INCREASING THE QUALITY OF DC01 STEEL BY DRECE METHOD

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Abstract

Development of production technology of very fine-grained material is currently very intensively accelerated. Even in scientific research, it is recognized that precisely controlled forming processes, including special processes, enabling control of technological parameters with regard to the structure and its further refinement, currently has the highest gradient utilization efficiency of scientific research findings into practice. Besides the methods C2S2 and ARB for sheet metal forming, in terms of industrial practice intensively develop new technologies, to which also belongs Dual Rolling Equal Channel Extrusion (DRECE) method. Forming device that uses the method in question is currently being installed at the workplace in Centre of Advanced Innovation Technologies, VSB Technical university of Ostrava. Experimentally were verified steel DC 01- strip sheet with dimensions 58 (width) x 2 (thickness) x 2 000 (length) mm. The paper evaluated the influence of severe plastic deformation (SPD) on the quality this steel at sizes angle forming tool 108°. In the present work are solved structural characteristics of carbon steel DC01 after application DRECE method, including an assessment of basic mechanical properties, that are important for application scientific research findings into practice.

Keywords: Severe plastic deformation, DRECE method, forming tool, steel DC01, structure and mechanical properties

1. INTRODUCTION

New technologies, which use high deformation for obtaining the fine-grained structure, are described namely by the following authors [1 - 4]. This research concerned the whole production of ultrafine-grained (UFG) materials, using Severe Plastic Deformation (SPD). Several types of SPD technologies serving for production of UFG metals were developed already at the beginning of the nineties. One of them is new type of methods called DRECE, designated for obtaining UFG structure in a strip of sheets and rods. Research areas of SPD processes as ECAP and DRECE technology at the Department of mechanical technology VSB - Technical University of Ostrava are intensively developed. Effectiveness of this method is evaluated by using simulations. According to the results, appropriate adjustments by the forming tool have been designed to achieve a higher intensity of deformation to obtain the UFG structure. With use of the simulation process SPD is seen to increase the intensity of deformation after each pass to a value of 3.5 which is a region of small and medium deformations. The functionality of the forming device that uses a new forming method DRECE has been verified by experimental activities, namely on non-ferrous metals [5 - 6].

For ensuring the general implementation of the UFG materials into industrial practice this direction of development is not only logical, but also highly desirable. Experiments are now carried out on different types of steels.

The DRECE method is similar to the DCAP (C2S2) process. Scheme of DRECE method is shown in **Figure 1** and forming device for extrusion of strip sheets is shown in **Figure 2**. Equipment consists of the following main parts: gear of the type Nord with electric drive, disc clutch, feed roller and pressure rollers with the regulation of thrust, forming tool made of the steel grade Dievar. A strip of the sheet with dimensions 58 x 2 x (1000 -

2000) mm is fed into the working space and it is pushed by the feed roller with help of pressure rollers through the forming tool without change of its cross section [6 - 9].

