

Study of Micro-texture during Recovery and Recrystallisation in Folded bcc and fcc Sheet Samples

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Abstract. The sheet folding process generates both tensile and compressive strains across the folded section, producing systematic strain and texture gradients. In this investigation the EBSD technique has been used to gain insight into this phenomenon in folded ferritic steel and nickel alloys, both in the as folded and after annealing conditions. As expected in the fcc material the {111} and {110} fibre texture components get reinforced in the tensile and compressive regions respectively, while the {110} and {111} components are reinforced in the bcc material during folding. After annealing at 600°C for 40 minutes the texture components formed during the folding process are retained despite the formation of new strain free grains. The new grains were found to be slightly larger in the tensile regions than in the compressed regions this was the case for both materials. However, in the mid-region of the section in the nickel alloy abnormal grain growth took place, while only recovery was observed in the ferritic alloy.

Introduction

The folding process has been found to generate both strain and texture gradients in the folded regions. Some work to study the micro structure that develops during the folding process and subsequent annealing was published recently [1]. However, micro-texture data was not presented as the statistics were limited due to the small area over which the changes are observed in sections through the fold as illustrated by the rectangular area in schematic Figure 1a. In order to improve the statistical data the samples for this study were carefully sectioned along the fold, thus exposing a large area containing the information in the rectangular area in Figure 1a, and indicated by the shaded area in Figure 1b.

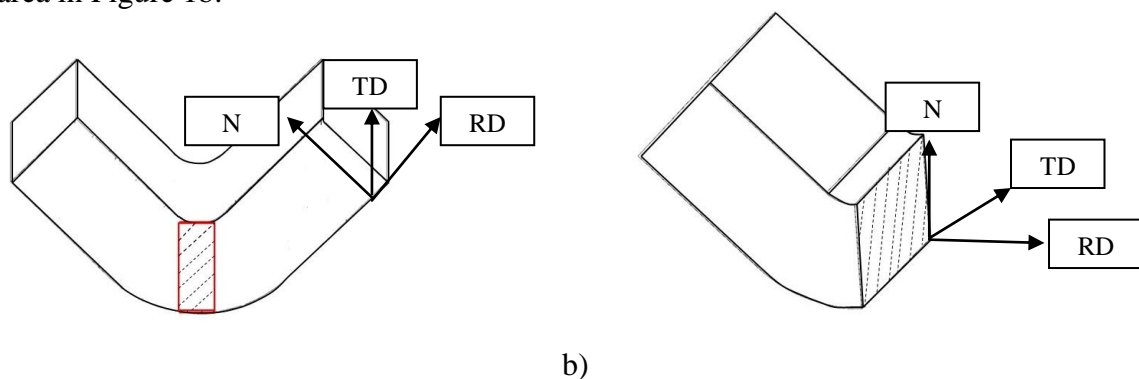


Figure 1a) Schematic diagram of the folded sheet and the area polished and b) sections along fold.

Experimental

Materials. Commercially available nickel alloy 200 and mild steel, sheets of approximately, 2 and 1.5mm thickness respectively were used. The sheets were folded perpendicular to the rolling direction as shown in Figure 1. Specimens of about 3mm length were cut from the folded sheets and heat treated.

Isothermal Heat Treatment. The nickel specimens were heat-treated in air, while the steel specimens were treated under a nitrogen atmosphere. The samples were heated at 10°C/min up to 600°C held for 40 minutes and allowed to cool in air.

Sample preparation and EBSD apparatus. All samples were mounted in conductive bakellite as if to polish the sectioned surface, Figure 1a. However, after the samples were planed, the mounts were carefully cut to reveal the surface shown in Figure 1b. These specimens were then remounted so that the newly revealed surface could be polished for EBSD examination. The specimens were polished mechanically using standard metallographic techniques. EBSD data acquisition and post-processing were done with OI- NordlysMax and NordlysNano detectors attached to FEGSEM's with AZtec and CHANNEL5 software packages. EBSD maps were collected at low magnification for all samples mounted in the microscope with the following coordinate the X=TD, Y=N and Z=RD (surface analysed). Indexing rates of above 95% were achieved.

