Development of Weldable Steels for North Sea Structures

[A write-up compiled by Mr. S. V. Nadkarni based on published technical literature of British Steel Corporation]**

The exploitation of North Sea oil and gas has spurred remarkable developments in several technological areas, and especially in steelmaking and welding. Since all the North Sea structures including drilling rigs, permanent wellhead platforms and pipelines had to be welded, steelmakers and welding engineers had to collaborate closely to develop weldable steels capable of meeting exceptionally stringent specifications. The story of how the technical personnel of the British Steel Corporation met the challenge makes inspiring reading.

Development was centred on the modifications of the existing BS 4360, 50 D grade which is specified to give a minimum yield stress of 340 N/mm^2 and maximum carbon equivalent of 0.43 (see Table 1).

Since the conditions in the North Sea are extremely arduous (especially sub-zero temperatures), it was deemed necessary that all parts of the structure should be resistant to brittle fracture and to propagation of cracks in any direction. Hence minimum charpy requirements were specified in both the longitudinal and transverse directions.

It is not normal practice to stipulate a minimum transverse impact requirement. But when this condition has to be met, one must remember the very important part which sulphur plays in the determination of this parameter. This is shown in Fig. 1. Logically, the only way in which adequate transverse impact properties can be achieved is by restricting sulphur to extremely low levels during steelmaking so that the occurrence of stringer sulphides is appreciably diminished, more so in thicker materials.

Welding can cause two potential defects : hydrogen-induced cracking and lamellar tearing. To control the former, the CE (Carbon Equivalent) of the steel, particularly in situations where application of high preheat

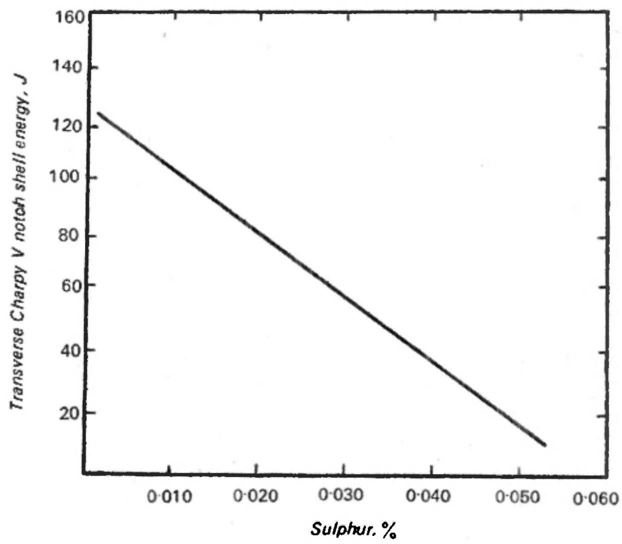

Fig. 1.

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Table 1 : Specification details for BS 4360, 50D (plates)

Chemical composition, %

		C. max.	Si	Mn. max.	Nb(I) max.	V.(I) max.	S. max.	P. max.	Normal deoxidation	Supply
50D or 50DI(2)	Ladle	0.18	0.10/0.50	1.5	0.10	0.10	0.04	0.04	Si-killed and Nb and/or V	Normalised
	Product	0.22	0.10/0.55	1.6	—	—	0.05	0.05		

Mechanical properties

	Yield stress min.				Longitudinal Charpy (up to 75 mm max.)
	⩽16mm	>16mm⩽40mm	>40mm⩽63mm	>63mm⩽100mm	41J at —20°C or
50D	355N/mm²	345N/mm²	340N/mm²	By agreement	27J at —30°C

(1) If Nb and V are used, the total shall not exceed 0.1 %.
(2) 50D1 is supplied up to 40mm to a CE max. of 0.41. Normal 50D is supplied to 0.43 max.
CE given by $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$

would be impractical, should be as low as possible consistent with the required mechanical properties. Table 1 shows how in the modified grade 50 D1, the CE has been lowered to 0.41 as compared to the value of 0.43 for the normal grade 50 D.

As regards lamellar tearing, it is acknowledged that the reduction of area in a short transverse tensile test provides an estimate of susceptibility. Specimen dimensions are appropriate to Hounsfield No. 14 single shouldered tensile specimens with a gauge diameter of 6.4 mm and an unspecified gauge length.

Three extraction procedures are available dependent upon the thickness of the plate being tested and the need to sample regions close to the plate surface.

(a) Plates<25 mm thick or a need to test plate surface regions. Specimens are extracted from a composite of the plate with friction welded extension studs (Fig. 2a).