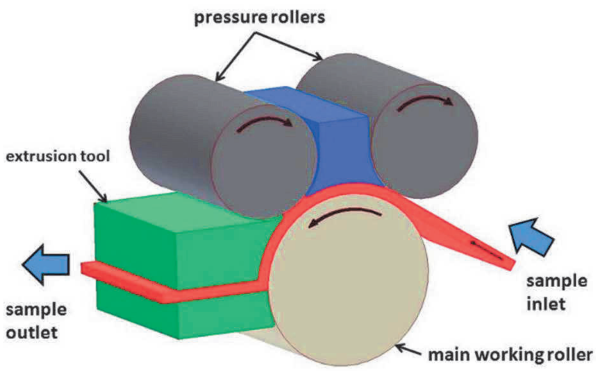


Figure 1 Scheme of DRECE method

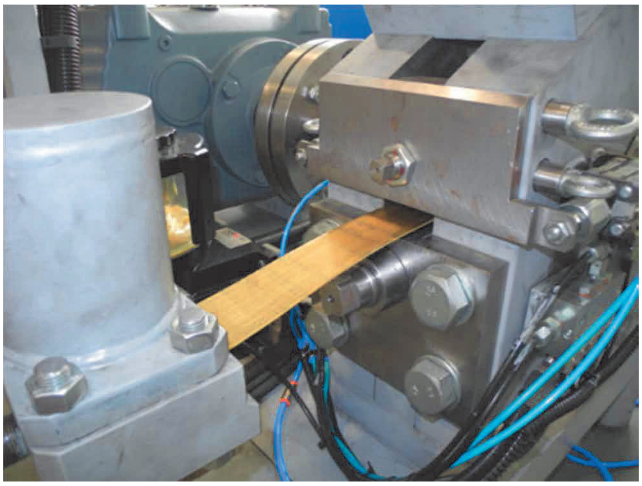


Figure 2 Forming device for extrusion of strip sheets

2. EXPERIMENTAL MATERIAL, PROCEDURES AND RESULTS

The strip sheet of steel DC01 with dimensions 58 x 2 x 1000 mm and 2000 mm length was used for investigation. The chemical composition of DC01 steel is given in **Table 1**. Used sheets were extruded through the DRECE equipment. Mechanical properties (yield strength $R_{p0.2}$, ultimate tensile strength R_m, ductility A_{80}, A_{50} and hardness HV_{10} were evaluated in initial state and after forming process [7]. All the tensile tests were performed according to the ISO 6892-1 with using standardized test-pieces according to Annex D. Investigation was completed by metallographic evaluation of microstructure of selected samples.

Table 1 Chemical composition of DC 01 steel in weight %

Element	C	Mn	P	S
wt. %	0.10	0.45	0.03	0.03

2.1. Evaluation of mechanical properties

Evaluation of mechanical properties by tensile test and HV10 hardness test shows **Table 2** and **Figure 3** for DC 01 steel.

Table 2 Results of tensile test - DC 01 steel

No. of passes	$R_{p0,2}$ (MPa)	R_m (MPa)	A_{80} (%)	HV_{10} (-)
Initial state	173	311	50.3	93
2	370	391	22.6	122
4	382	411	15.8	135
6	390	415	14.8	133
8	415	419	6.0	149

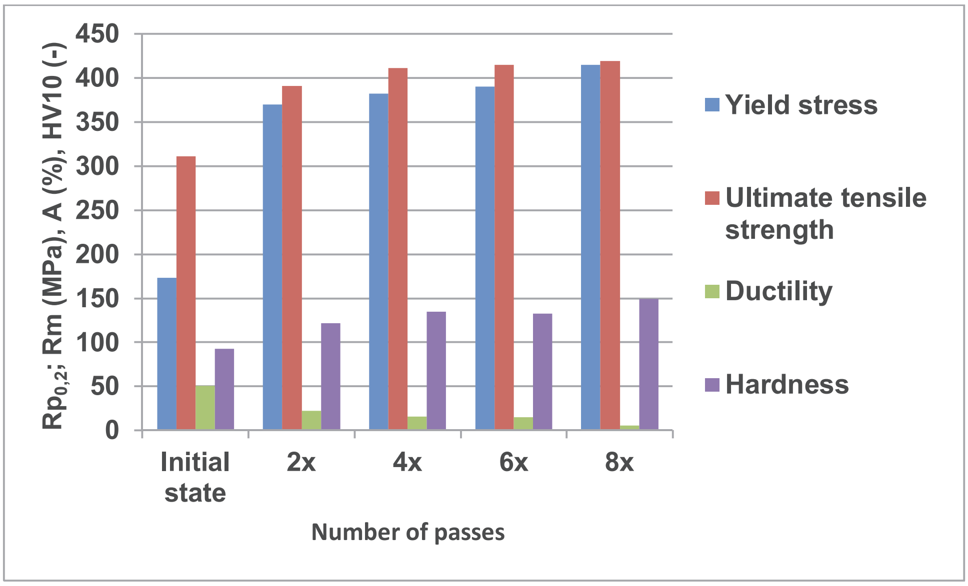
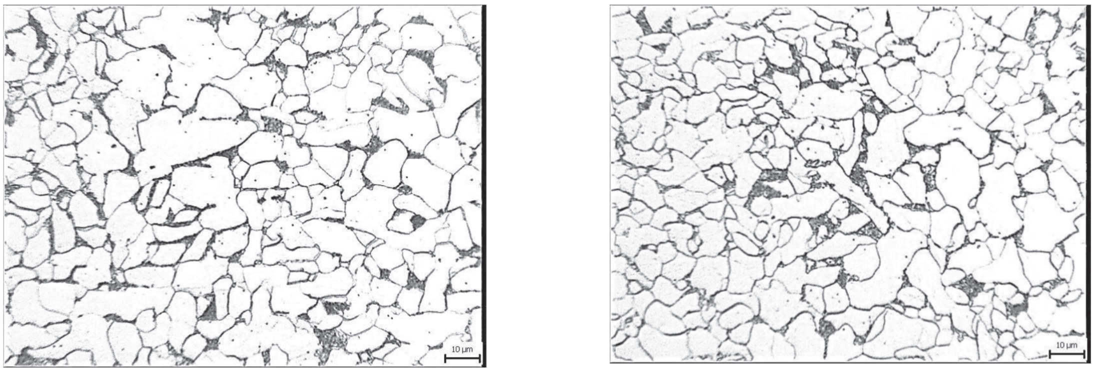


