# INVESTIGATION OF MICROSTRUCTURE AND CRYSTALLOGRAPHIC TEXTURE OF AUSTENITIC STAINLESS STEEL MULTI-PASS TIG WELD USING EBSD AND NEUTRON DIFFRACTION

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## ABSTRACT

In the present work, crystallographic texture of TIG weldments was investigated using EBSD and neutron diffraction. The specimens were in the shape of cuboids machined from austenitic stainless welds. Optical microstructure of the weld metal was also investigated. The neutron diffraction texture has been measured at the STRESS-SPEC diffractometer of FRM II reactor, Germany. Nearly random texture has been observed in the weldments.

## INTRODUCTION

Welding of austenitic stainless steel finds wide use in nuclear, thermal and process industry. TIG welding is one of the most commonly used processes. It is important and vital to characterize certain properties of the weld metal from structural integrity point of view. Texture is an important aspect as it introduces significant anisotropy in an otherwise isotropic material. The present study is part of a larger experimental investigation and modeling of various types of weldments. This involves investigation of crystallographic texture and elasto-plastic anisotropy of weld metal. In the investigations of MMA welds, very intense recrystallization texture has been observed (results yet to be published).

## SPECIMEN DETAILS

### TIG Cuboids

TIG weld cuboids were machined from an 8 pass TIG groove weld Fig. 1. A 304 stainless steel plate was machined to 200x150x20 mm blanks to produce the groove weld plate specimens [1]. In the center of each specimen, a 10 mm groove was machined. The specimens were solution annealed (in a vacuum furnace) at 1050°C, followed by gas fan quenching to relieve machining residual stresses from the blank after machining. Weld metal was laid down within each groove of the treated blank. TIG welding was carried out with a type 308L filler wire, 0.9 mm in diameter using argon as a shielding gas. The typical composition of an austenitic 308 weld is:


Fig. 1TIG groove weld plate (3D view)

**Table 2.3 Chemical composition (wt%) of the austenitic 308 weld.**

| C | Si | Mn | Cr | Ni | N |
|---|---|---|---|---|---|
| 0.05 | 0.5 | 1.7 | 20.2 | 9.4 | 0.06 |

The tungsten electrode was the cathode and a pulsed current was used with the peak current ranging from 180 – 200 A and with the background current of 130 – 150 A. The peak current was applied for 50% duration of each cycle with a pulse frequency of 1 Hz. The nominal heat input was approximately 1.3 kJ/mm and the welding speed was 75 mm/min. The inter-pass temperature remained at 70°C for each pass and the plates were not restrained.
The first pass was placed along the groove centreline filling the base of the groove with subsequent passes being laid down at either side of the center line. The TIG cuboids were compressed along two principal orientations LD and TD. The size of the cuboid for the LD orientation was 7.55 mm x 8.12 mm x 14.54 mm. The size of the cuboid for the TD orientation was 8.01 mm x 7.28 mm x 14.68 mm. The loading axis was always along the 14 mm dimension.

## METALLOGRAPHY

### Sample Preparation for Metallographic Examination and EBSD

For metallographic examination the specimens were mounted in Bakelite moulds using a Metaserv automatic mounting press. After mounting in Bakelite the specimens were ground using a Buehler grinder with grit sizes of 220, 500 and 1200. The force was set to 10 lb at 140 RPM and each grit size was used for 5 minutes.
After grinding the specimens were polished in a Struers polisher. A Struers Roto Force–4 polisher was used. The force was set to 20 N and the RPM to 150. The specimen was polished with diamond suspension of 9 µm, 6 µm and finally 1 µm to get a mirror finish. For EBSD texture analysis, the specimens were electrolytically polished at 22 V, 300 mA for 20 s. The electrolyte used was Struers A2-1 electrolyte. A map was obtained on a 2mm x 2mm region, with 5 µm steps between each measurement.