Results and Discussion

A series EBSD IPF Z coloured map and associated pole figures from respective tensile, neutral and compressive strain regions from the as folded and annealed nickel and steel sheet sections together with plots of grain size and mean local mis-orientation vs distance across the specimen thickness are given in Figures 2-7.

The IPF coloured EBSD maps clearly show a systematic variation in texture with strain, in the nickel alloy. Under tension the partial {111} and {100} fibre components present in the as received sheet are reinforced, whereas in the compressed region a partial {110} fibre component is generated, see Figure 2. On annealing even though a fresh strain free micro-structure evolves with a varied but systematic grain size variation (Figures 4a and b), the texture components present during folding are retained as observed in Figure 3.

Similarly the IPF coloured EBSD maps from the steel sheet show that the existent partial {110} fibre component in the sheet is reinforced in the tensile region, whereas in the compressed region weak {111} and {100} partial fibres develop, Figure 5. These are not as marked compared to the nickel sheet, probably due to the lower thickness of this sheet. Annealing of this sheet only caused recovery in the region with neutral strain, with no change from the original texture. In both the tensile and compressed regions recrystallisation occurs producing strain free grains, (see plots Figure 7), but as in the nickel sheet the original deformation texture components are retained, albeit they are much weaker, Figure 6.

These findings are in keeping with those reported in the literature [2] and have been explained in terms of slip systems operating in fcc and bcc structures during deformation and recovery and recrystallisation processes during annealing. However, detailed study of such behavior on the micro scale has been made possible by the EBSD technique. EBSD data can further lend itself in understanding these phenomenon through modeling of texture and recrystallisation behaviours.

Conclusions

The folding process causes reinforcement of textures components favored by the different slip systems operating under tensile and compressive strains in fcc and bcc structures. Despite the generation of strain free gains during annealing, texture components generated during deformation are retained. This study has shown that EBSD is a powerful tool for following deformation and recrystallisation phenomenon in terms of strain, grain size and texture development.

Acknowledgments

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References

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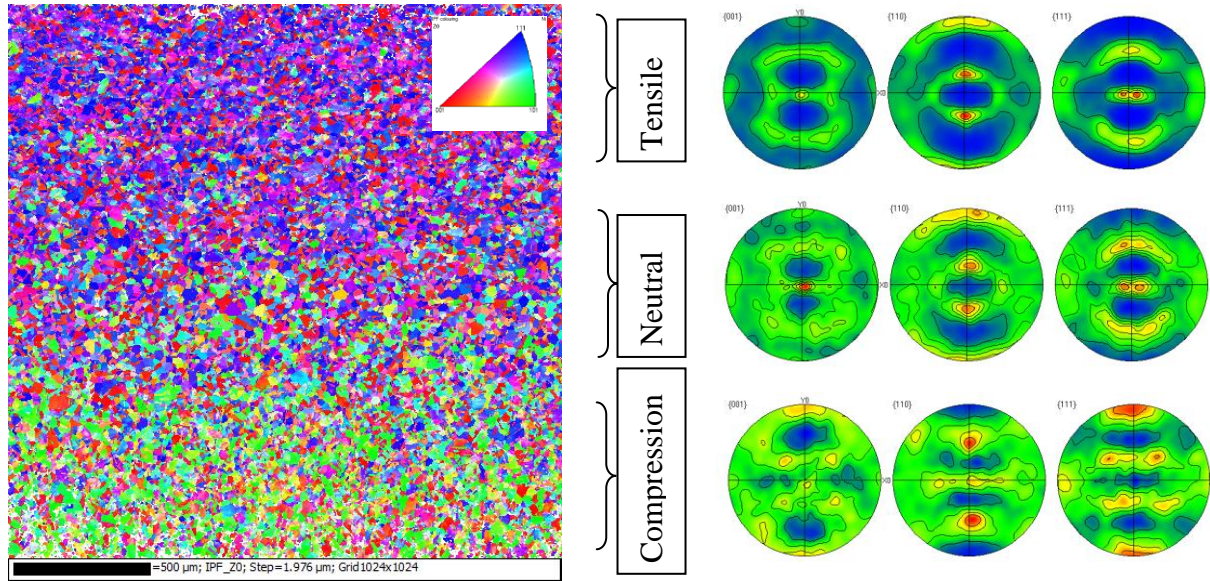


