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ABSTRACT - Small amounts of alloying additives to weld materials are known to result in a beneficial effect on the impact and fracture toughness properties. Three welds, with different amounts of Ti and B in ppm level, were examined using the transmission electron microscope (T.E.M.) and the atom probe field-ion microscope techniques. The inclusions and precipitates observed could be classified into three broad groups depending on their size. The largest ones in the micron range could be analysed using the energy dispersive analyser attached to the T.E.M. The medium ones in submicron range were analysed using electron diffraction methods and the smallest ones in the nanometer range could be analysed only with the atom probe. The volume fraction and composition of the precipitates were found to vary with the microstructure and the impact properties of the three welds. An attempt has been made to correlate the composition of the precipitates with Ti and B content.

I - INTRODUCTION

The off - shore industry requires welded structures with excellent low temperature impact and high COD properties. Conventional electrodes containing upto 3% Ni have been found to be inadequate in meeting this combination. Addition of Ti and B in ppm level has been found to drastically improve the properties. This is mainly because of the grain refining effect of B, the deoxidation effect due to Ti and their combined ability to form small precipitates. The aim of the present investigation is to study the microstructural changes in the three welds prepared under identical conditions.

II - EXPERIMENTAL

Three multi - pass welds prepared by submerged arc welding on St 52 plates were selected for investigation. The material composition of the wires, which are designated G26, G45, and G46, is given in Table 1.
Charpy V - notch impact tests in the welded direction were conducted in the temperature range -100 to +60°C and the results are presented in Fig. 1.

Figure 2 shows the histograms of inclusion sizes and distributions in the three welds. The optical micrographs of the three welds at 100 and 500x magnification are shown in Fig. 3.

Table - 1: Chemical composition of the welds.

	%C	%Mn	%Si	%P	%S	%Ti	%B	%O	%N
G 26	0.069	1.28	0.55	0.014	0.012	0.001	-	0.066	0.0085
G 45	0.091	1.27	0.53	0.016	0.009	0.039	-	0.055	0.0080
G 46	0.087	1.37	0.61	0.017	0.009	0.051	0.0085	0.050	0.0090

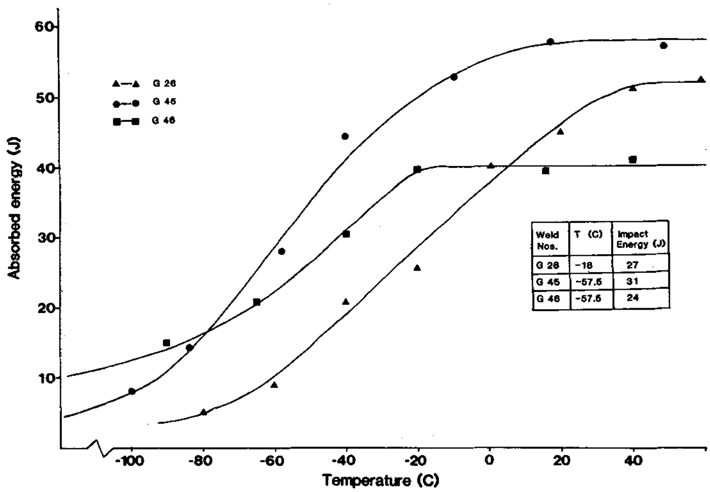

Fig. 1: Relationship between absorbed energy and temperatures for the three welds.