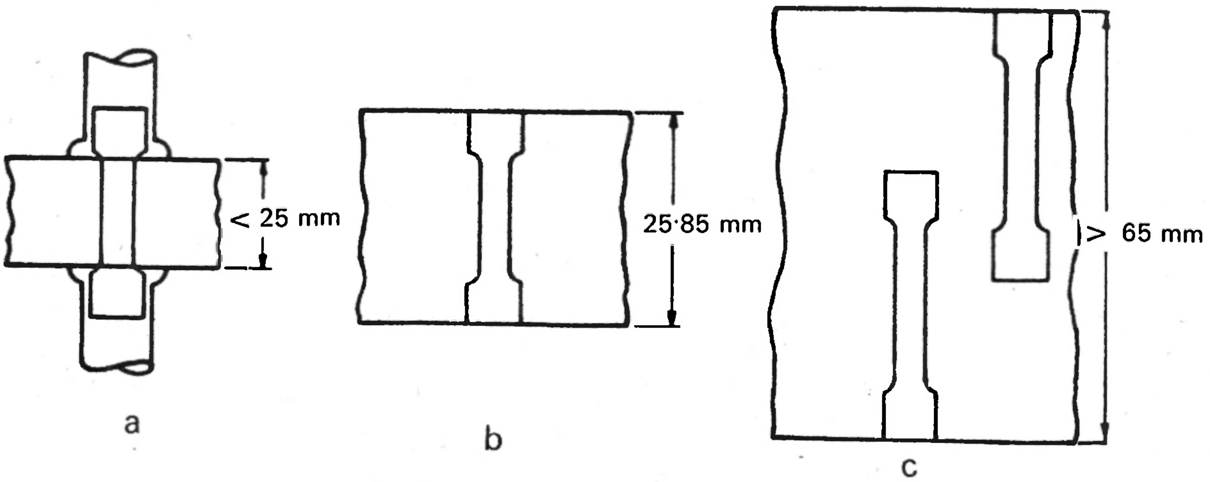

Fig. 2. Extraction of short transverse tensile specimens.

(b) Plates 25-65 mm thick. Specimens are extracted from the complete plate thickness with grip ends retained within the plate thickness. (Fig. 2b).

(c) Plates>65 mm thick. Specimens extracted from various positions through the thickness to sample the complete plate thickness (Fig. 2c).

A minimum of 20% average reduction of area is expected to ensure freedom from lamellar tearing.

In the North Sea structures, the areas which are most susceptible to lamellar tearing are the nodes. Nodes are those regions of the jacket structures at which cross bracings join the main tubular elements. At these points, internal stiffening of the leg cans is also essential. The result of this design is that considerable strain acts through the thickness of the node plate both during fabrication and subsequently in service. This in turn demands a high level of through-thickness ductility if lamellar tearing is to be avoided.

Recent research has shown that lamellar tearing is also controlled by the same stringer sulphides which influence transverse impact properties, and to obtain satisfactory short transverse ductilities, it is again essential to effect a dramatic reduction in sulphur levels. The node materials of course, also require the same high degree of CE and notch toughness control as the remainder of the general jacket material, and the supply of steels to meet such a stringent specification therefore necessitates special control of steelmaking procedures.

Table 2 : Material specifications for BP Forties field offshore platforms (345N/mm² min. yield stress)

Specification	MC/1001, issue 2	MC/1001, app. A	MC/1001, supp. 1
Plate application	General jackets	Platform jackets	Node tubes
S level (max.)	>38mm 0.025%	>38mm 0.025%	0.010%
N level	0.009%	0.009%	0.013%
Tensile properties	As per BS 4360, 50D	As per BS 4360, 50D	As per BS 4360, 50D
CE	⩽25mm 0.43% (ladle) >25mm ⩽38mm 0.41% (ladle) >38mm 0.46% (ladle)	As per MC/1001, Issue 2	⩽38mm 0.41% (ladle) >38mm 0.44% (ladle) All thickness 0.44% (product)
Through-thickness ductility	—	—	20% R of A (mean of 6) 15% min. individual
Charpy (longitudinal)	⩽25mm 41J at —20°C >25mm 61J at —20°C Cross values 50% of above	As per MC/1001, Issue 2	As per MC/1001, issue 2
Steelmaking and supply comments	Up to 25mm normal C-Mn-Nb 50D (killed). Material is supplied above 25mm. C-Mn-Al material is required to meet enhanced impacts at thickness>38mm to ensure adequate S control. An OH vacuum degassed route is used	As per MC/1001, Issue-2	Although specified as C-Mn-Si with Al +Ce, can be supplied with better control to C-Mn-Si-Nb-Al 0.006% S (max.) target

The fabrication of North Sea structures often involves forming of plate material into tubular components. This implies that

(a) the material must be resistant to deterioration in hot and cold forming, and

(b) where internal diameter-to-thickness ratios of less than 20 to 1 result from a cold forming operation the required properties must be achieved after a subsequent normalising treatment (to conform with BS 1515 requirements). In addition, all critical joints in steel greater than 41 mm thick require a postweld stress relieving treatment of up to 3hr at 600°C, and it must be kept in mind that such treatments cause small reductions in both yield stress and impact properties, though any effect of such changes on stability of the structure is far outweighed by the beneficial effects of the stress-relieving process.

In view of the fact that hot forming is in most cases an integral part of tubular fabrication, the supply of quenched and tempered or controlled rolled material cannot be considered except where cold forming has been specifically stipulated.

BSC has successfully met all the above-mentioned stipulations by using special techniques in the manufacture of BS 4360, 50 D grade steel. In the first instance accurate control of steelmaking and deoxidation, including vacuum degassing when necessary, are used to ensure compliance with CE limitations and to produce the low sulphur levels required. At thicknesses greater than 25 mm, enhanced impact properties are ensured by producing fully aluminium-killed material, and this, in conjunction with sulphur level control, produces a steel suitable for application in all but the most stringent areas of the jacket structure.

With respect to the supply of node quality steels, past experience has shown that sulphur levels well below 0.01 % are essential to ensure high levels of short transverse ductility. In the light of the control necessary the BSC has developed an electric furnace route employing double and triple slag teachniques.

Table 2 describes the actual customer specifications for BP Forties field offshore platforms which appear extraordinarily stringent when compared to the conventional steel specifications. And it is to the credit of the British Steel Corporation that they have succeeded in meeting them, thereby contributing to the unique success of the North Sea project.