



About the welding effects on thin stiffened panel assemblies in shipbuilding

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Abstract

Last year, the definitive closure of one of the major French Shipyards was announced and planned for the beginning of 2000. It has really been a great loss for the whole shipbuilding industry. The ACH shipbuilder (Ateliers et Chantiers du Havre) is well-known in the world for having built several prestigious cruise-liners which are still in active service such as the Wind Star, Wind Song, Wind Spirit, Club Med One, Club Med Two, . . .

The origine of this closure of the Yard financially weak came, among other unforeseen difficulties, from the delay of ship construction that was too much overlapped. One of the prime causes of this failure in the fabrication process was the distortion problem due to welding effects induced onto the thin stiffened panel assemblies of the superstructure of the first ship at fabrication stage (Stolt Achievement) of a series of three 37,000 dwt Chemical Parcel Tankers. The distortions were so important that all the straightening operations could not overcome the vicious welding defects.

By recommendation of the shipbuilder and after checking-up the superstructure, two thermo-mechanical simulations on two 3D models of thin stiffened plate panels of a deck and of a bulkhead respectively, have been performed with a conventional FEM code using the IRCN numerical method. The calculation results obtained have shown and confirmed the buckling state reached by entire bulkhead panel. This panel buckled in fact under the effects of V butt weldings executed on board during the assembly operations.

In this paper, some other applications of the method on thin stiffened plate panels are presented showing the influence of the welding sequence on the

residual stresses and initial deflections of such thin plates usually employed in shipbuilding.

1 Introduction

Up until October 1999, the definitive closure of the shipbuilder Ateliers et Chantiers du Havre (ACH), one of the major French Shipyards, was officially announced and planned by the French Government for the beginning of the year 2000 through national and international press-galleries [1,2,3,4,5,6,7,8] and internet [9].

Early on the Saturday morning of October 23rd 1999, at 9:30 exactly, on the dry dock of Graville, the launch of the hull of the 37,000dwt Stolt Perseverance, the second of a series of three Chemical Parcel Tankers, was carried out by the yard [Figure1].

That was the first ship delivered, the second vessel and also the last ever built by ACH shipyard before the definitive closure. The yard was to complete the hull of the vessel, leaving further work to an as-yet -undesignated shipyard.

The first vessel, the Stolt Achievement had been due for delivery in May 1997, but was now expected to be handed over at the end of November 1999. The construction of the third vessel was abandoned. That was the final decision saddening for 700 ACH yard-workers, and really a great loss for the whole shipbuilding industry.

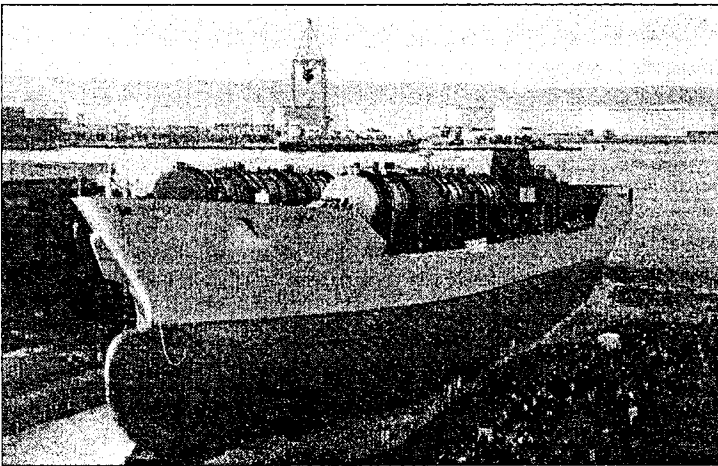


Figure 1 : The launch of the hull of the 37 000 dwt Stolt Perseverance on October 23rd , 1999 [6]

2 The Yard and the closure

The launching of the vessel on October 1999 marked the end of the history of « Le Havre Shipbuilding » that began in the 16th century, just one year after the founding of the City which was created earlier in 1517, by the French King

« François 1er » (Le Havre is situated in North of France, on the Channel, nearly 200 kms from Paris).

For two centuries (18th and 19th), several shipyards which had existed in Le Havre, disappeared successively one after the other in the 20th century. Until 1966, only one yard was still subsisting: the Ateliers et Chantiers du Havre. This yard had been formed by regrouping three yards: the « Forges et Chantiers de la Méditerranée », the « Augustin Normand » and the « Ateliers Duchesne et Bossière ».

The ACH shipyard had its glory days during the 1980s when it built several prestigious cruise-liners, the first in the world and the largest sailing cruise ships fully automated and computer controlled, these are still in active service today on the Mediterranean Sea and on other Caribbean Seas for example the Wind Star (1986) , Wind Song (1987) [Figure 2], Wind Spirit (1988), Club Med One (1989) [Figure 3], Club Med Two (1992), ...

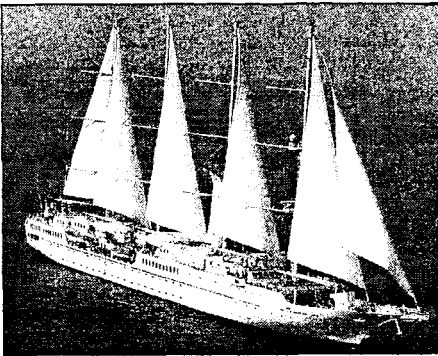


Figure 2 : Wind Song (1987) [11]

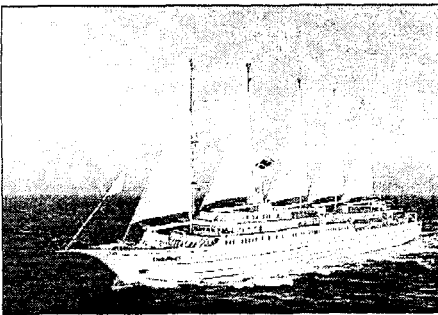


Figure 3 : Club Med One (1989) [11]

That is not to mention the car-ferries built for the SNCM (Société Nationale Corse Méditerranée) such as the Ferryterranee (1994) [Figure 4] , Paglio Orba (1994) and other Monte-Stello (1979), Monte-Cinto (1984), Monte-d'Oro (1991), Research vessels, Cable layers , etc .