### Optical Microstructure

Homogeneous wrought austenitic stainless steels generally exhibit an austenitic microstructure at room temperature [2]. However, during welding these materials may solidify with a structure containing some retained ferrite at room temperature. This depends on the composition of the austenitic stainless steel as well. Using a Schaeffler diagram and alloy chemical composition the as-welded ferrite content can be predicted by plotting the calculated Ni and Cr equivalents ($Ni_{eq}$ and $Cr_{eq}$) [3].
$Cr_{eq}$ = [wt % Cr] + 1.5 [wt % Si] + [wt % Mo] + 0.5 [wt % Nb] + 2 [wt % Ti]
$Ni_{eq}$ = [wt % Ni] + 0.5 [wt % Mn] + 30 [wt % C] + 30 [wt % N-0.06]
The optical microstructures from the multi-pass TIG weld are shown in Fig. 2. The microstructure exhibits skeletal ferrite morphology. The dark phase is ferrite and the lighter phase is austenite. The direction of the dendrites is along the sample normal direction. The dendrites are several mm long along the heat flow direction.
In the present case, Ferritic-austenitic solidification mode has been observed which have the equivalent ratio range ($1.48 < Cr_{eq}/Ni_{eq} < 1.95$) [4].

$Cr_{eq}$ = [20.2] + 1.5 [0.5] = 20.95
$Ni_{eq}$ = [9.4] + 0.5 [1.7] + 30 [0.05] + 30 [0.06-0.06] = 11.75
$Cr_{eq}/Ni_{eq}$ = 1.78