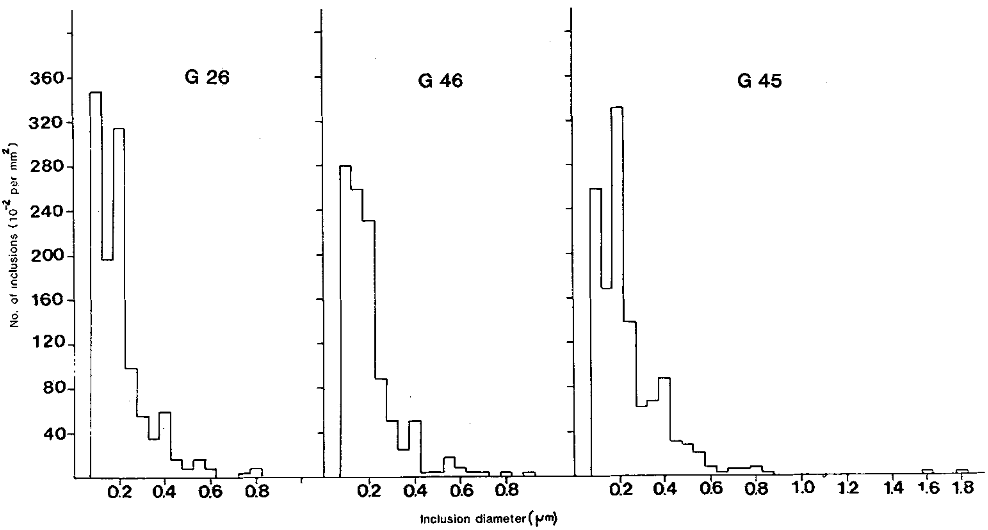

Fig. 2: Inclusion distribution in the three welds.

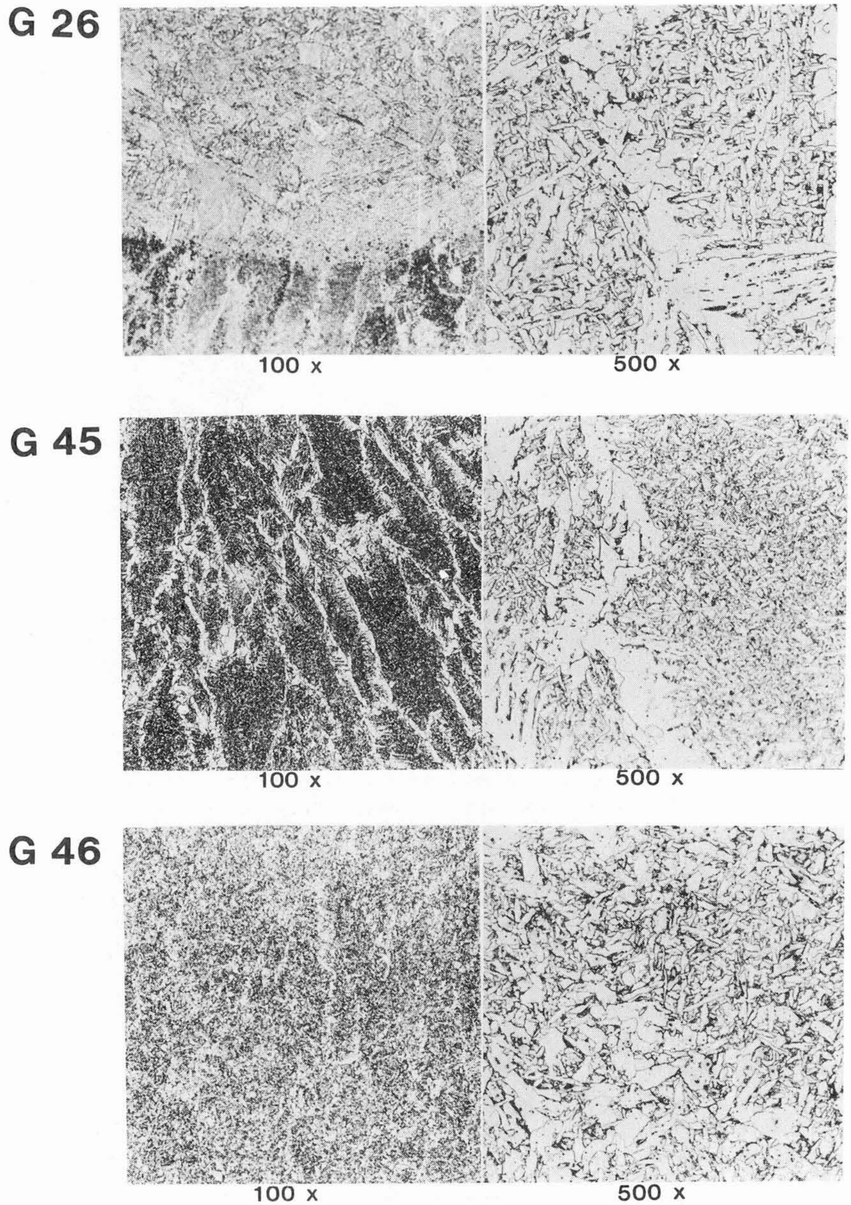

Fig. 3: Optical micrographs.