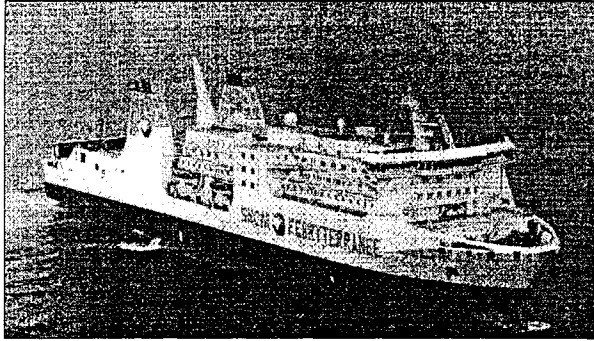


Figure 4 : Ferryterrancee (1994) [12]

At the end of November 1999, one month after launching the second vessel, the first of three tankers to be built by the Yard, the Stolt Achievement was finally delivered, behind schedule, to the Ship-Owners Group two and a half years later than the construction deadline of this vessel [Figure 5].

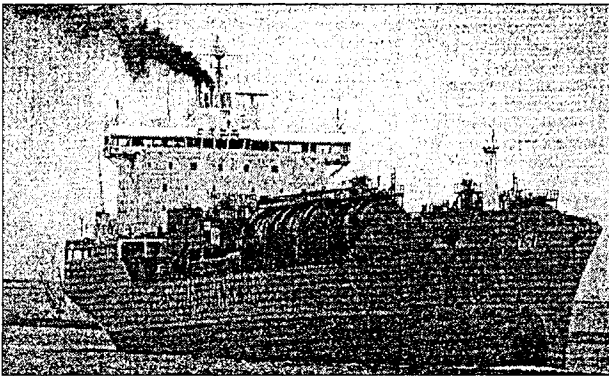


Figure 5 : Stolt Achievement (1999) [10]

Since May 1997, the deadline of the delivery of this vessel, the accumulation of overlapped days of the delay as well as the cost of credit and bank loans made the Yard financially weaker and weaker.

As the definitive closure was ordered for the end of 1999, the total subsidy of the French Government to help the Yard for its running expenses reached a substantial 3 billion FF (~ 457.32 million Euros), although the market value of these three vessels was approximately 1.13 billion FF (~ 172.25 million Euros).

The need to close the Yard came from a multitude of unforeseen difficulties encountered by the Yard during the Fabrication Stage of the first ship (Stolt Achievement). This so called « industrial accident » caused many technical and

financial problems to the ACH shipyard that was obliged to achieve these three tankers for the Stolt Nielsen SA [1]

3 The ships and the innovations in technology

By order of March 1995, the ACH shipyard had to build three Chemical Parcel Tankers of 36700 dwt exactly and to deliver them successively from May 1997 through December 1998.

The main characteristics of these tankers called Stolt Achievement, Stolt Perseverance and Stolt Endeavour and identified under new-building numbers as ACH-294, ACH-295 and ACH-296 are as follow [Figure 6]:

| | | |
|-----------------|---|---------------------------|
| Length overall | = | 176.70 m |
| Breadth | = | 31.20 m |
| Depth | = | 16.20 m |
| Draught | = | 11.85 m |
| Number of tanks | = | 48 + 6 deck tanks |
| Service speed | = | 16.2 knots |
| Propulsion | = | Diesel - Electric 10 MW |
| Classification | = | Det Norske Veritas |
| Owner | = | Stolt Parcel Tankers Inc. |

The Innovations required by the Stolt - Nielsen SA to the ACH shipyard consisted in applying new technologies in the construction of their ships following four main requested objectives :

- 1 - Flexibility in Manoeuvrability,
- 2 - Respect of Environment,
- 3 - Reliability, Safety and Durability,
- 4 - Automated and Computer controls

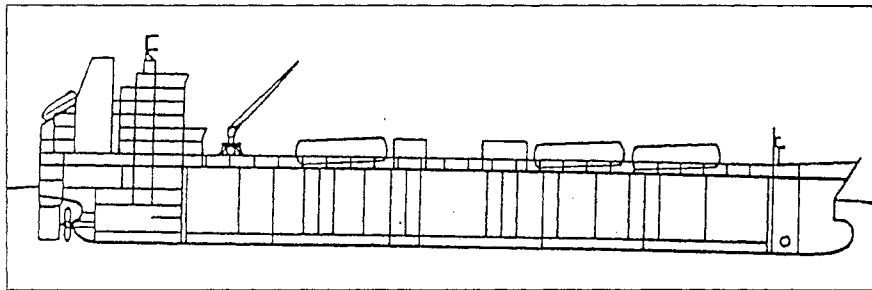


Figure 6: Chemical Parcel Tankers [13]

For these objectives, the shipbuilder had to design and build the tankers in incorporating in particular :



- a large number of tanks (48+6) of various volumes ;
- a system of automatic tele-control and pilotage by PC on board with pumps and valves to load and unload 12 tanks simultaneously ;
- special material for tanks such as « Duplex » stainless steel of which the mechanical properties and the resistance against corrosion are better than those of stainless steel 316 usually made for such tanks ;
- separate cofferdams, double hull, double bottom ensuring the reliability against any damage in collision and in grounding and so on , protecting against any pollution ;
- high quality of welded-joints ensuring the durability of ship structure;
- diesel-electric propulsion system, the first application in the world for this category of tankers, ensuring the reliability and the flexibility in exploitation, the gain in space for supplementary tanks and the gain in installation and maintenance costs.