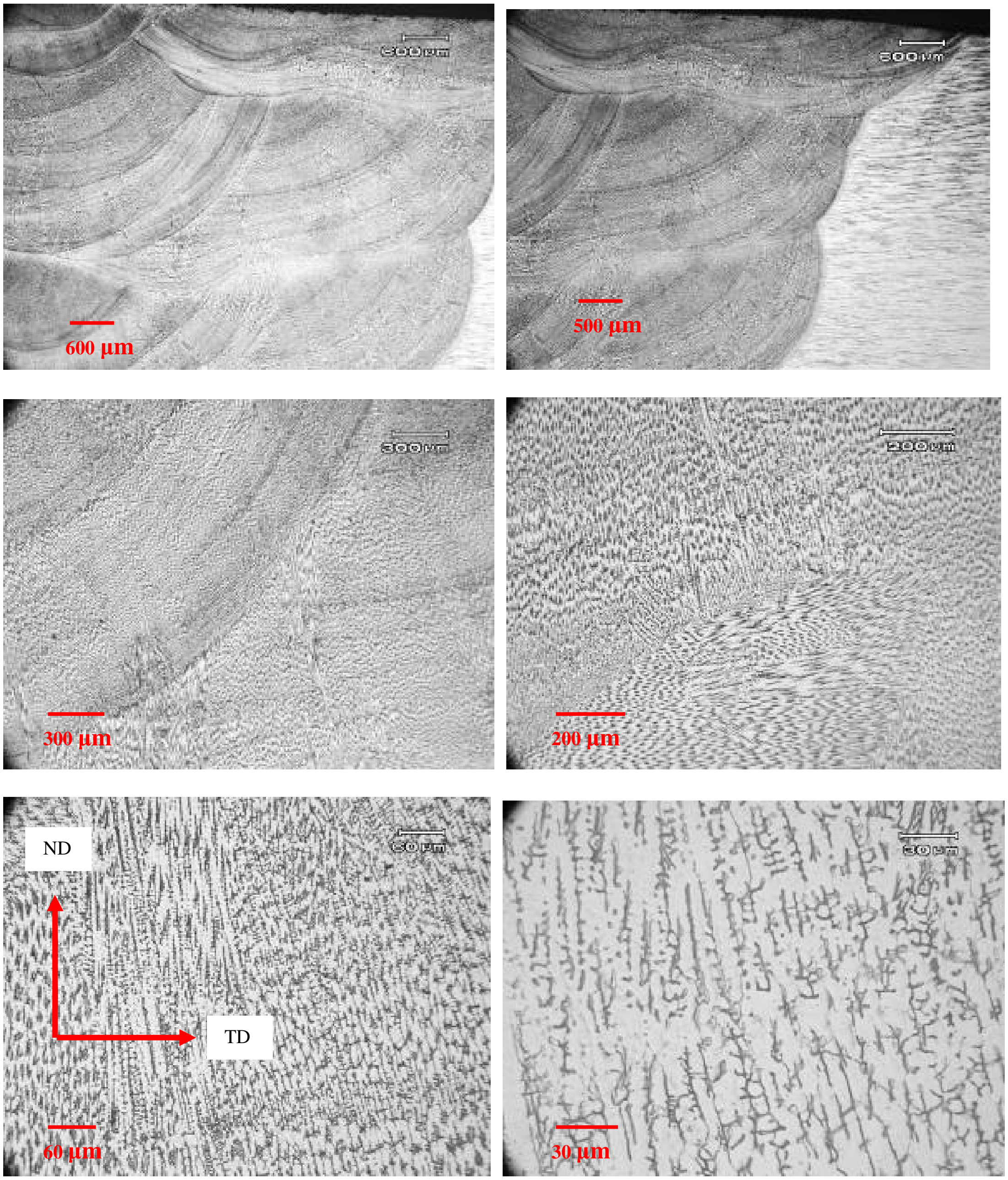



Fig. 2 Multi-pass TIG weld: Optical micrographs at different magnifications.

**TEXTURE ANALYSIS**

The texture measurements were carried out using EBSD and neutron diffraction. EBSD measurements were carried out on a Zeiss SUPRA 55 VP SEM. The SEM was operated at 20 kV with the sample tilted at 70°. Neutron diffraction texture measurements were carried out at STRESS-SPEC diffractometer of FRM-II research reactor in Germany.

The EBSD microstructural map is shown in Fig. 3. The EBSD pole figures for austenite and ferrite are shown in Fig. 4 and Fig. 5 respectively. The austenite pole figures from EBSD measurements exhibit very nearly a random texture. The experimental pole figures for austenite from neutron diffraction texture measurements are shown in Fig. 6. The {200} and {111} pole figures exhibit an intense texture with a times random intensity of 4.17 and 4.41 respectively. The recalculated and experimental pole figures for ferrite from neutron diffraction texture measurements are shown in Fig. 7. The ODF sections for the austenite from EBSD and neutron diffraction are shown in Fig. 8 and Fig. 9

respectively. The ODF sections for ferrite from EBSD and neutron diffraction are shown in Fig. 10 and Fig. 11 respectively. During the TIG welding a filler wire of diameter 0.9 mm was used. This has resulted in a very small bead size. The average heat input was 1.3 kJ/mm. The texture exhibited by the TIG weld can be considered as nearly random texture.

