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An Assessment of an Alternative Submarine Steel

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An Assessment of an Alternative Submarine Steel

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ABSTRACT

Steel used in submarine construction has, over the past fifty years, developed from mild steel through Q1N/HY80 in the UK and US navies, HY100/HLES80/BIS812 respectively in the US, French and Australian navies and HLES100 in the French navy. Variants of these which have been considered and evaluated have included HLES65 and HSLA80 at the 550MPa 0.2% proof strength level and HSLA100 at the 690MPa 0.2% proof strength level. The HSLA steels were specifically designed to reduce cost and be more easily weldable, namely with reduced preheat. Unfortunately these steels have not lived up to the earlier promise and the expected full cost savings potential has not been met. Some amongst the naval fraternity have continued an optimistic approach to finding a more construction friendly steel and have been looking at a number of offshore steels, X65, X70, X80 and X100 as possible contenders. This paper looks at one such steel Shoralsim 500, a development of an offshore grade, exhibiting adequate strength, outstanding toughness, increased weldability and with a significant potential for reduced fabrication cost.

Introduction

- Introduction
- Goal/Objective
- Test Programme
- Key Results & Comparisons
- Cost Benefits
- Further Work
- Summary

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Goal/Objective

- Goal
  - To find a cheaper more readily weldable alternative to Q1(N)-the current UK submarine steel
    - Q1(N)~£1600/tonne
    - requires preheat of 120°C to avoid cold cracking of its hard martensitic heat affected zone (HAZ)
- Objective
  - To evaluate the mechanical properties and weldability of two plates Shoralsim 500 MOD (25mm & 50mm)
  - Comment on its suitability for submarine primary and secondary structure applications

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Shoralsim 500 MOD Plate Production

- Manufactured by Fabrique De Fer, Charleroi, Belgium
- 250 tonne continuously cast strand (2100mm x 180mm)
- Quenched and Tempered @ 620°C for 2 minutes/mm thickness

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Test Programme

- Chemical Composition
- Metallography
- Mechanical Properties
  - Through Thickness Hardness
  - Tensiles (Long./Trans.)
  - Charpy & EDM Charpy Impact
  - Drop Weight J tests
  - Hull Toughness Element
  - Corrosion Fatigue
- Weldability
  - Contolled Thermal Severity

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Chemical Composition (wt%)

Steel	Gauge (mm)	C	Si	Mn	S	P	Cr	Mo	Ni	Al	Cu	V	Nb	B	CEV
Shoralsim 500 MOD	25	0.08	0.28	1.60	0.0005	0.005	0.05	0.25	1.40	0.040	0.03	0.01	<0.01	-	0.55
Shoralsim 500 MOD	50	0.08	0.28	1.60	0.0005	0.005	0.05	0.25	1.40	0.040	0.03	<0.01	<0.01	-	0.55
HSLA80	25	0.06	0.37	0.52	0.007	0.008	0.66	0.20	0.70	0.045	1.10	0.01	-	-	0.50
QT550	25	0.07	0.35	1.38	0.002	0.007	0.10	0.16	0.50	0.050	0.07	0.05	<0.01	0.0025	
X80	9	0.06	0.28	1.55	0.004	0.012	0.05	0.25	0.01	0.027	0.01	<0.01	0.08	-	0.42
Q1(N)	Min.	-	0.15	0.10	-	-	1.00	0.20	2.25	0.015	-	-	-	-	
	Max.	0.18	0.35	0.40	0.015	0.015	1.80	0.60	3.25	-	0.20	0.02	-	-	0.66

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Microstructure

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Tensile Properties

Steel	Gauge (mm)	Orientaion	0.2% PS (MPa)	UTS (MPa)	0.2%PS/UTS	Elongation (%)	Reduction in Area (%)
Shoralsim 500 MOD	25	Long.	600	665	0.90	25	83
		Trans.	593	661	0.90	23	79
Shoralsim 500 MOD	50	Long.	603	662	0.91	22	81
		Trans.	604	663	0.91	21	79
HSLA80 (UK)	25	Long.	549	628	0.88	27	78
		Trans.	553	634	0.87	27	78
QT550	25	Long.	544	615	0.89	28	80
		Trans.	524	604	0.87	27	78
X80	9	Long.	600	708	0.85	-	-
		Trans.	568	697	0.81	-	-
Q1(N)	Min.		550	-	-	20	50 Trans
	Max.		655	-	0.88	-	-

