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Evaluation of the deep-drawing steel sheets processed by DRECE device

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ABSTRACT

Purpose: The article describes a new developed method for producing fine-grained materials, such as DRECE (DRECE, Dual Rolling Equal Channel Extrusion).

Design/methodology/approach: The process of forming ofmaterial using the DRECE technique is based on making use of the material's intensive plastic deformation, i.e. that process is a combination of two known technologies, ECAP and CONFORM.

Findings: The article presents the results of both exams, including photographs of cracks. Mechanical properties of thesteel grade11 321 before and after extrusion by DRECE tool are described as well.

Research limitations/implications: The article describes the process of forming of metal sheets made of steel grade 11 321. It further describes two methods for detection of deep drawing - Erichsen and Fukui.

Originality/value: The article describes the process of forming ofmetal sheets made of steel grade11 321. It further describes two methods for detection of deep drawing - Erichsen and Fukui. These methods were applied to the extruded metal sheet by DRECE tools.

Keywords: DRECE; Erichsen method; Fukui method; Steel 11 321; SPD

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MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

In recent years we witnessed a gradual introduction of fine-grained materials produced by one of the techniques belonging to the SPD (Severe Plastic Deformation) technologies, even in the area of two-dimensional forming. Characteristics of the development of high-strength steels consists in increasing their strength by means of strengthening processes, with the aim to avoid reducing the material's formability and weld ability.

2. The DRECE process

The process of forming of material using the DRECE technique is based on making use of the material's intensive plastic deformation, i.e. that this process is a combination of two known technologies, ECAP and CONFORM. As it has already been mentioned earlier, the equipment is a prototype possessed by the Faculty of Mechanical Engineering of the VŠB – Technical University Ostrava. The equipment consists of a NORD gearbox and an electromotor with speed frequency converter, which gives us the option to change the deformation rate even during the process, and thus allows us to flexibly react to the process progress. Other components include a plate clutch, a drive roller, two pressure rollers and a bottom and top forming tool. The pressure applied onto the front pressure roller is controlled by a pair of hydraulic cylinders; the pressure applied onto the rear pressure roller is controlled mechanically. This combination has so far proven itself when controlling the pressure in both non-ferrous alloys (on Al, Cu basis), as well as in sheet steel (11 321, 12 060). The machine's design of course allows application ofhydraulic control also to the rear pressure roller. The entire DRECE equipment is shown in Fig. 1.

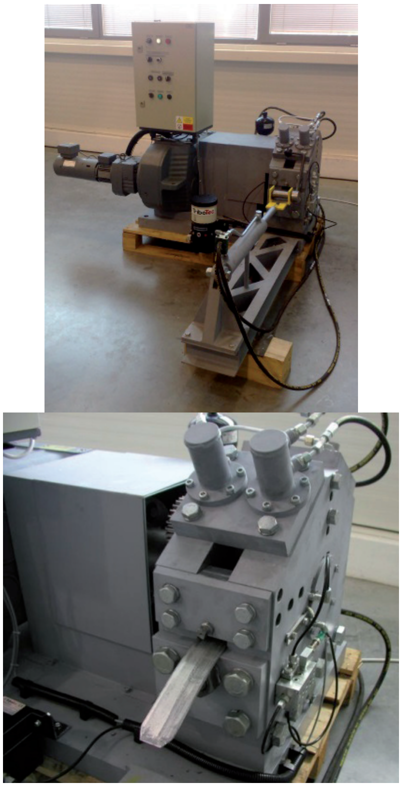

Fig. 1. The DRECE equipment

In our experiments, we use samples with dimensions 58 mm × 2 mm – 1000 mm. It is also possible to use a smaller thickness of sheets, by adapting the pitch deformation zone using distance washer placed under the pressure rollers. We further studied the effect of the passes by DRECE tool on the final microstructure and mechanical properties of these materials.

We monitored primarily the impact of the initial structure, thermal treatment, the number of passes, and now also the impact of the orientation of the sample being turned around between passes, on the resultant mechanical properties, such as hardness, strength, yield point, ductility, but also on the material's structure and the size of the resultant grain. Evaluation of these properties was performed on standard test machines according to relevant standards.

3. Actual process of forcing sheet metal through drece tool

3.1. Material

Thin sheet metal made from non-alloyed steel of enhanced quality and cold-rolled according to ČSN EN 10131. The sheet metal is suitable for medium drawing, cold-forming, varnishing, deep-drawing and metal-plating in molten state on rimmed steel for enamelling. Rimmed steel has a tendency to age after cold-rolling. Chemical composition and mechanical properties of the steel 11 321 are presented in Tables 1 and 2 below.