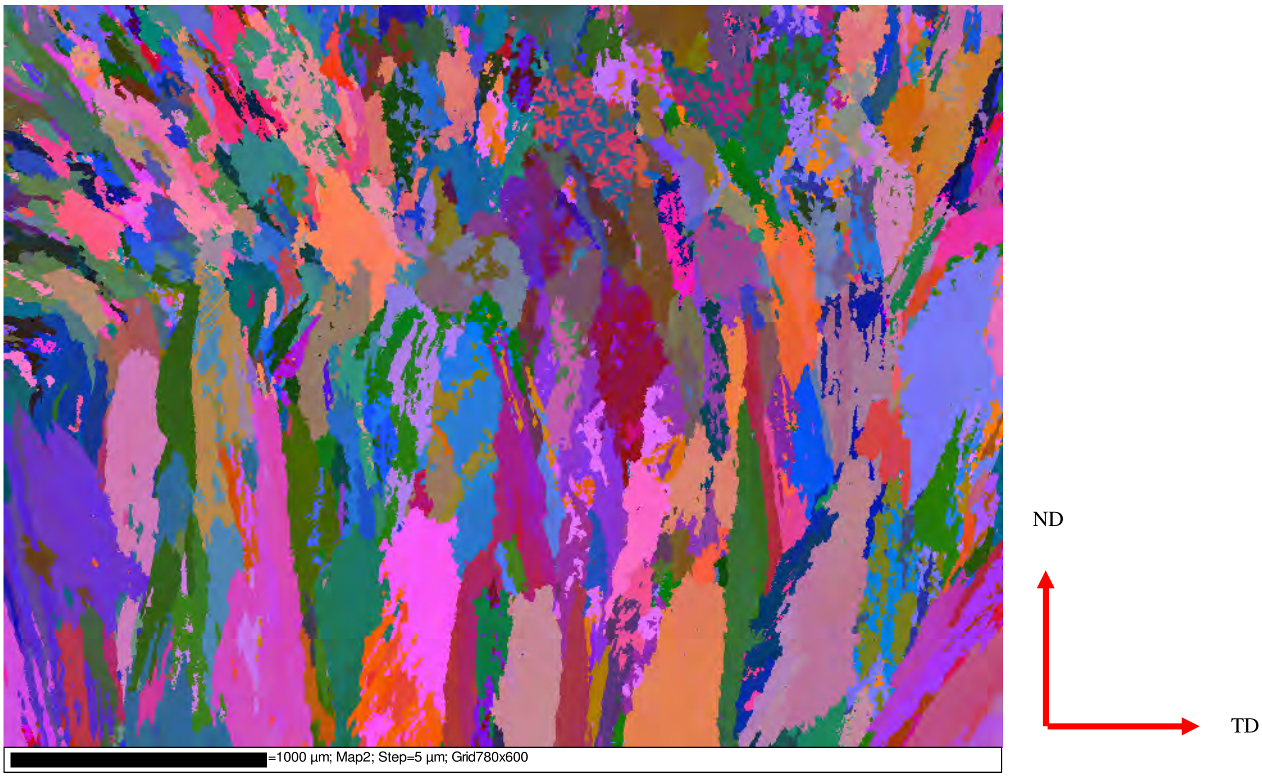



Fig. 3 EBSD microstructure map (cubes machined from TIG weld): Scale bar 1mm

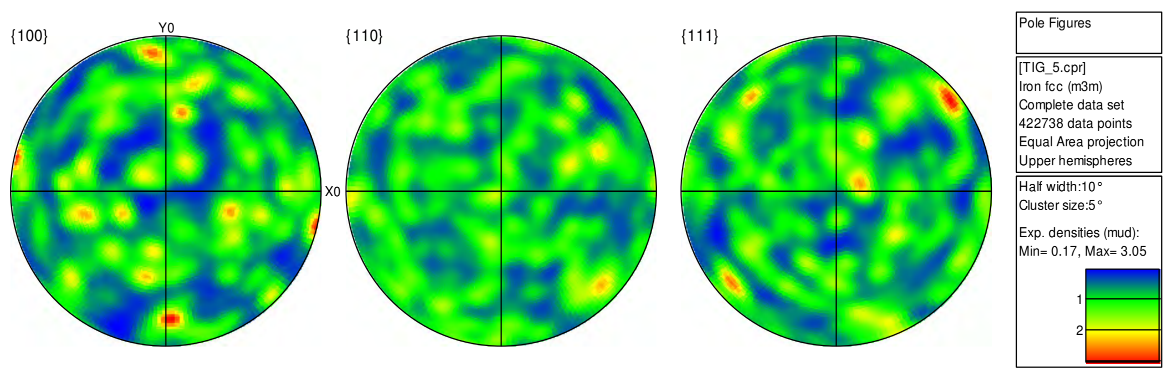



Fig. 4 Austenite pole figures: EBSD (cubes machined from TIG weld)

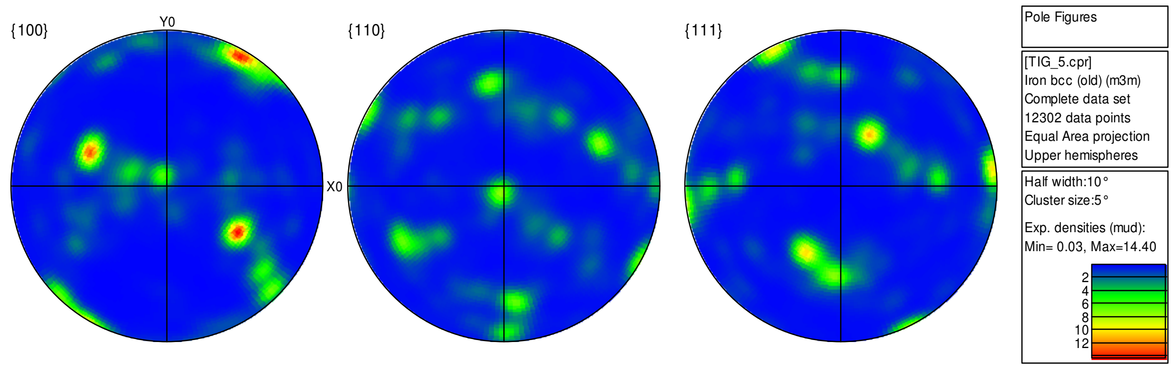



Fig. 5 Ferrite pole figures: EBSD (cubes machined from TIG weld)