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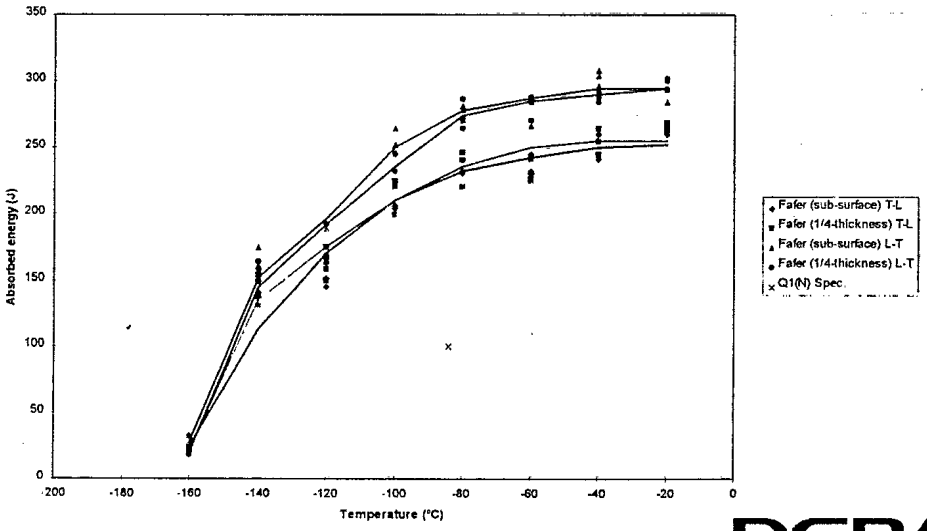
Charpy Impact Curves for 25mm Shoralsim 500 MOD



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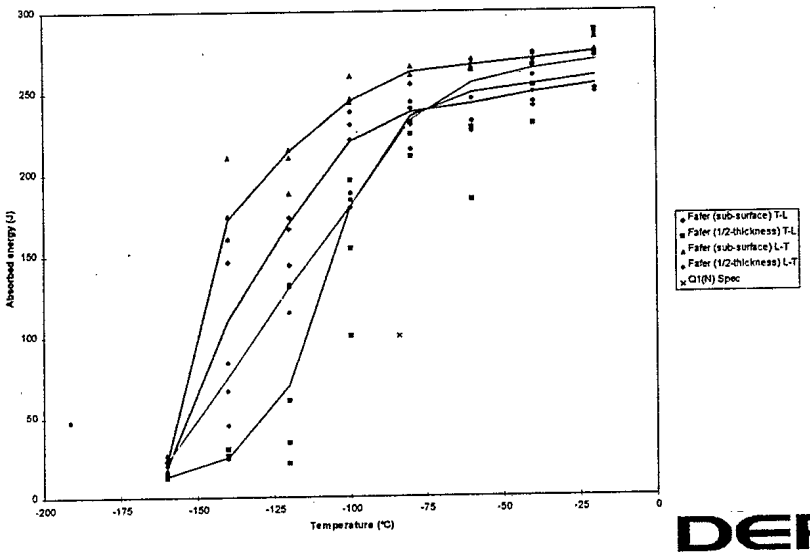
Charpy Impact Curves for 50mm Shoralsim 500 MOD



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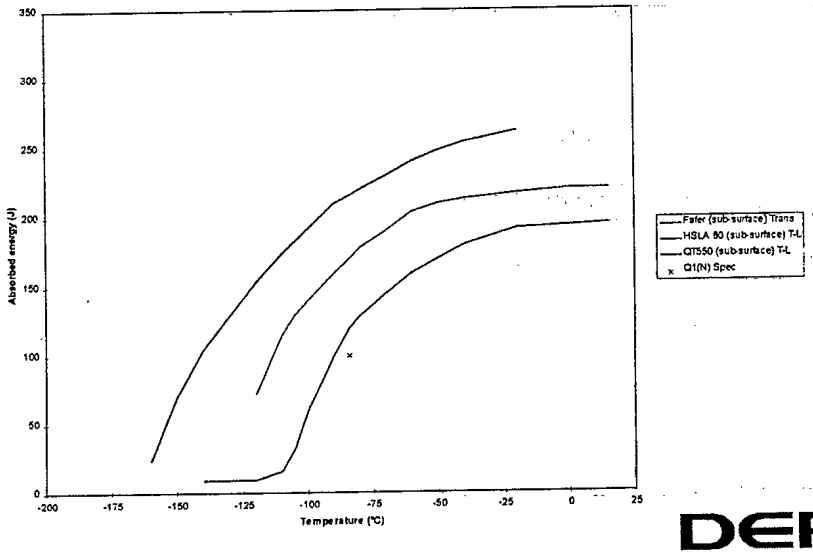
Charpy Impact Comparisons