Figure 2. EBSD map across the as folded nickel sheet (inset IPF legend) and associated pole figures.

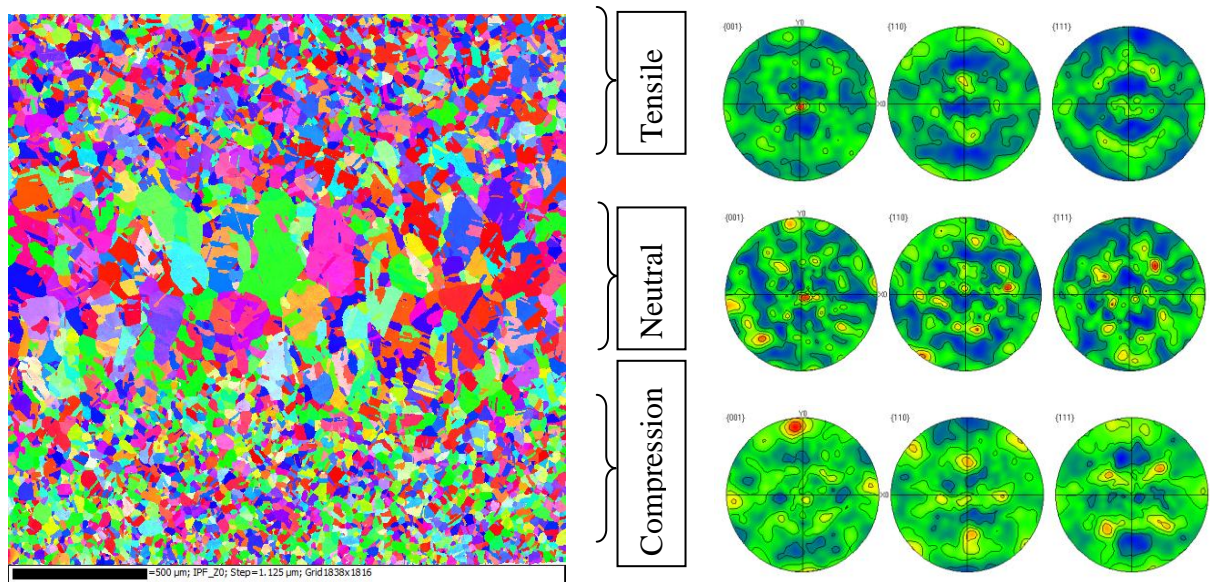


Figure 3. EBSD map across the annealed nickel sheet and associated pole figures

