DRECE FORMING METHOD AS A WAY TO IMPROVE METALS AND ALLOYS FOR ADVANCED STRUCTURAL AND FUNCTIONAL APPLICATION

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Abstract

The creation of UFG (ultra-fine grain) materials is a new and promising way to improve metals and alloys for advanced structural and functional application. To date, it is common knowledge that UFG materials can be successfully produced by intense plastic deformation. Severe plastic deformation (SPD) is one of the most effective techniques to improve the physical and mechanical properties of metallic materials through structural refining for UFG and nano-crystalline (NC) states. One of the approaches that has been the subject of basic and applied research for two decades is the preparation of materials with UFG structure with a grain size below 1000 nm. Such materials will find use primarily where they use stress, while preserving the required plasticity, it will be due to the reduction of the weight of the structure, which will also contribute to the preservation of its safety (steel is used in the automotive industry, steel for engineering, of non-ferrous alloys in the aerospace industry), or high strength and hardness in combination with biocompatibility ensures greater life of the products (titanium implants, etc.). Some ultra-fine-grained steels are already introduced in mass production, while the expected properties are achieved by methods of plastic deformation. These materials include, for example, DC01 and DC03, which will be analyzed in the following article after several passes through the DRECE method. The DRECE forming process is based on extrusion technology with zero change in cross-section dimensions with the ultimate goal of achieving a high degree of deformation in the formed material. With the help of severe plastic deformation of the material, a substantial refinement of the structure of the material is achieved. The following article will deal mainly with the influence of the DRECE forming speed on the hardness and microstructure of the material of the sheet metal blank for DC01 and DC03 steel.

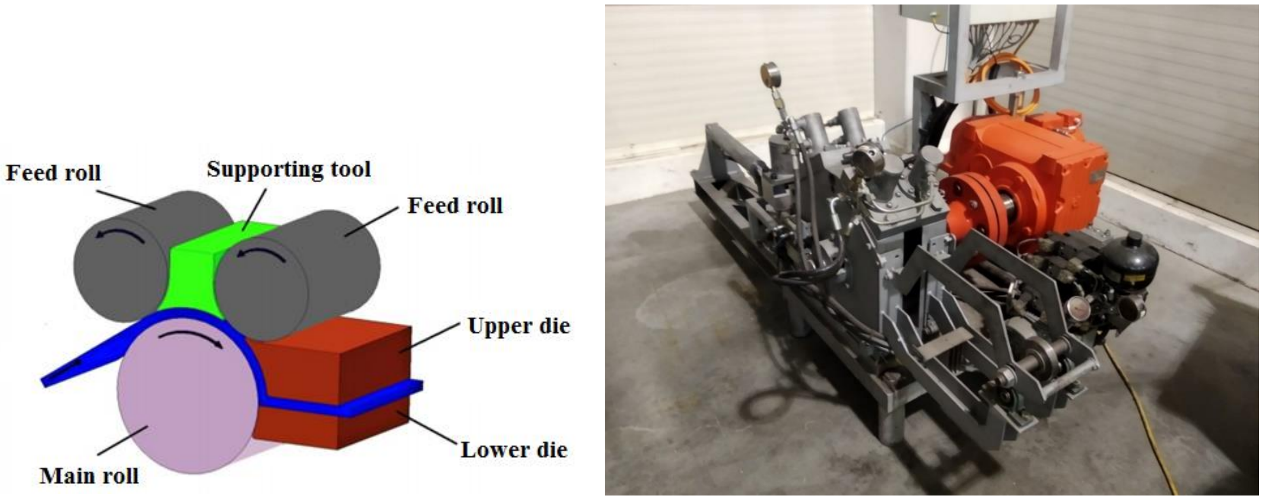
Keywords: DRECE Method, Severe Plastic Deformation, Ultra-Grain Structure, Effective Plastic Strain, Effective Stress, DC01 steel, DC03 steel