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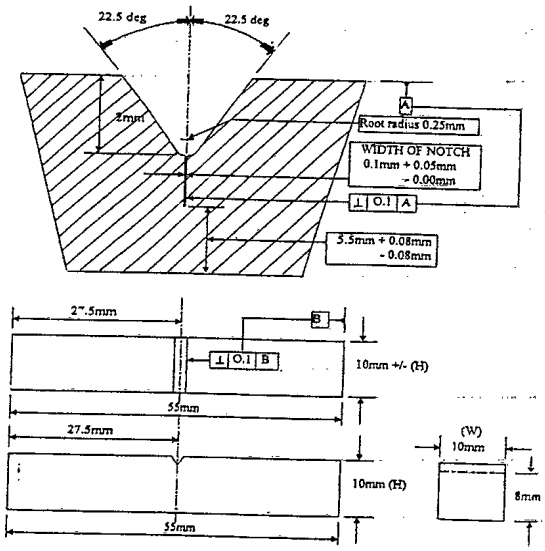
EDM Charpy Impact Specimen



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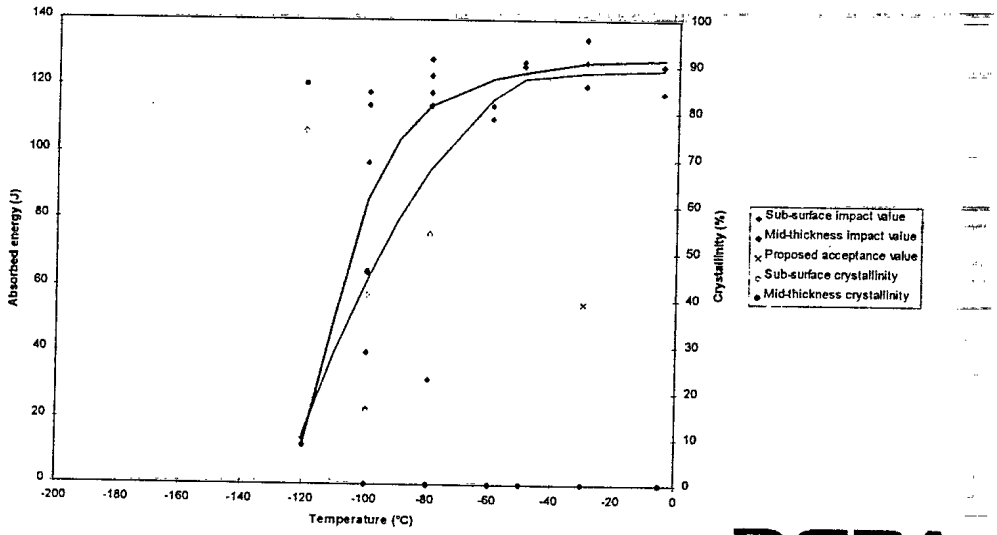
EDM Charpy Impact Curves for 25mm Shoralsim 500 MOD



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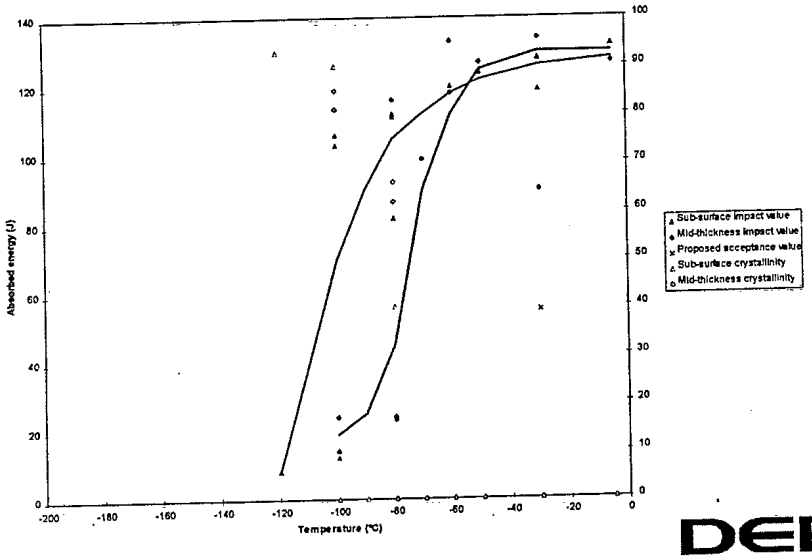
EDM Charpy Impact Curves for 50mm Shoralsim 500 MOD