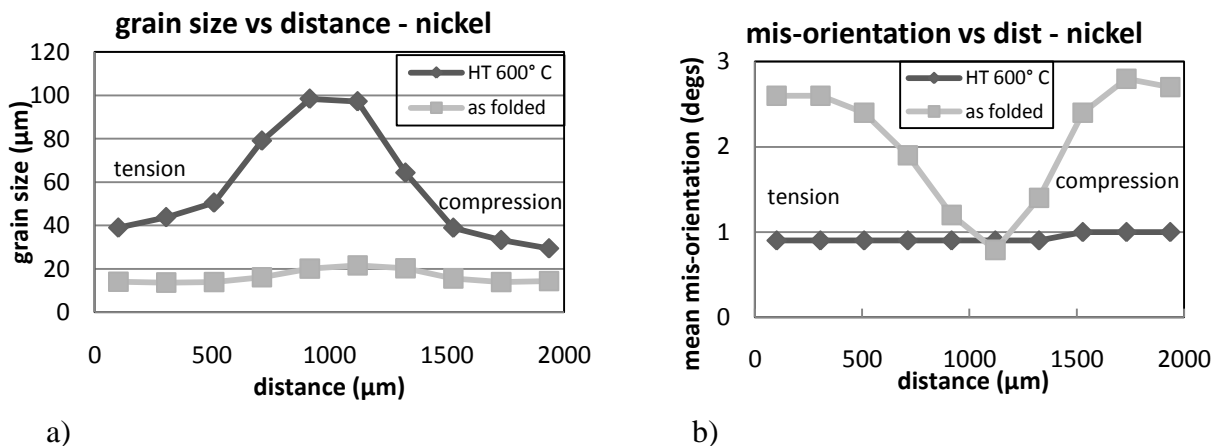


Figure 4. a) Grain size vs distance and b) Mis-orientation vs distance for the nickel sheet

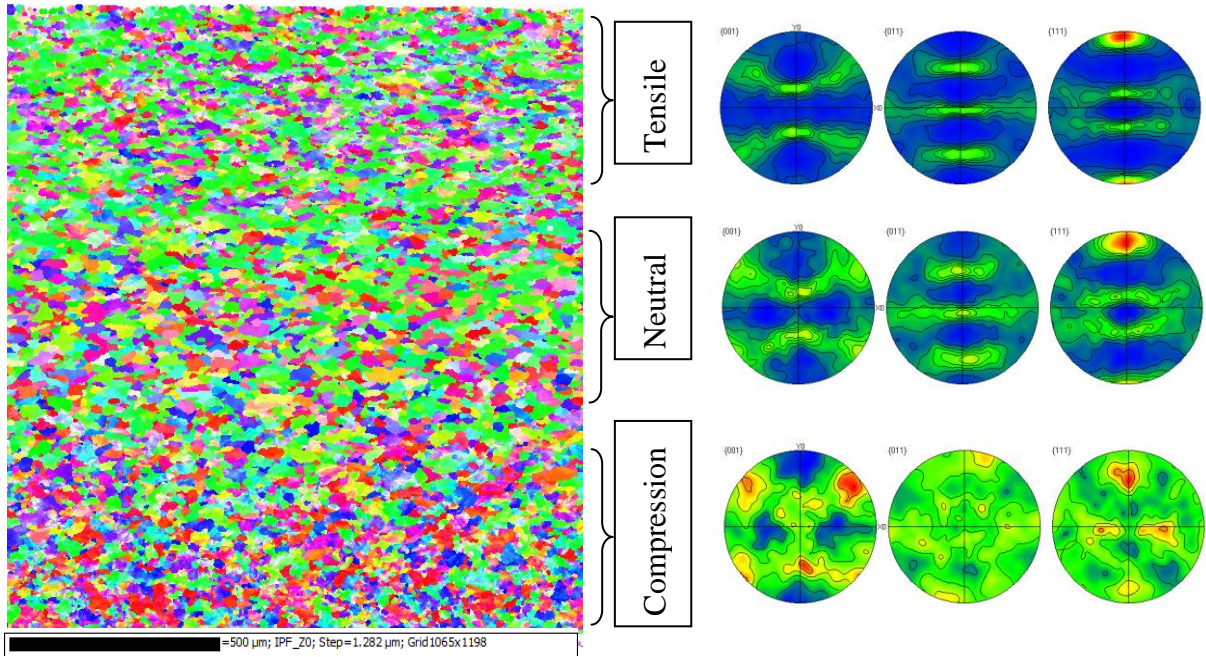


Figure 5. EBSD IPF map across the as folded steel sheet and associated pole figures