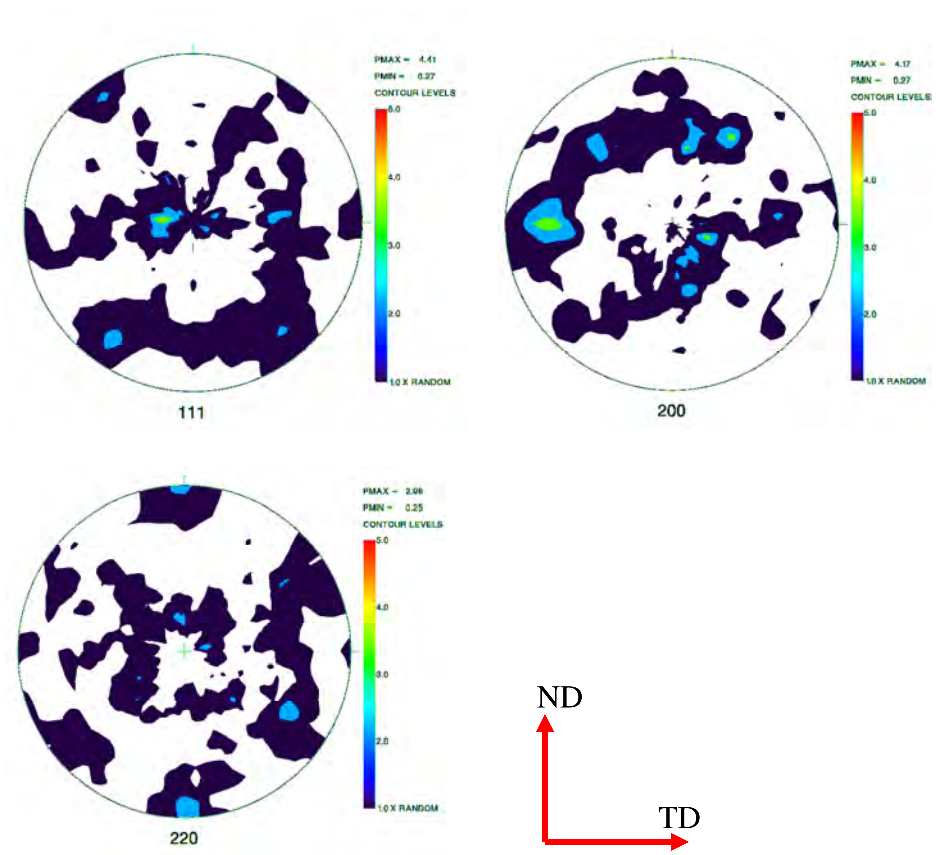



Fig. 6 Experimental pole figures (austenite): neutron diffraction texture (cubes machined from TIG weld)

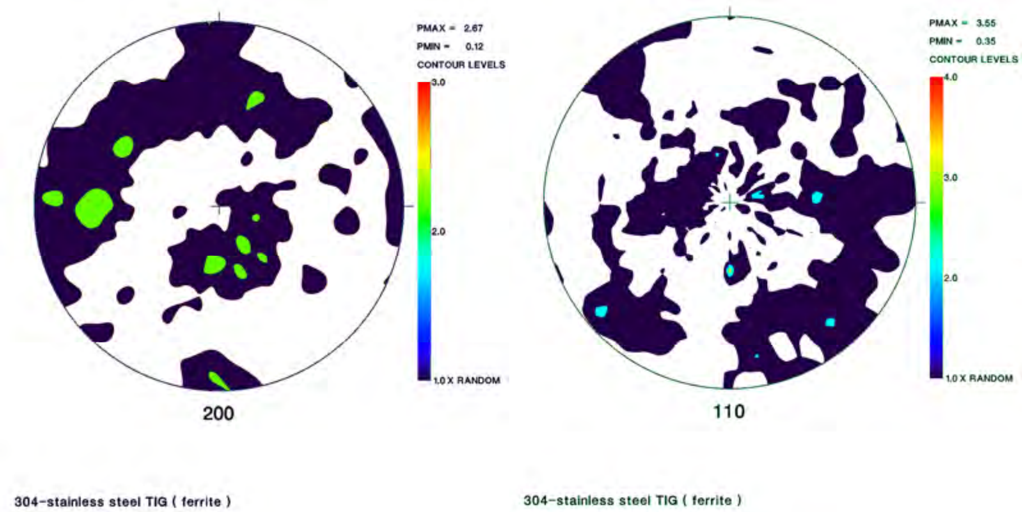
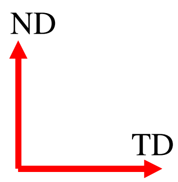