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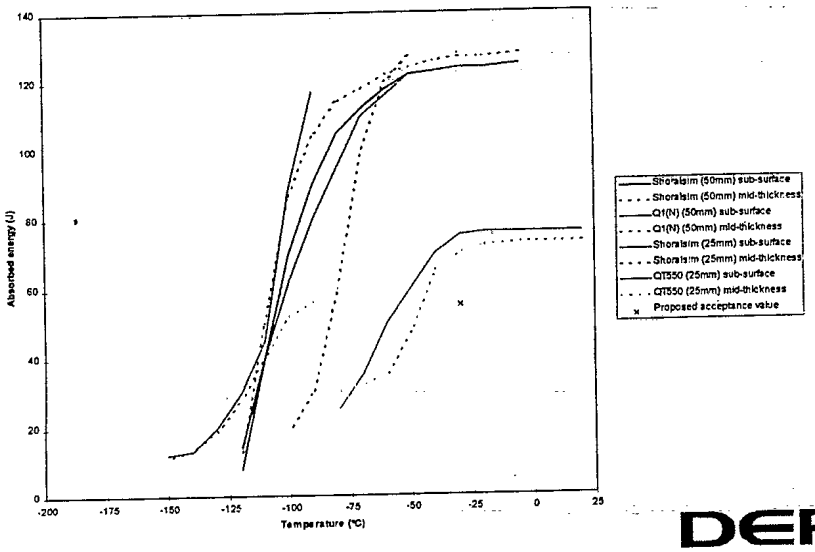
EDM Charpy Impact Comparisons



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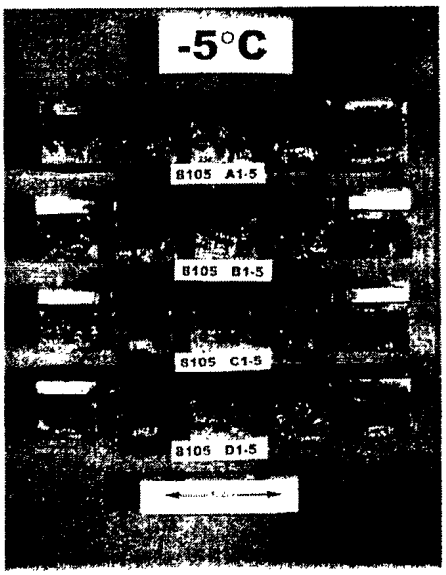
Drop Weight J Testing



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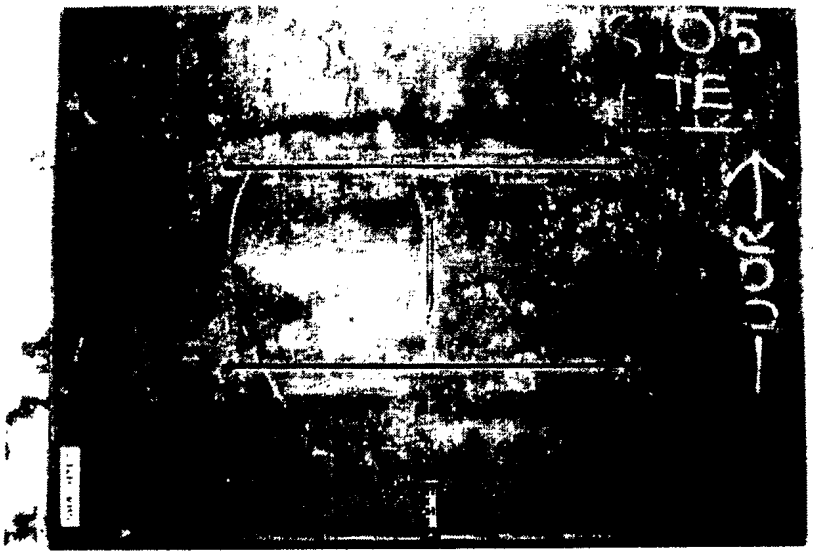
Explosively Loaded Tests (HTE)