Figure 3 Mechanical properties of DC01 steel after extrusion process

On the basis of the results obtained from the tensile tests, it can be stated with respect to the initial state, that after the 2nd passes the yield strength $R_{p0,2}$ is increased by 31.5 % and the ultimate tensile strength R_m by 8 %. At the same time, there will be a slight decrease in the ductility by 8 %. After the 4th - 8th passes through the forming tool, the yield strength increased by 48 % $R_{p0,2}$ and the ultimate tensile strength R_m by 8 % relative to the initial state. As it is seen from these tables the yield strength and ultimate tensile strength after DRECE processing are increased while the elongation is decreased.

2.2. Metallographic analysis

Metallographic analysis was made on optical microscope NEOPHOT 2 for obtaining orientation information, as to whether grains were refined. Structure was analysed on the cross section of the sheet. Microstructures of DC01 steel is shown in **Figure 4**.



a) initial state (500×) **b) after 6 passes (500×)**

Figure 4 Microstructure of DC 01 steel

Comparison was made of the initial state and of the states to the 6th pass. The structure of the steel used is ferrite-perlite with low perlite content. It was observed that refining of grains after each pass was only small [7]. From the reason deformation of material we can presume creation of sub-grains which will be studied with application TEM (SAED) method.

The metallographic analyze was occurred no significant refinement in the structure during the SPD process. The average grain size was determined in accordance with EN ISO 643 as standards G 8-9. The grain structure was most significantly influenced after the 2nd pass through the forming tool, where the average size in the initial state, reached the value d_{AV} = 60 μm and after the 2nd pass approximately d_{AV} = 15 μm. After the 6th pass, the grain size was occurred 10 μm.

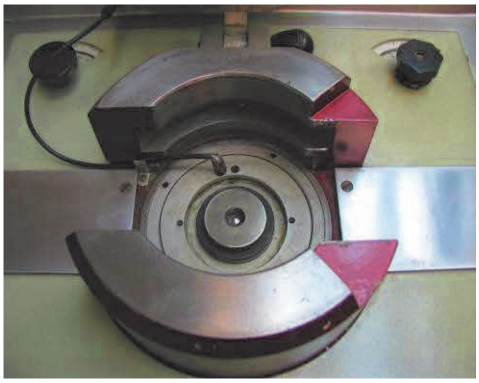
2.3. Erichsen and Fukui technology test

Technological tests of the material have been proposed to verify formability of steel DC01. Erichsen deep-drawing test and Fukui cone drawing were carried out at the Center of the Plastometric Technology at the University of Žilina. Universal device BPM-TESA-Schweiz is shown in **Figure 5**.