Fig. 7 (a) Recalculated pole figure (ferrite) (b) experimental pole figure: neutron diffraction texture (cubes machined from TIG weld)



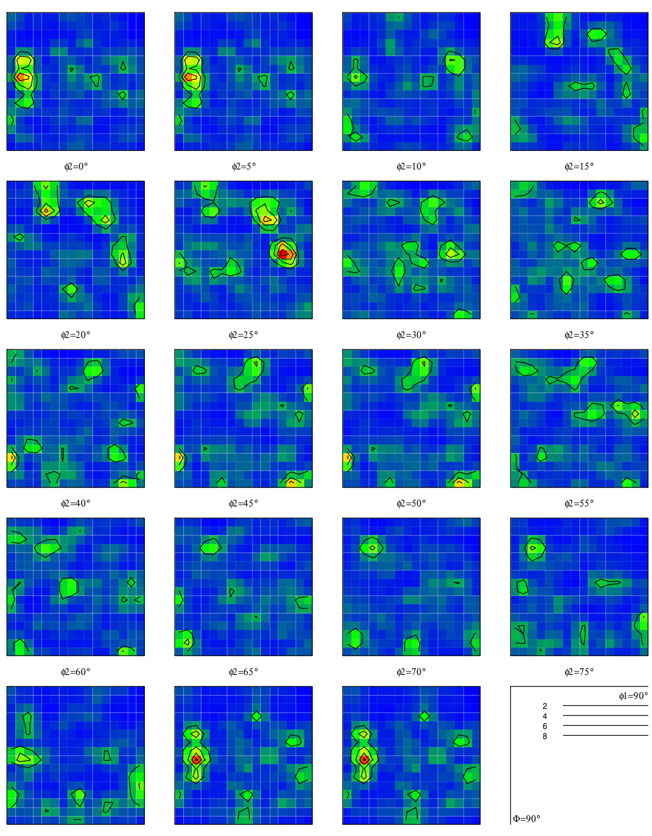




Fig. 8 ODF sections (austenite): EBSD Texture (cubes machined from TIG weld)

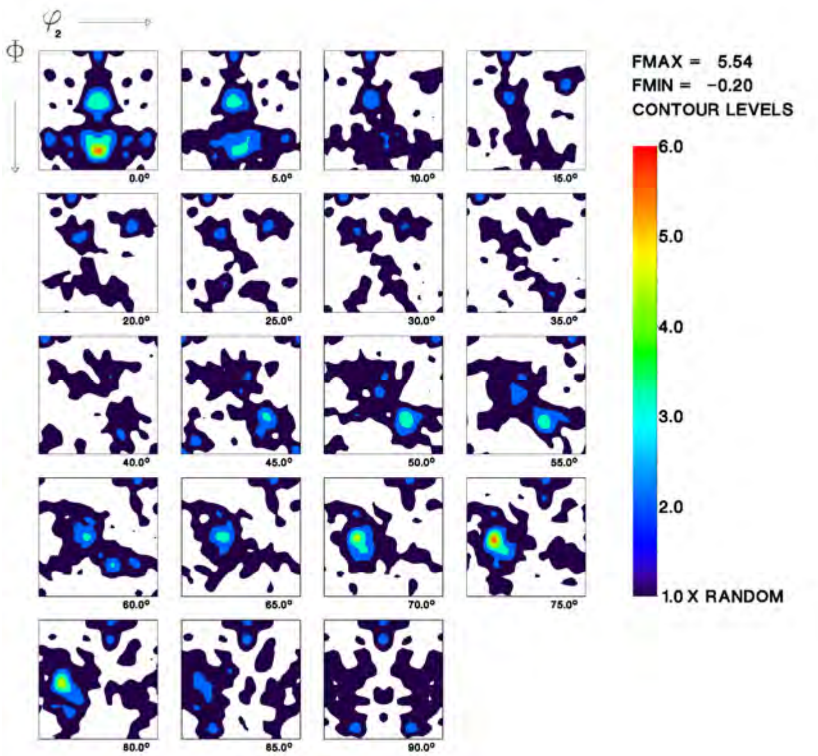



Fig. 9 ODF sections (austenite): neutron diffraction texture (cubes machined from TIG weld)