4 The superstructure and the welding effects

By the Stolt's order on March 1995 and owing to their required innovations, the ACH had to start up the re-organization of the shipyard and particularly the modernization of the fabrication chain by investing in new automated equipment, two shipyards (Graville and Harfleur), three building berths for ships up to 200 meters long and 35meters wide, large prefabrication facilities (a large panel factory, a travelling gantry crane of 100 tons), as well as the reinforcement of the fabrication crew by contracting numerous young workmen .

The construction of the first vessel (Stolt Achievement) started soon after a schedule for both Design and Fabrication stages was set up in order to keep the delivery of these three Chemical Parcel Tankers on time .

This was a really strong desire within the Yard and amongst its staff to take up the challenge to build these innovative ships.

Armed by its past experience in 1994 , the ACH had succeeded in delivering some vessels of the same dead-weight tonnage (dwt) namely the Ferrytarrancee and Paglio Orba. Most of the staff had been renewed by the recent recruitment of skilled engineers for the Research and Design Department and more particularly the recruitment of young workers to get higher dynamic productivity and to improve the use of new materials for future construction .

Strictly following the drawings issued from the Design stage for the Stolt Achievement, the construction of the hull was proceeding normally on time until one day, on July 1st, 1996 at 5:45pm, the IRCN (The French Shipbuilding Research Institute) received a fax from ACH. This fax concerned the distortion problem happening to the superstructure of the ACH-294 in Fabrication stage.

The following handwritten words ended the fax:

« . . . The problem is urgent. A viable solution passes by a good understanding of the phenomena . We would like you to come and visit this week.. Kind regards. F.F »

And so, early in the following morning, after welcoming at « Le Havre » airport, we were received by the shipbuilders in a conference room at the yard. The schedule of the visit covered four different parts in one day.

4.1 General overview on the superstructure situation

The first part consisted of a presentation of a general overview of the situation of the superstructure in Fabrication stage, exposing the assembly procedure and the welding parameters used by the constructors for assembly of thin stiffened plate panels issued from the pre-fabrication factory.

4.1.1 Decks and bulkheads :

- The superstructure built of 3 decks (G,H,I) up to deck L, was positioned from frame 1 to frame 40 and in transverse $\pm 12.172\text{m}$ from portside to starboard ;
- For decks and bulkheads, all the thin plates were 7mm thick; except in the middle front bulkhead at frame 40 and from deck F up to deck H, thin plates were 5 mm thick [Figure 7];
- All the stiffeners on decks were HP 100x6;
- All the stiffeners on bulkheads were HP100x7 (including thin plates 5mm thick in the middle part);
- The distance between two consecutive stiffeners was 700 mm;
- The length of the Deck stiffened panel was 3,20 m.
- The length of the Bulkhead stiffened panel was 2,80 m.

4.1.2 Arc-welding parameters:

- For HP100x6 on deck and HP100x7 on bulkhead:

Chain intermittent-alternate- fillet welded-joints :

Heat input energy = 840 J/mm

Arc voltage = 24 volts Arc current = 175 amp.

Welding speed = 5 mm/s Fillet weld size = 3.5 mm

- For T-beam (Girder) 490x7 /160x10 on deck:

Continuous double fillet welded-joints :

Heat input energy = 1575 J/mm

Arc voltage = 21 volts Arc current = 250 amp.

Welding speed = 3.3 mm/s Fillet weld size = 4 mm

- For V butt weld-joints on bulkhead plates of 5mm and 7mm thick :

Continuous weld-joints (vertical position)

Heat input energy = 3060 J/mm

Arc voltage = 60 volts Arc current = 85 amp.

Welding speed = 1.6 mm/s Weld size = 4.8 mm (root), 60°(angle)

4.1.3 Initial imperfections of thin stiffened plate panels for assembly:

- Initial deflection of all thin stiffened plate panels for the deck and bulkhead issued from the pre-fabrication factory was $\delta_{max} \sim 5\text{mm}$, smaller than the limit tolerance ($\delta_o = 6\text{mm}$) fixed by the IRCN Quality Standard .

4.1.4 Assembly procedure:

- First, all the stiffened panels of bulkheads and of deck H were put in place by tack-welds ;
- And then, all the panels of bulkheads and of deck H were assembled using V butt weld-joints (3 pass-weld) in the same time by several yard-welders ;
- And so on , to upper decks .