Samples of the initial state of forming steel and samples after the 1st to the 6th passes by the forming tool were prepared. The samples to the Erichsen test were prepared with dimensions 58 mm × 58 mm × 2 mm. At the same time the series of samples for the Fukui test were prepared with dimensions ∅ 50 mm × 2 mm.

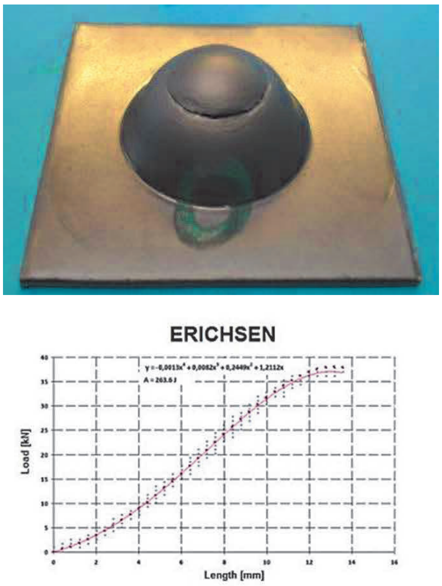
The test results, including crack occurrence on selected samples are shown in **Figure 6** (Erichsen) and **Figure 7** (Fukui).

a)

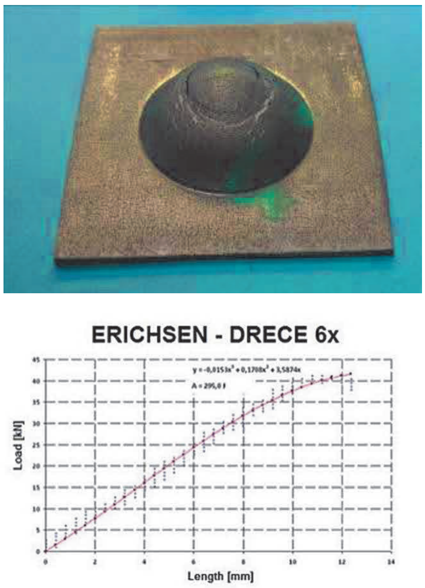


b)