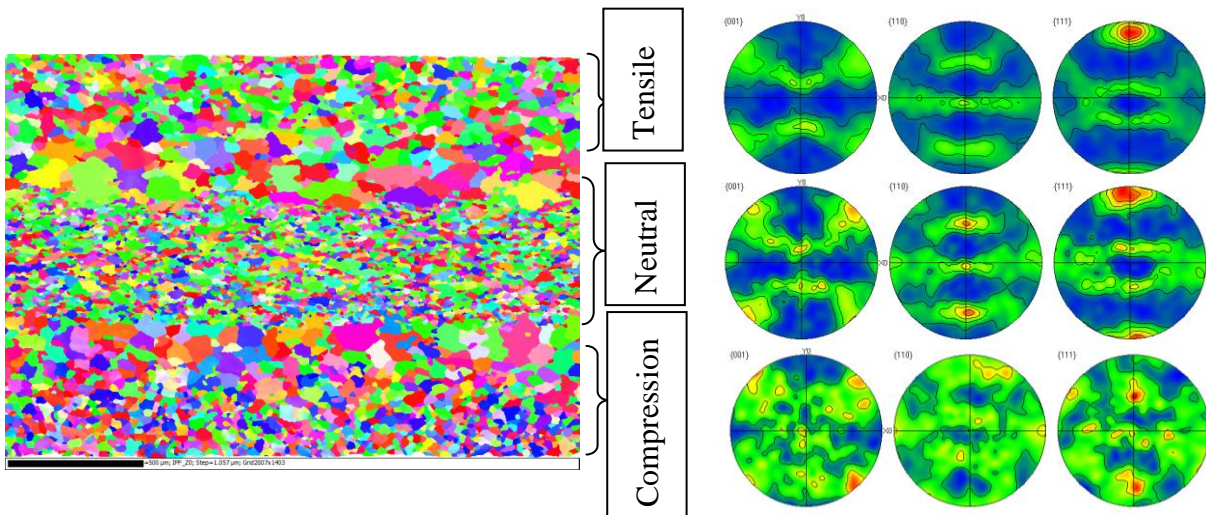


Figure 6. EBSD IPF map across the annealed steel sheet and associated pole figures

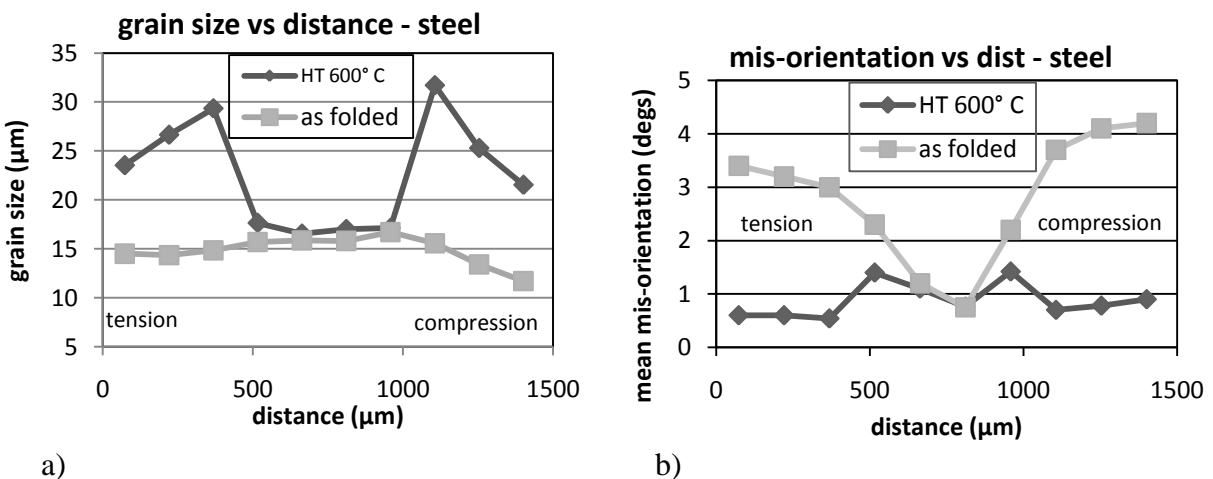


Figure 7. a) Grain size vs distance and b) Mis-orientation vs distance plots for the steel sheet