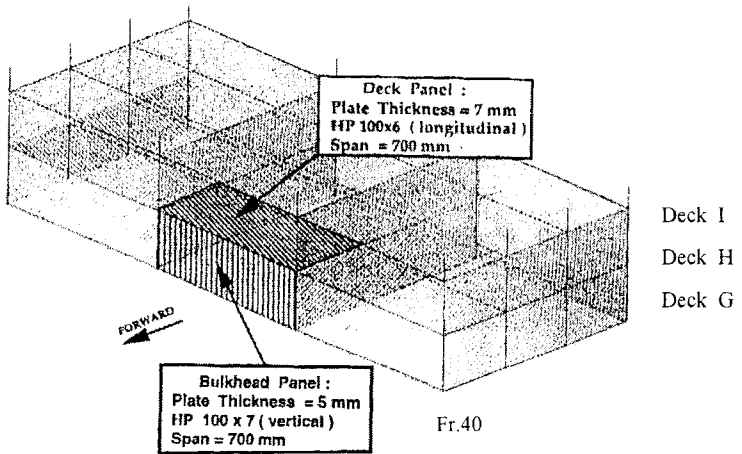


Figure 7 : Superstructure of the ACH-294 tanker

4.1.5 Distortion problem:

- During the construction of ACH-294 superstructure, excessive distortion was found occurring, for the first time, in thin plate panel (5mm) after assembly of the middle part of the front bulkhead at frame 40, between decks G and H, by V butt welding on board;
- The deflection in this thin panel increased quickly and grew up to about $\sim 12\text{mm}$ (greater than the limit tolerance = 6mm);
- After the first flame straightening of the middle part of this front bulkhead, from deck G through deck I, these excessive deformations were resorbed by all the bulkhead panels between these decks;
- Unfortunately, after this straightening operation, distortion occurred in other parts of the superstructure, in the stiffened plate panels of deck H ;

- The second straightening operation, this time by electro-magnetic induction on deck H reduced the distortion of these deck thin plates, but another distortion happened once again in the thin plate panel (5mm) of the middle part, this increased more and more and exceeded 12mm;
- And vice-versa, a vicious distortion appeared and disappeared under thermal effects of straightening operations on bulkheads and decks of the superstructure.

4.2 Visit on site

The second part was devoted to visiting the superstructure of the ACH-294 in Fabrication stage on site of Gravelle.

4.2.1 Observation on the welding effects:

- The superstructure being built up to three decks (G,H,I), looked like a « black-striped castle» because of a lot of thermal line marks on the plates due to the straightening operations on decks and bulkheads;
- Deformations of three decks were in wave form due to the welding effects;
- Bulkheads were in the form of a wavy black-striped coat;
- Stiffeners were not in straight lines but in wavy lines due to deformations by chain intermittent-alternate-fillet welding.

4.3 Pre-fabrication factory

The third part was to visit the pre-fabrication factory where all the thin stiffened plate panels had been realized on an automatic arc-welding machine .

4.3.1 Initial imperfections of thin stiffened plate panels:

- All the stiffened plate panels of the decks and bulkheads fabricated in the pre-fabrication factory must be checked as to their initial deflection with respect to the limit tolerance of the IRCN Quality Standard;
- A straightening operation was sometimes carried out to fit on the panel if any deformed shape exceeded;
- Coming out from the pre-fabrication factory, all the thin stiffened plate panels having a maximum initial deflection of 5 mm (smaller than the limit tolerance of 6mm) were quite fit for further block welding assembly operations.

4.4 Checking-up the superstructure:

The fourth part-time was to check the principal causes of distortions of the superstructure in order to find a solution for construction of the two sister ships.

4.4.1 Comments on the welding assembly procedure:

- As mentioned in the first part (4.1.4), the welding assembly operations that had been executed at the same time on the deck and bulkhead did not seem suitable in regard to the compressive strength produced in the bulkhead by the deck's own weight.
- Furthermore, as the bulkhead had been submitted to high temperatures induced in the plates by the welding-heat-input energy, the mechanical properties of mild steel such as the Young modulus quickly became weaker under high temperatures [14].
- And then, the buckling state of thin stiffened plate panel of the bulkhead would be reached if the compressive stresses induced by the welding effects were greater than the effective buckling limit of the thin plate [15].

4.4.2 Comment on the welding parameters of V butt weld-joints:

- The Heat-Input-Energy of 3060 J/mm used for the V butt weld-joints on board seemed too high for such thin plates (5mm) of the bulkhead.

4.4.3 IRCN proposals:

- Taking account of the above information concerning the distortion problem and after visiting the « Castle », IRCN proposed to carry out two numerical simulations on two 3D models of thin stiffened plate panels of a deck and of a bulkhead in order to verify the thesis of the buckling phenomena induced in these thin stiffened plate panels by the welding effects .
- IRCN had to agree to supply the ACH shipyard with all the calculation results in a short time, as well as to find a suitable solution, if this was necessary, to avoid any excessive distortion in such thin stiffened plate panels and so on, to reduce the straightening operations .

5 The Distortion and the IRCN numerical method

At the end of 1995, IRCN finished the Conventional Studies of AC.1.2.3 and AC.1.2.5 entitled « Study on deformation of ship plane structures induced by the welding effects on the thin plates of decks and bulkheads in order to reduce straightening works » [15] sponsored by the French Ministry of Industry and Research and French Shipyards (Chantiers de l'Atlantique and Ateliers et Chantiers du Havre). The studies had been well-attended for five years (1991-1995) by a Technical Group formed of skilled people of the three partners (C.A., A.C.H and IRCN). The Technical Group met every three months in order to report all the results obtained after each phase study or to clarify any difficulty or issue.

Carried out from these studies, a procedure and a simple numerical method had been validated by experiments in full scales on 2D and on 3D models and presented four years later at the Third International Conference on Marine Technology (ODRA'99) on October 11-13, 1999 at Szczecin, Poland. For



more information about the method, its validation on experiment testings, please refer to Reference [16].

The distortion problem encountered by the ACH shipyard in July 1996 had been an opportunity to test the validation of the previous procedure and the numerical method on such concrete industrial applications.

The application of the method necessitated two 3D Finite-Elements Models: one of thin stiffened plate panel (7mm) of Deck H and another (5mm) of middle front Bulkhead at frame 40 between decks G and H. Calculation results obtained on two models were presented in two Technical Reports provided by the ACH shipyard [18,19].

5.1 Model 1 : Thin stiffened plate panel of deck H :

This model, shown in Figure 8, represents one of the panels to be assembled to form deck H of the superstructure.