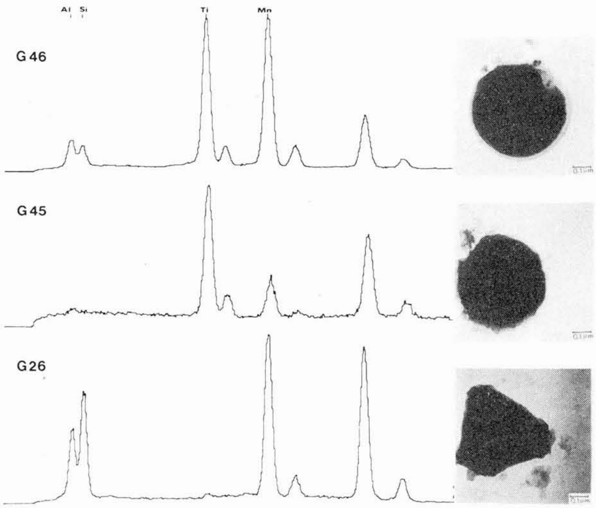

Fig. 4: Energy dispersive spectra obtained from a STEM analysis of micron sized inclusions.

Figure 4 shows the energy dispersive analysis spectrum from selected inclusions from a STEM analysis of extraction replicas in a JEOL 200-CX electron microscope. A number of inclusions, around 0.5-1 µm size, were analysed and all of them gave similar results.

Smaller size inclusions/precipitates, around 0.1 µm size, were analysed by microdiffraction technique and the micrographs and diffraction patterns are shown in Fig. 5. Most of the larger particles were found to be MnS, Al_2O_3 and MnO and a few Ti(C,N). The grain boundary precipitates had typical compositions of B_2O_3 and $Fe_{23}(B,C)_6$.

A typical field-ion image from weld G45 and the atom-probe spectra from the matrix region are shown in Figs. 6 (a & b). The spectra from the larger and smaller precipitates are respectively shown in Figs. 6c and 6d. The spectra show Ti, C, TiC and considerable amounts of Fe suggesting that their composition is of the type $M_{23}C_6$.

III - DISCUSSION

The results of the microstructural and mechanical properties do not conform with the earlier reports (1). While the total inclusion content in Ti - B containing welds was less than the other grades as anticipated, the impact energy in the temperature range -20 to +40°C was lower than the other two grades and the transition temperature did not show marked improvement over G45 which had only Ti. The impact energy was even lower than the normal grade which was without any Ti and B. The trend is perhaps attributable to different Ti and Mn contents of G45 and G46. The beneficial effect of B in G46 is offset by the higher Ti content (than in G45) because increasing the Ti content from an optimum value is known to result in higher transition temperatures (2,3). The Mn content affects the precipitation of borocarbides (4) and the formation of these carbides at grain boundaries drastically lowers the uppershelf energy (5).

Until now there are at least two opinions as to how B affects the austenite ferrite transformation. In one of these, it is held that B atoms reduce the free energy of the austenite grain boundaries (6) and thereby reduces the effectiveness of such boundaries for proeutectoid ferrite nucleation. In the other one (5) the formation of borocarbides at austenite boundaries is considered to be the critical factor

