



THE MARINE TECHNOLOGY
DIRECTORATE LIMITED

**CURRENT AND POTENTIAL USE
OF HIGH STRENGTH STEELS
IN OFFSHORE STRUCTURES**
J.Billingham, J.Healy and J.Spurrier

PUBLICATION 95/102

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LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|-------------|--|
| AWS | American Welding Society |
| BOP | bead on plate |
| CE | carbon equivalent |
| CGHAZ | coarse-grained heat affected zone |
| CP | cathodic protection |
| CTOD | cracktip opening displacement |
| CTS | controlled thermal severity |
| CVN | Charpy vee notch |
| FCAW | flux cored arc welding |
| FE | finite element |
| HAZ | heat affected zone |
| HSLA | high strength low alloy |
| MAC | martensite, retained austenite and aligned carbides |
| PWHT | post weld heat treated |
| Q & T | quenched and tempered |
| SAW | submerged arc welding |
| SMYS | specified minimum yield strength |
| S - N curve | stress range plotted against number of cycles to failure |
| SRB | sulphate reducing bacteria |
| TMCP | thermomechanically controlled processing |
| TS | total sulphide |
| UTS | ultimate tensile strength |
| YR | yield ratio |

Abbreviations of chemical elements

| | |
|----|------------|
| Al | aluminium |
| B | boron |
| C | carbon |
| Cr | chromium |
| Cu | copper |
| Mn | manganese |
| Mo | molybdenum |
| Ni | nickel |
| Nb | niobium |
| P | phosphorus |
| S | sulphur |
| Si | silicon |
| Ti | titanium |
| V | vanadium |

NOTATION

| | |
|-----------------------|---|
| a | crack length |
| a_{eff} | critical flaw parameter |
| B | thickness |
| CE_{nw} | IIW carbon equivalent |
| Co | surface/absorbed hydrogen concentration |
| da/dN | crack propagation rate per cycle |
| F_u | ultimate tensile strength |
| F_y | yield strength |
| H_v | Vickers hardness |
| J_c | critical value of J-integral |
| K_c | apparent toughness, critical value of stress intensity factor |
| K_{IC} | plane strain fracture toughness |
| K_{th} | threshold stress intensity |
| m | magnification factor |
| R | ratio of minimum load/maximum load |
| W | width |
| | |
| δ_c | critical crack tip opening displacement |
| σ_{app} | applied stress |
| σ_y | yield stress |
| ΔK | applied stress intensity factor |

1. GENERAL INTRODUCTION

High strength steels have been available for many years, but their use in offshore engineering has been severely restricted except in specialised applications. This is largely because, in general, satisfactory performance can be achieved with cheaper, more readily available, lower strength steels. Additionally, as strength increases, not only does the cost increase but the ductility and weldability generally decrease. In major structural applications such factors have significant influence. Thus most steels used in offshore structural applications have yield strengths in the range 250 to 350MPa. Indeed, there are restrictions in many codes which militate against using steels with yield strengths greater than 460MPa⁽¹⁾.

The major requirement offshore is for tubular construction practice which utilises steel plate as the raw material. The ferrite pearlite steels used must be readily available in tonnage quantities and in a range of thicknesses up to 100mm. The conventional steel production route is normalising in order to produce satisfactory properties in the thicker section components. A primary requirement for this production route is adequate weldability, which is provided by limiting the steel hardenability through compositional limitations usually imposed through restrictions in allowable carbon equivalent values⁽²⁾. This factor, combined with the need for good notch ductility, has led to a continual reduction in carbon levels in such steels over the past two decades⁽³⁾.

In contrast, over the same period, the pipeline industry has successfully exploited large tonnages of higher strength steels in marine environments. Thus, X70 grade (480MPa) steels are commonly used in subsea pipelines. Such steels are ferrite pearlite steels which are micro-alloyed to produce a fine grain size, to give both strengthening and resistance to low temperature brittle fracture. They also have low carbon contents to ensure good weldability and toughness, and low levels of impurities to ensure resistance to ductile failure processes, which might occur in gas pipelines as a result of overpressurisation. Pipelines utilise much smaller section thicknesses (usually 19mm or less), and they can therefore take advantage of alternative steel production routes such as controlled rolling or TMCP to develop the necessary fine grained microstructure⁽⁴⁾.

Even higher strength steels (700MPa yield strength) have been used for some time in jack-up platforms⁽⁵⁾. Such steels have usually had a relatively high carbon content, because good abrasive resistance is required in the jacking operation, and weldability is not a prime requirement⁽⁶⁾. Because of the periodic docking arrangements which allow easier inspection capabilities, fatigue is also not seen as a major design limitation. More recent proposals to use such structures on much longer term operational schedules have instigated a more widespread interest in the likely fatigue performance of the type of steels used⁽⁷⁾.

Another traditional application for higher strength steels in marine environments has been submarines⁽⁸⁾, where higher strength (700MPa) steels are utilised to reduce section thicknesses because of their excellent mechanical property combinations in terms of strength and toughness⁽⁹⁾. However, such steels are generally much more highly alloyed, making them more expensive and more difficult to weld. In turn, this often necessitates lengthy and costly pre-, and sometimes post-welding treatments, which extend and complicate fabrication procedures, and introduce considerable additional costs⁽¹⁰⁾. Similar steels have also been used in mooring applications such as the tethering attachments in tension leg platforms, where their high strength and good resistance to fatigue can be utilised. In this application, the steels are not usually used in the welded condition, screwed connectors being used for example, so that their excellent resistance to fatigue initiation or sudden overloads can be utilised⁽¹¹⁾. However, a recent example used welded connections on a 38-mm thick lower strength X70 (485MPa) tether string for the Heidrun project⁽¹²⁾.