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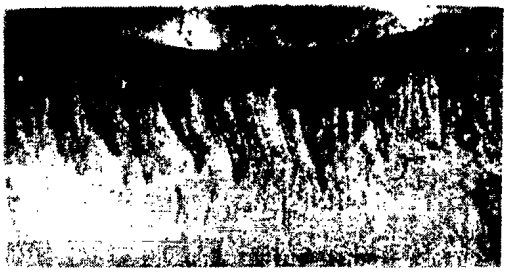
HTE Fracture Surfaces

- 25mm Thick Plate (Top)
- 50mm Thick Plate (Bottom)



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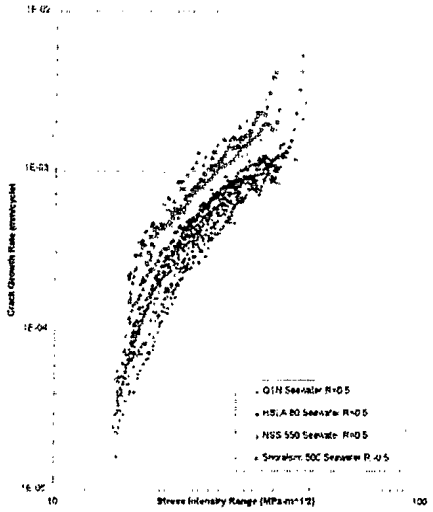
Corrosion Fatigue



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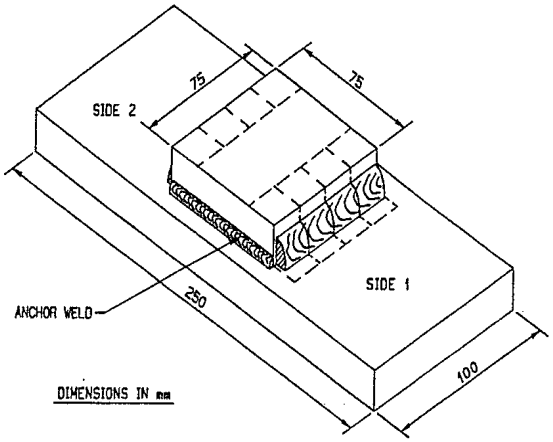
Weldability (CTS Specimen)



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CTS Results

Process	Consumable	Heat Input (kJ/mm)	Preheat (°C)	Crack Result
MIG	Fluxofil 41/ATAL 5	1.0	20	Cracked near lack of fusion
MIG	Corofil NQ1	1.3	18	Uncracked
MIG	Fluxofil 41/ATAL 5	1.5	20	Uncracked
MIG	Corofil NQ1	1.6	18	Uncracked
MIG	Corofil NQ1	2.0	18	Uncracked
MIG	Union MoNi/ATAL 5	1.0	20	Uncracked
MIG	Union MoNi/ATAL 5	1.5	20	Uncracked
MMA	Tenacito 65R	1.0	20	Uncracked
MMA	Tenacito 65R	1.5	20	Uncracked
MMA	Fortrex NQ1	2.0	18	Cracked, [H] > 5mls

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Cost Benefits

- Q1(N) ~ £1600/tonne
- Shoralsim 500 MOD expected to be < £1000/tonne
- Welding without preheat should reduce fabrication costs by ~30%.

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Further Work

- Short Term
  - Identify the cause of brittle fracture observed in a small number of drop weight J tests.
  - Further weldability studies.
- Longer Term
  - Establish that the properties are reproducible and consistent in all the product forms and exceed the requirements of NES 736.
  - Demonstrate that the material can be welded without preheat in the shipyard environment.

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Summary

- Shoralsim 500 MOD, Belgian steel, available in gauges up to 50mm.
- Tensile properties exceed the demands of NES 736 Part 1.
- Charpy impact energy >100J @ -84°C.
- EDM Charpy exceeds the proposed test requirements.
- 25mm and 50mm thick plate has passed the explosively loaded test requirement but cleavage fracture has been seen at -5°C in one drop weight J test.
- Corrosion fatigue crack growth rates are higher than Q1(N) but comparable to other high strength low alloy steels.
- Steel is weldable at ambient temperature preheat.

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