1. INTRODUCTION

The grain size of polycrystalline materials plays a major role in dictating many critical properties including the strength and flow stress [5,6,8,11]. In general, materials with small grain sizes have several advantages over their coarse-grained counterparts because they have higher strength and other favorable properties including a potential for use in superplastic forming operations at elevated temperatures. This significance was recognized several years ago and led to the concept of nanocrystalline materials which were discussed in detail in an early review [1,12,14]. A possible way for microstructure refinement of metals is the use of SPD - principle on the base of thermomechanical processing [2,3,4,7,13,15]. It is important to note that the shape of the sample is retained in SPD processing by the use of special tool geometries which effectively prevent free flow of the material and thereby produce a significant hydrostatic pressure which leads to a high density of dislocations and consequent grain refinement [9,10].

1.1. Principle of DRECE method

The DRECE method (Dual Rolls Equal Channel Extrusion) [2,3,4,7,13,15] is based on the principle of angular extrusion through an equilateral channel using contact friction between the extruded blank, in the form of a metal strip, and feed rollers. Based on the generated friction force, the strip is continuously extruded into a special forming tool, where is intensively deformed by shear strain as passes through the deformation zone. As a result of the accumulation of strain, microstructural changes occur, which lead to an increase in the strength characteristics of the extruded strip [15]. A schematic representation of the SPD method of DRECE is shown in **Figure 1**.



a) b)

Figure 1 Schematic illustration of DRECE device a) [15] - and real device b)

2. INVESTIGATION PROCEDURES

The work is focused on analyzing the influence of the speed 20, 40, 60, 80 and 100 mm/s when pushing a metal strip made of commercially produced DC01 and DC03 steels with dimensions of 2 x 58 x 2000 mm.

Table 1 Chemical composition - steel DC01 and DC03

	C (wt%)	Mn (wt%)	Si (wt%)	P (wt%)	S (wt%)	Cr (wt%)	Ni (wt%)	Mo (wt%)	Cu (wt%)
DC01	0.10	0.45	0.03	0.03	0.03	0.06	0.06	0.01	0.08
DC03	0.05	0.20	0.02	0.01	0.01	0.05	0.06	0.01	0.08

Before extrusion using the DRECE method, lubricant (based on MoS_2) was applied to the strips to minimize friction in the deformation zone of forming tools. Experimental extrusion was carried out at room temperature and different forming speed.

The analysis of the effect of the applied deformation speed in DRECE forming on the change of microstructure was performed on the NEOPHOT 21 optical microscope with OLYMPUS GX51.

3. INVESTIGATION RESULTS

3.1. Microstructural characterization

The microstructure of the supplied samples was checked on their transverse cuts. Due to the insignificant changes in the microstructure, areas were selected for documentation in approximately one third of the width of the sheet (these are the areas where the microhardness of HV0.1 was subsequently determined), in the subsurface areas themselves, as well as in the middle of the thickness - see **Figure 2.**