Model data:

Plate = 3200mm x (700mm + 350mm)

Thickness = 7.0mm

Stiffener = HP 100x6

½ T-beam = 490x7 / 160x10

Finite-Elements Model Data:

35 450 volume elements

54 954 nodes

158 665 dof

Welding data :

½ T-beam

HP 100x6

Continuous Fillet Weld:

Chain Intermittent-Alternate Fillet Weld:

Heat input energy = 1575 J/mm

= 840 J/mm

Arc tension = 21 volts

= 24 volts

Arc current = 250 ampères

= 175 amperes

Welding speed = 3.3 mm/s

= 5.0 mm/s

Weld size (throat) = 4 mm

= 3.5 mm

Boundary conditions:

Supported at the extremities of Girder (T-beam) and HP

Symmetric conditions alongside

Mechanical and Physical properties of Mild Steel (E24):

$E = 21000 \text{ MPa}$ $\alpha (\alpha) = 1.20\text{E-}05 / ^\circ\text{C}$ (ferrite expansion coeff.)

$\nu = 0.3$ $\alpha (\gamma) = 1.60\text{E-}05 / ^\circ\text{C}$ (austenite expansion coeff.)

$\rho = 7.85\text{E-}06 \text{ kg/mm}^3$

Metallurgical Specific Peak Temperatures :

$T_f = 1520^\circ\text{C}$ (Fusion temperature)

$T_c = 1000^\circ\text{C}$ (Limit Fusion zone Temperature)

$T_a = 720^\circ\text{C}$ (Limit Heat-affected zone Temperature)

$T_o = 20^\circ\text{C}$ (Ambient Temperature)

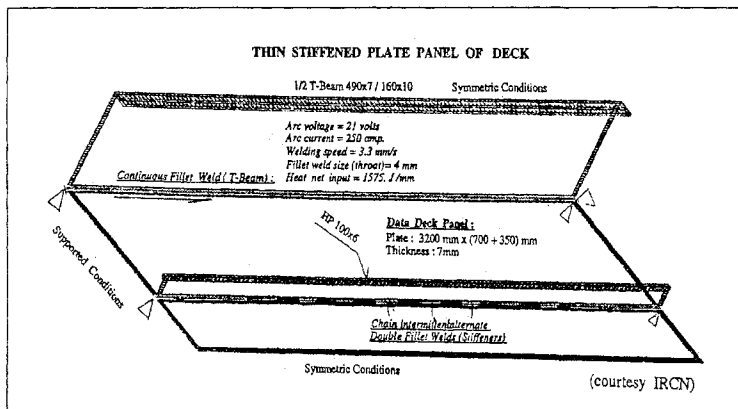


Figure 8 : Model of thin stiffened plate panel of deck H (model 1)

5.2 Model 2: *Thin stiffened plate panel of Bulkhead*

The model, shown in Figure 9, represents one of the thin panels to be assembled which form the middle part of the front Bulkhead at frame 40 between decks G and H of the superstructure.

Model data:

Plate = 2800mm x (600mm + 350mm)
 Thickness = 5.0mm
 Stiffener = HP 100x7

Finite-Elements data:

22 070 volume elements
 33 335 nodes
 99 332 dof

Welding data:

½ V Butt Weld

Continuous V Butt Weld:

Heat input energy = 3060 J/mm
 Arc Tension = 60 volts
 Arc Current = 85 amperes
 Welding speed = 1.6 mm/s
 Weld size = 4.8 mm (root), 60°(angle)

HP 100x7

Chain Intermittent-Alternate Fillet Weld:

= 840 J/mm
 = 24 volts
 = 175 amperes
 = 5.0 mm/s
 = 3.5 mm (throat)

Boundary conditions:

Supported at the extremities of HP and ½ V Butt weld
 Symmetric conditions alongside

Mechanical and Physical Properties of Mild Steel (E24) :

E = 21000 MPa α (α) = 1.20E-05 / °C (ferrite expansion coeff.)
 ν = 0.3 α (γ) = 1.60E-05 / °C (austenite expansion coeff.)
 ρ = 7.85E-06 kg/mm³

Metallurgical Specific Peak Temperatures:

$T_f = 1520^\circ\text{C}$ (Fusion Temperature)
 $T_c = 1000^\circ\text{C}$ (Limit Fusion zone Temperature)
 $T_a = 720^\circ\text{C}$ (Limit Heat-affected zone Temperature)
 $T_o = 20^\circ\text{C}$ (Ambient Temperature)

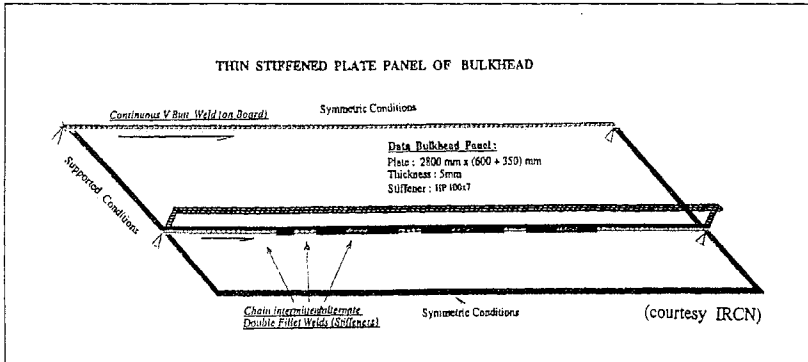


Figure 9: Model of thin stiffened plate panel of bulkhead (model 2)

5.3 Calculation results - Model 1: *Thin stiffened plate panel of Deck H*

5.3.1 Residual welding stresses:

An elastic analysis under thermal loadings was performed on a FE code (Permas V4.0 from INTES, GmbH, Germany).