Figure 5 Device BPM-TESA-Schweiz a) Overall view, b) Detail of the mandrel

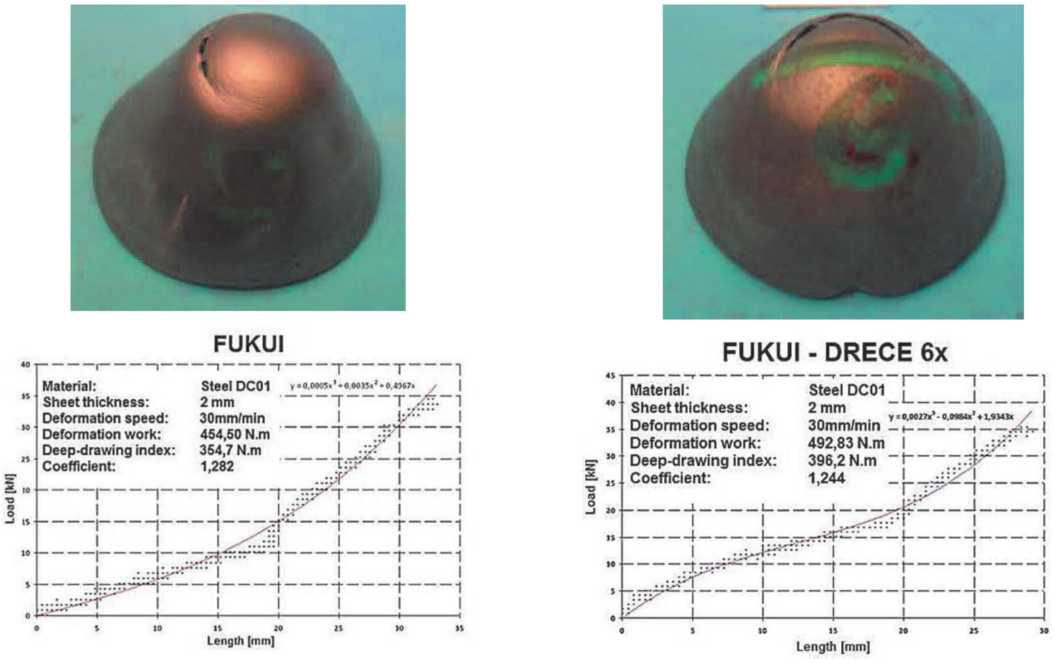


a) initial state



b) after the 6th pass

Figure 6 Results of Erichsen technology test



a) initial state **b) after the 6th pass**

Figure 7 Results of Fukui technology test

As it is seen from this pictures for all tested samples, a so-called concentrated crack was created - i.e. material is suitable for deep drawing process. A detailed description of the experimental results is shown in the paper [8].

2.4. Industrial using

Through the tests use properties in industrial practice will tested conducted door lock made by companies HOBES, Ltd. (see **Figure 8**).

By using this technology, manufacturers can achieve significant economic effect by replacing the currently used expensive materials and therefore will create a more favorable price relation in the production of finished parts.

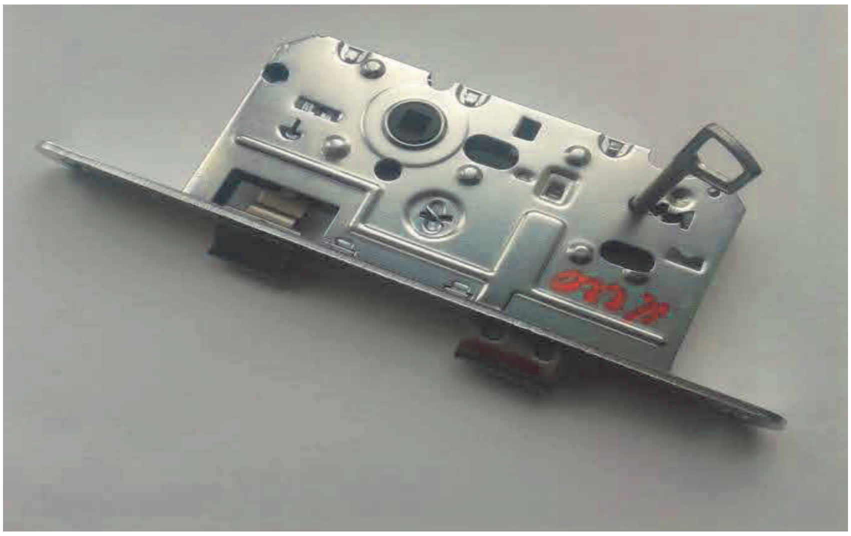


Figure 8 Door lock

3. CONCLUSION

Equipment DRECE mentioned above is suitable for substantial enhancement of mechanical properties of metallic materials. From the viewpoint of forming parameters higher number of passes will bring considerable strengthening of the formed material.

As it is seen from the results of tensile test the yield strength and ultimate tensile strength after DRECE processing are increased while the elongation is decreased. It may be assumed from dependence mechanical properties on number of passes the optimal ratio yield stress and ultimate tensile stress due to the achievement of the ductility value is after the 2nd or the 4th pass.
The experimental verification of the structure refinement by light microscopy was not occurred. From the reason deformation of materials we can presume creation of sub-grains which will be studied with application TEM and SAED methods.

Results of Erichsen and Fukui technology tests show that for all tested samples, a so-called concentrated crack was created - i.e. the material is suitable for deep drawing process

The results of this work should contribute to the development of new forming method DRECE for needs of industrial practice.

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