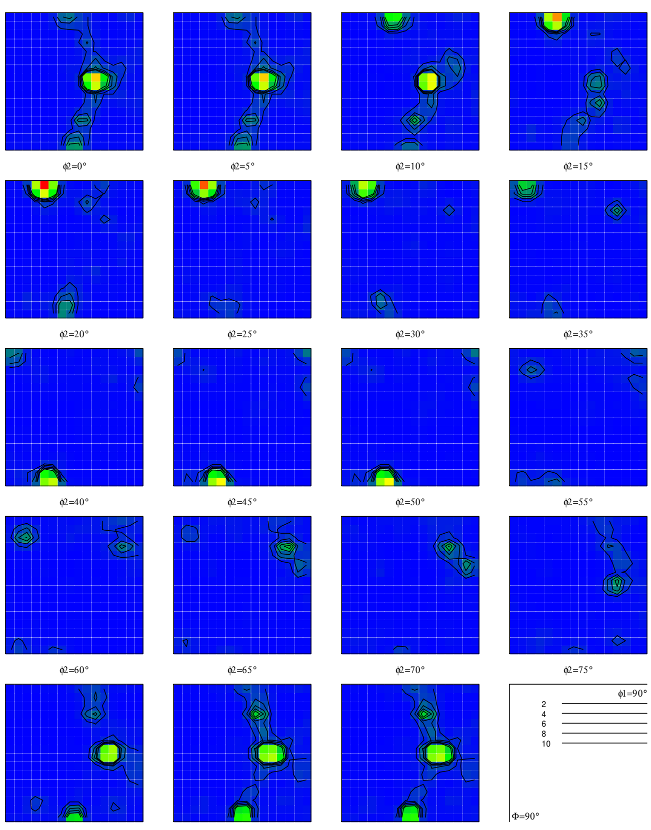



Fig. 10 ODF sections (ferrite): EBSD texture (cubes machined from TIG weld)

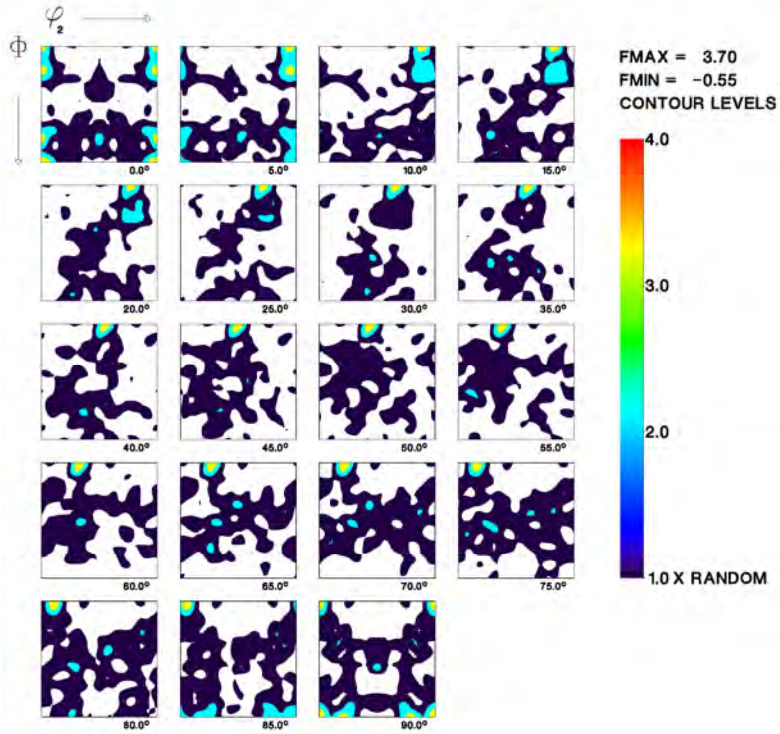



Fig. 11 ODF sections (ferrite): neutron diffraction texture (cubes machined from TIG weld)

**CONCLUSION**

Nearly random texture has been observed in the TIG weld.

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