The calculated stress results of model 1 are shown in Figure 10.

Most of the calculated longitudinal compressive stresses on top surface layer of the plate are lower than the effective buckling limit of the plate (-60 N/mm^2 : *Out - of - buckling state* [16]).

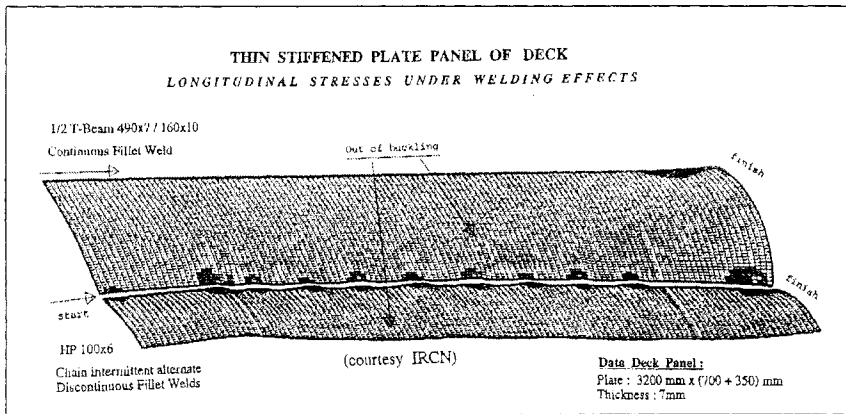


Figure 10: Calculated longitudinal stress distribution of thin deck H stiffened plate panel (model 1) under welding effects

5.3.2 Deformed shape:

Figure 11 shows the out-of-buckling state of the deformed shape of model 1. The maximum calculated deflection of the plate is of 2.2 mm (less than the limit tolerance of 6mm): *this confirms the fitness of thin stiffened plate panels coming from the pre-fabrication factory for block assembly as mentioned in 4.1.3 [16].*

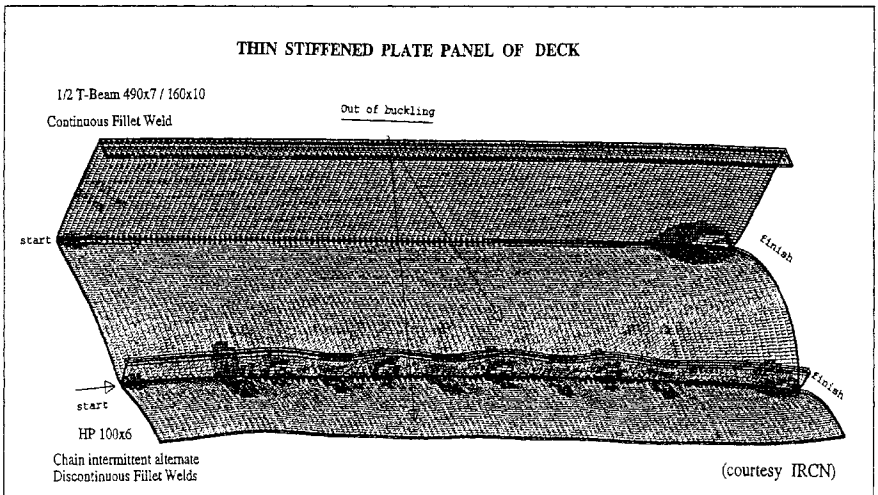


Figure 11: Calculated deformed shape of thin deck H stiffened plate panel (model 1) under welding effects [16].

5.4 Calculation results - Model 2 : *Thin stiffened plate panel of Bulkhead*

5.4.1 Residual welding stresses:

A second elastic analysis under thermal loadings was performed on a FE code (Permas V4.0 from INTES, GmbH, Germany). The calculated stress results of model 2 shown in Figure 12 remain within the large red zone of the plate on that the effective buckling limit (-42 N/mm^2) is exceeded: *the buckling state is reached [16].*

This confirms the excessive distortion which occurred on thin stiffened plate panels of the middle part of the front bulkhead under V butt welding on board as mentioned in 4.1.5, 4.4.2 and 4.4.3.

5.4.2 Deformed shape :

Figure 13 shows the deformed shape of the thin bulkhead stiffened plate panel just before buckling state was reached. As the effective buckling limit of the thin plate is exceeded (Figure 12), the deflection of the plate will increase

quickly, highly and certainly go beyond the limit tolerance fixed by the IRCN Quality Standard ($\delta o=6\text{mm}$) [16].

5.5 Discussion

5.5.1 Heat-input-energy of V butt welding process

In the welding process, Heat-input-energy is one of the most important parameters among others to provide welded-joints of high quality.

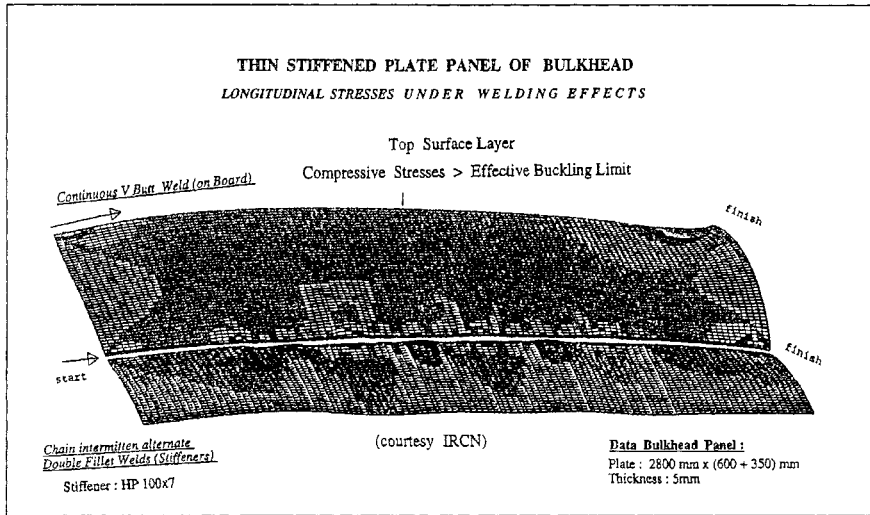


Figure 12: Buckling state reached: calculated long. compressive stresses on top surface layer of thin bulkhead plate panel (model 2)