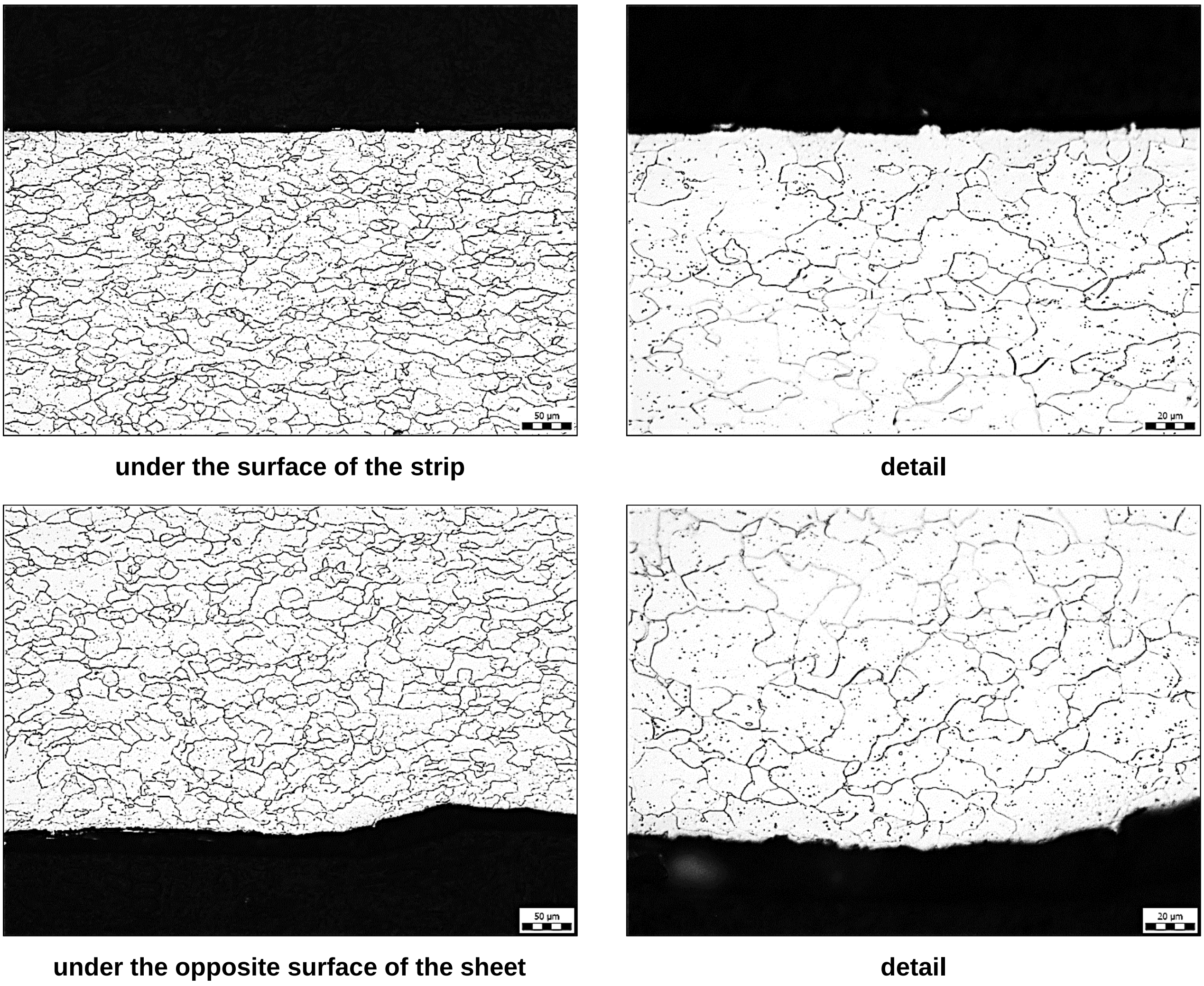


Figure 2 example for steel DC01 after DRECE speed 6 m.s.$^{-1}$

The microstructure of all samples was identical, fairly uniform, consisting of polyhedrical grains of ferrite and cementite precipitated along the boundaries and inside the grains. No significant signs of grain deformation were observed in the sample areas of interest.

3.2. Microhardness evolution

The way to monitor the effect of DRECE forming on the uniformity of the distribution of mechanical properties is to measure microhardness through the thickness of the extruded strip. For the analysis, an inductor was used to measure HV with a load of 0.1 kg for 15 seconds.

Figures 3 a 4 graphically shows the course of microhardness HV0.1 depending on the distance from the top surface of the sheet metal, extruded by the DRECE method. Based on the presented process, it can be stated that thanks to increasing DRECE forming speed, higher hardness values were achieved, especially in the surface parts of the analyzed sheet metal samples. With increasing speed, the average microhardness increased from 155 HV0.1 to 169 HV0.1 for DC 01 steel, and from 154 to 178 for DC03 steel in the area below the surface.

