure after cycle 1

5.4.2.2 Cycle 2

Figure 8. Duplex Stainless steel Microstructure after cycle 2

5.4.3 Liquid Carbonitriding

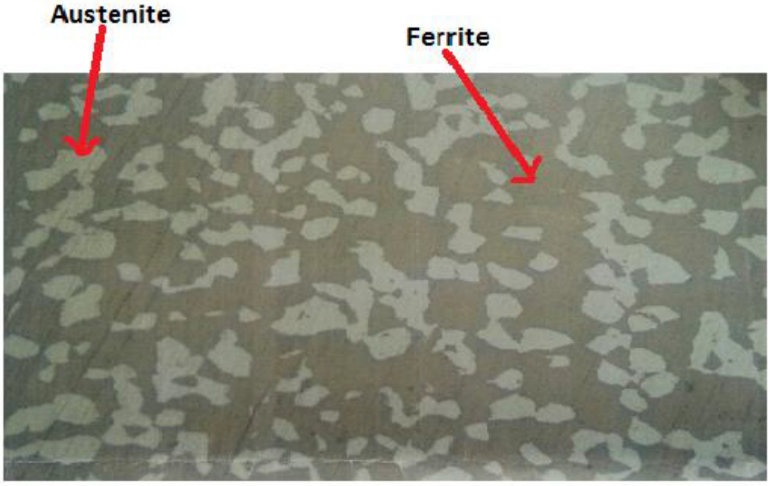

Figure 8. Duplex Stainless steel Microstructure after Liquid Carbonitriding

OBSERVATION: Figure shows that in this microstructure austenite and ferrite reveled and grain boundary free from inter metallic phase and grain size increase (magnification 500X and etchant is NAOH).

VI. EXPERIMENTAL RESULTS

Table 9. EXPERIMENTAL DATA

Parameters	Solution Annealing		Liquid Carbonitriding
	Cycle 1	Cycle 2	
Hardness	223	223	233
UTS	797.6	595.47	806.02
Wear Resistance	Low	Low	High
Fracture	Ductile	Ductile	Brittle
Ductility	High	High	Low
Hardenability	Low	Low	High
Friction Resistance	Low	Low	High
Toughness	High	High	Low
Cost	Low	Low	High

VII. CONCLUSION

In conclusion, liquid carbonitriding gives case hardness and wear resistance, improved resistance against friction and solution annealing gives ductility and toughness of 2205 duplex stainless steel. For the application of pump casing of fertilizer industry, oil and gas explosion ,transport and storage tank in which solution annealing preferred on 2205 duplex stainless steel, Whereas gear and shaft, bearing in which liquid carbonitring preferred.

VIII. REFERENCES

[1] http://www.northamericanstainless.com/wp-content/uploads/2010/10/Grade-2205-Duplex.pdf
[2] http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.elsevier-fb905c36-30e4-344a-80b0- b986c659bb33
[3] http://www.hardnesstesters.com/applications/brinell-hardness-testing.aspx
[4] http://en.wikipedia.org/wiki/Tensile_testing
[5]http://www.smt.sandvik.com/en-in/products/tube-pipe-fittings-and-flanges/high-performance-materials/duplex-stainless-steel/
[6] http://www.bssa.org.uk/topics.php?article=668
[7] http://www.diva-portal.org/smash/get/diva2:9607/FULLTEXT01.pdf
[8] http://www.oxford-instruments.com/getmedia/82d8409e-a9bd-445d-91e3-02c3d9cc1dee/Microstructure-and-phase-analysis-of-duplex-stailess-stell-after-heat-treatment
[9] http://www.ysesm.ing.unibo.it/Abstract/57%20Dyja.pdf
[10] http://www.twi-global.com/technical-knowledge/published-papers/effect-of-intermetallic-phases/
[11] http://www.stainless-steel-world.net/pdf/sswNNB_duplex_padova.pdf?resourceId=105
[12] http://www.journalamme.org/papers_vol59_1/5914.pdf
[13] http://www.euro-inox.org/htm/p_232_EN.html