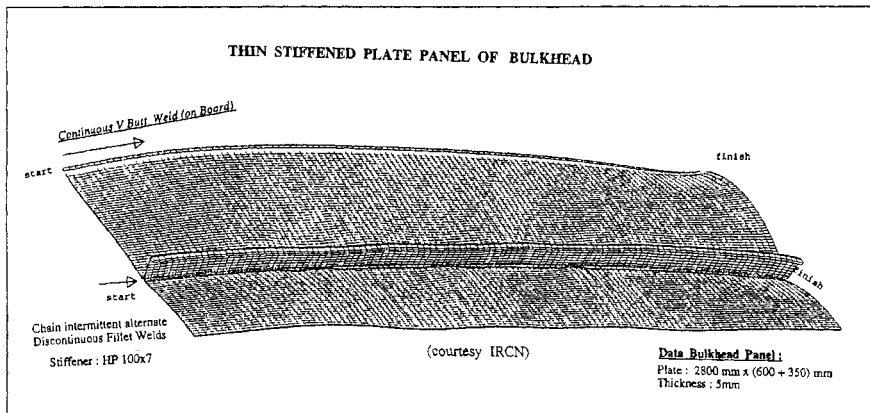


Figure 13 : Calculated deformed shape of thin bulkhead plate panel (model 2) before buckling state reached

It is always delicate to choose any energy quantity for these welded-joints .

In the Fabrication stage, the constructor cannot use any heat-input-energy neither less than the minimum value nor greater than the maximum value in order to ensure the best quality of the welded-joints [17] .

A competent welding laboratory could have undertaken this task: to take care in choosing, testing and verifying the best energy value to be used for the V butt welding process for thin plates, especially of 5mm thick .

5.5.2 Plate thickness of thin stiffened panel of front bulkhead

The middle part of the front bulkhead at frame 40, between decks G and H was made of thin plates of 5mm thick. It was remarked that these plates were the thinnest plates of the entire front bulkhead at frame 40.

The critical buckling strength of these thin plates was not strong enough (in Finite-Elements rigidity term) to resist the contraction forces developed inside of the V butt welded-joints executed with high heat-input-energy (3060 J/mm) as noted above. The thickness of these plates should have been thicker.

5.5.3 Assembly procedure

« A mechanical law says that the weakest links of a chain always break first »

Thus, under the own-weight of deck H submitted to high temperatures due to the welding heat-input-energy, the thinnest plates (5mm) of the middle front bulkhead buckled first, of course, under V butt welding effects.

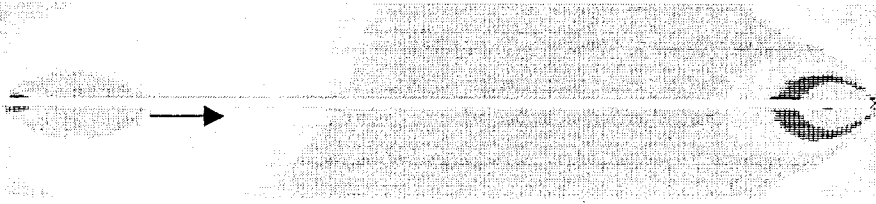
So, the assembly procedure could have been executed in two successive times, but not at the same time:

- Firstly , to assemble all the thin stiffened plate panels of bulkheads included lateral , front and back bulkheads by V butt welding with lower heat-input-energy;
- Secondly, to put all thin stiffened plate panels of deck H in place by tack-welds and then, to assemble them using V butt welding;
- And so on, to upper decks.

6 The residual stresses and the initial imperfections

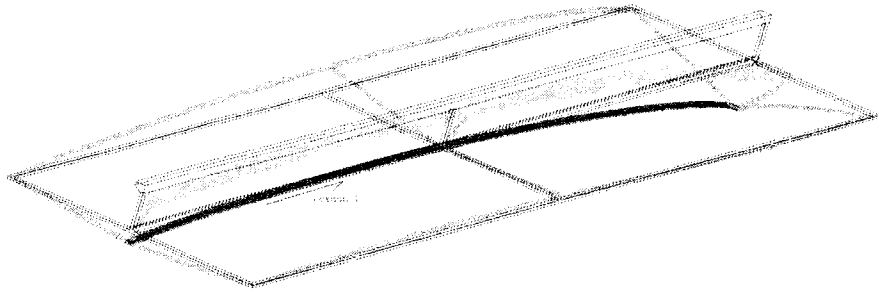
The residual stresses and the initial imperfections of any thin stiffened plate depend on the plate dimension and the welding parameters and also on the welding sequence.

Figures (14,15) and (16,17) illustrate the welding sequence effects of one fillet welded-joint and of two alternate fillet welded-joints on a test thin stiffened plate in full scale of 5.7mm thick made for study AC1.2.5.