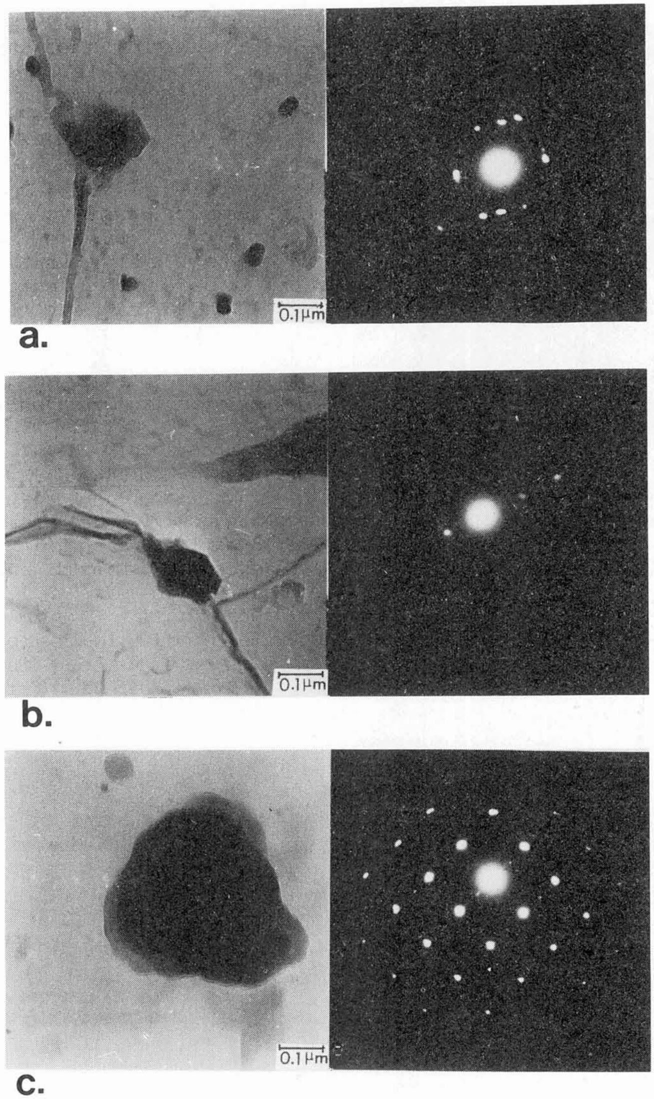

Fig. 5: Electron micrographs and diffraction patterns from (a) B_2O_3, (b) Fe_{23} $(B,C)_6$ and (c) TiC.

in nucleating proeutectoid ferrites depending on the coherency of the interface. The effect that Ti and B have on the notch toughness and transition temperature is a complex matter and depends on many parameters which, in turn, affect the microstructure of the welds and the precipitation in the grain interiors and at the grain boundaries. Detailed atom probe analysis is in progress to understand the exact mechanism.

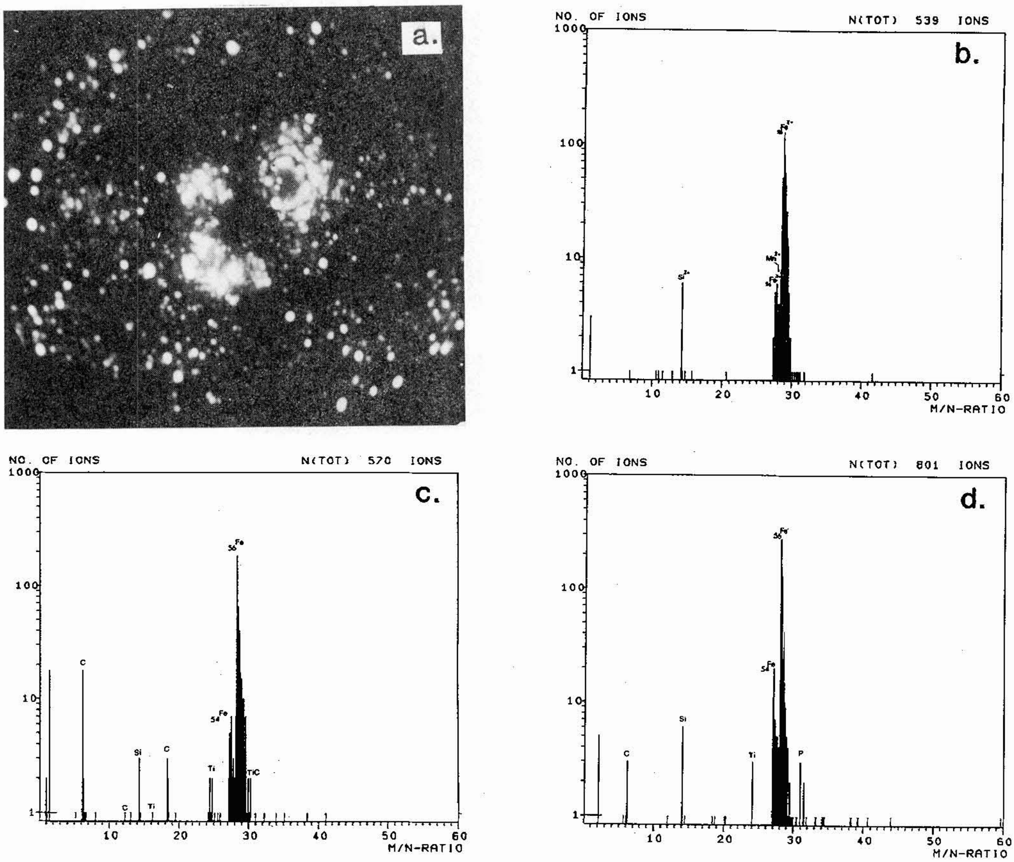

Fig. 6: (a) Field-ion micrograph from G45 weld specimen.
Mass spectrums from (b) the matrix region and (c & d) from two precipitate regions.

IV - ACKNOWLEDGEMENT

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