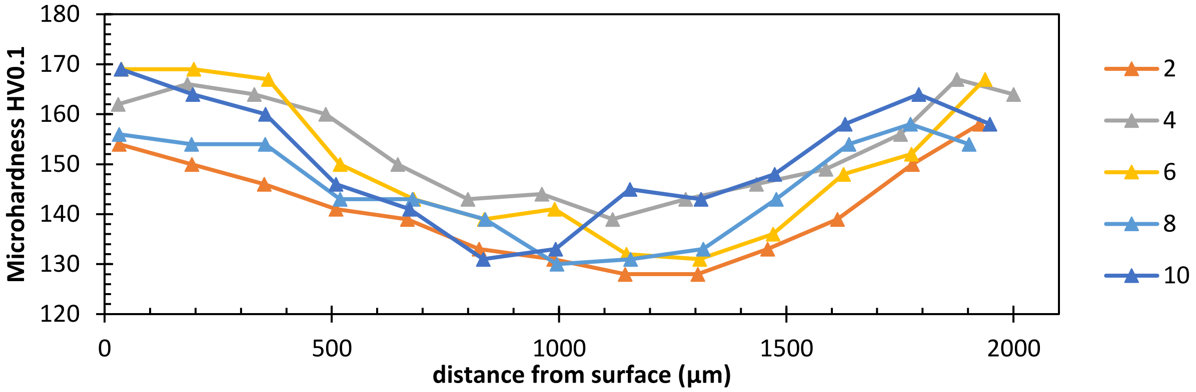


Figure 3 Microhardness distribution through thickness in DC01 sheets processed by DRECE method, where 2, 4, 6, 8, 10 are the feed rates of the sheet in cm.s.$^{-1}$

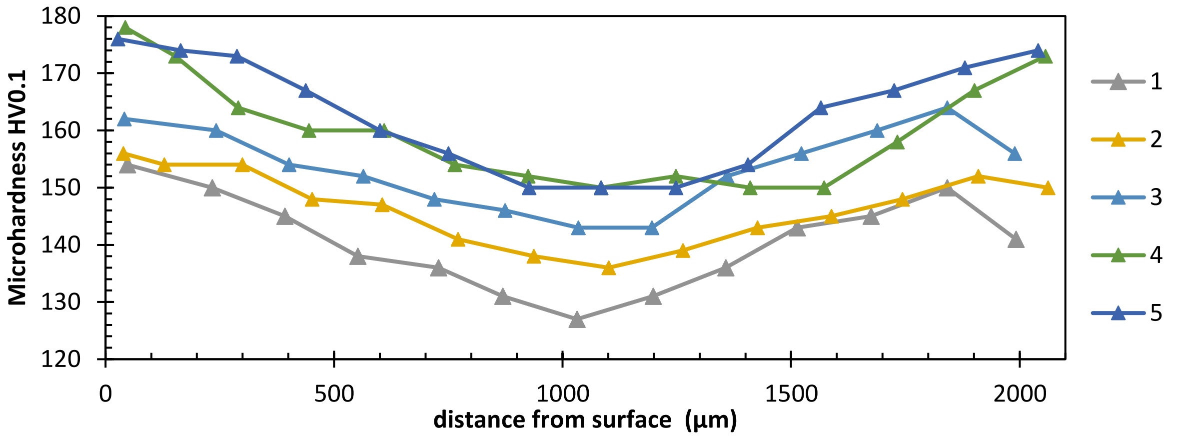


Figure 4 Microhardness distribution through thickness in DC03 sheets processed by DRECE method, where the numbers 1, 2, 3, 4, 5 are the feed rates of the sheet metal in cm.s.$^{-1}$

4. CONCLUSION

According to the results obtained, it was observed that the microstructure of all samples was identical (example **Figure 2**), fairly uniform, consisting of polyhedral grains of ferrite and cementite excreted along the borders and inside the grains. No significant signs of grain deformation were observed in the sample areas of interest. By increasing speed during DRECE method, higher hardness values were achieved, especially in the surface parts of the analyzed sheet metal samples. With increasing speed, the average microhardness increased from 155 HV0.1 to 169 HV01 for DC01, and for DC03 steel from 154 to 178 in the area below the surface.

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