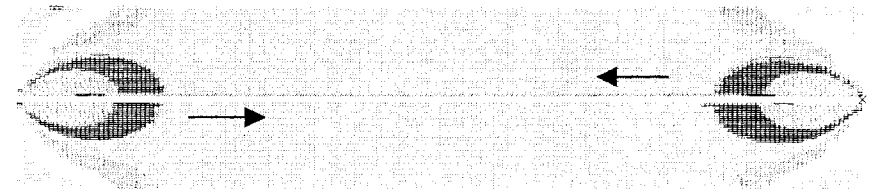
(Courtesy IRCN)

Figure 14 : Effects of one fillet weld-joint (residual stresses)



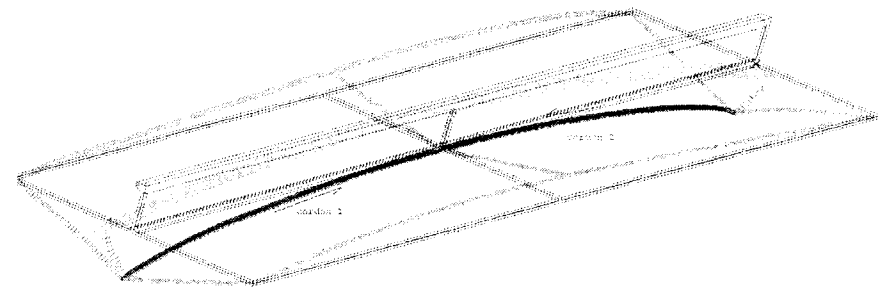
Courtesy (IRCN)

Figure 15 : Effects of one fillet weld-joint (deformed shape)



(Courtesy IRCN)

Figure 16 : Effects of two alternate fillet welded-joints (residual stresses)



(Courtesy IRCN)

Figure 17 : Effects of two alternate fillet welded-joints (deformed shape)



7 Conclusion

In the industrial context of the ACH shipyard situation around 1995, the shipbuilding industry in the world was in total crisis: European shipyards, beyond the successive devaluation of certain European monies (pesetas, pounds, liras, Finnish marks), were in severe difficulties and ferocious competition from some Asian shipyards in spite of several subsidies from respective Governments.

The Stolt's order of a series of three Chemical Tankers had really been an opportunity for the ACH shipyard and its staff to take the challenge to build these innovative ships.

The Innovations in Technology required by the Stolt Nielsen SA conformed in fact to the innovatory tradition of the ACH shipyard so that the Research and Design Department had proposed, more than ever, « The Shape of Ships to come ».

Unfortunately, one of the prime causes of the failure in the ACH fabrication process was the distortion problem due to welding effects induced onto the thin bulkhead stiffened plate panels of the superstructure. The buckling state was reached by such plates being too thin and by an on board V butt welding having a too high heat-input-energy in assembly operation.

And as a consequence of successive straightening operations, distortion happened again on plates of the decks and bulkheads of which the constructors could not control the levels sufficiently; although the bulkheads had always supported the permanent weight of several upper decks.

For such distortion problems, the IRCN numerical method could be more useful and could be used for any new shipbuilding project in the following way:

- to evaluate early at Design stage the levels of residual stresses and initial deflections induced by any welding process to be used at Fabrication stage; and also if necessary:
- to estimate the thermal effects due to the straightening operations onto any thin stiffened plate panel.

The validation of such a study should be made by experiments on model testings in full scale carried out in a welding laboratory.

Another interesting possibility of the method would enable the discovery of the straightening techniques held up to now by the skilled straighteners.

Acknowledgment

Homage to ACH shipbuilders for their courage in attempting to overcome the welding effects and in succumbing, alas, to the vicious distortion of thin stiffened plate panels.



References

1. Press : « Le Marin » hors série : *Chantiers Navals Français*, February 1999.
2. Press : « Fairplay Daily Shipping News », October 18th 1999.
3. Press : « Le Havre libre », October 19 - 20 - 21st 1999.
4. Press : « Les Echos », October 22nd 1999.
5. AFP-MAIL : *Mer-equip-trso-social*, October 23rd 1999.
6. Press : « Le Marin », October 29th 1999.
7. Press : « Lloyd's » List, October 30th 1999.
8. Press : « Lloyd's » List, November 4th 1999.
9. Internet : www.latribune.fr, October 22nd 1999.
10. Press : « Le Havre libre », November 8th 1999.
11. ACH shipyard brochure .
12. Journal de la marine marchande : *nouveautés techniques maritimes*, Friday 29th April 1994.
13. Journal de la marine marchande : *nouveautés techniques maritimes*, Friday 29th December 1995.
14. Boulton, N.S. & Lance Martin, H.E., Residual Stresses in Arc-welded Plates, *Proceedings of the Institute of Mechanical Engineers*, London, 1936.
15. Chau, T.T., « Etude des déformations des structures planes des ponts et des cloisons de navire en vue de diminuer les travaux de redressage », *Final Technical Report*, IRCN/SEA 95013, 1 rue de la Noë, 44321 Nantes, France, April 1995.
16. Chau, T.T., Paradis, A. & Masson, J.C., *Proceedings of the 3rd Internat. Conference on Marine Technology*, ODRA '99, (11-13 Oct. 1999), Szczecin, Poland; pp 485-530, WIT Press ; E-mail: witpress@witpress.com
17. Chau, T.T. & Besnier, F.: *Proceedings of the 6th International Symposium on Marine Engineering*, Tokyo, Japan, October 23-27, 2000; pp663-670.
18. Chau, T.T. & Jancart, F. ; *Technical Report (Part 1)*; IRCN / SEA 5125/96 August 5th 1996.
19. Chau, T.T. & Jancart, F. ; *Technical Report (Part 2)*; IRCN / SEA 5133/96 August 28th 1996