Table. 1.
Chemical composition of the steel 11 321

Element	C	Mn	P	S
% by mass	0.10	0.45	0.03	0.03

Table 2.
Mechanical properties of the steel 11 321 (initial state)

Mechanical properties	Unit	Value
Ultimate strength R_m	MPa	280-380
Yield stress R_e	MPa	235
Ductility A_{80min}	%	29
Hardness HV	-	179

3.2. DRECE tool drawing process

Strips of made of 11 321 sheet steel were gradually forced through the DRECE tool. Between individual passes the sheet metal was always turned by 180°. This allowed creation of an even material structure. The process took place at ambient temperature, i.e. 21°C. The strips of sheet metal had not been thermally treated prior to or during the drawing process. The sheet metal's deep-drawing properties were determined after 2, 4 and 6 passes. During the

DRECE process the deformation zone was lubricated with the GLEIT – µ® HP 515 lubricant. The sheet metal strip prior to and after the DRECE process, is illustrated in Figs. 2 and 3.

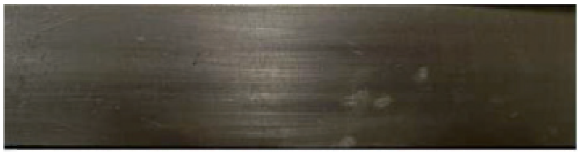

Fig. 2. Sheet steel 11 321 prior to the DRECE process

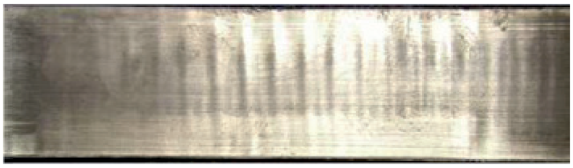

Fig. 3. Sheet steel 11 321 after the DRECE process (rotation 6×180°)

4. Deep-drawing property tests

Deep-drawing property tests belong to the category of technological tests. When assessing material by mechanical tests, such as tensile strength, hardness and notch toughness tests, or for example by metallography, we do not obtain a complete picture of the material's suitability for its processing by forming. In our research programme we newly added the Erichsen and Fukui technological tests for assessing the material's suitability after the DRECE process [1,2].

4.1. Cupping test (Erichsen)

An indicator for assessment, whether the sheet metal is suitable for forming, is the size of the cup h; according to the ČSN ISO 20482 standard, the parameter defining the depth of the cup in the sheet metal is designated as IE [mm]. In this test the parameter IE is not the only criterion for assessing the sheet metal's quality. The crack's propagation and shape is also assessed[2].

4.2. Conical cup drawing test (Fukui)

The criterion of the deep-drawing ability according to the Fukui test is the coefficient:

$$\eta_f = \frac{D_0}{D_2}, \qquad (1)$$

where:
D_0 – is diameter of the cut-outs of semi-finished product,
D_2 – is the largest diameter of the pressing at the moment of development o fa crack.

Deep-drawing ability indicator *MF*:

$$MF = \frac{A_{def.}}{\eta_f}, \qquad (2)$$

where:
$A_{def.}$ – is the integral deformation work at the moment of the sample's failure,
η_f – is a geometric criterion of deep-drawing ability according to Fukui.

The results of the conical cup drawing tests indicate that the lower is the *MF* value, the more suitable is the tested sheet metal is for deep drawing[3].

5. Test evaluation

Two series of samples were made for the test evaluation. The first series was made for the Erichsen test. These samples had dimensions 58 mm × 58 mm × 2 mm. Two pairs of identical samples were made for the initial state and then pairs after 2, 4 and 6 passes through the DRECE tool. The holding force in this test was constant – 10 kN. And identical series of samples were made also for the Fukui test. However, these samples had dimensions ϕ50 mm × 2 mm.

5.1. Erichsen – evaluation of test readings

The Erichsen test measurement readings were recorded by a Tektronix TDS 2022B oscilloscope, which was attached to the BPM-TESA-Schweiz testing machine. The oscilloscope recorded the time and the stressing until the sample failed. By adjustment we transformed these data to a force – trajectory diagram. From these diagrams it is possible to read for each measurement the value of *IE* and, by means of integration, to determine the required work.

Table 3 lists for illustration the values of *IE* and *A*. It is apparent that after the second pass through the DRECE tool, the index *IE*, as well as work *A*, decreased compared to the previous state. The value of the index *IE* grew therefore with the growing number of passes.

Figures 4 to 7 are photographs of the samples after completion of the Erichsen test. From the developed cracks it is possible to deduce that even after six passes through the DRECE tool, the material remained suitable for deep drawing operations. A concentric crack developed in all the tested samples also developed.

Table 3.
Evaluation of tests by Erichsen (steel 11 321)

Steel 11 321 – Erichsen		
	IE, mm	*Work A*, J
Initial state	13.56	263.6
DRECE 2x180°	11.56	252.4
DRECE 4×180°	11.96	253.9
DRECE 6×180°	12.36	295.0

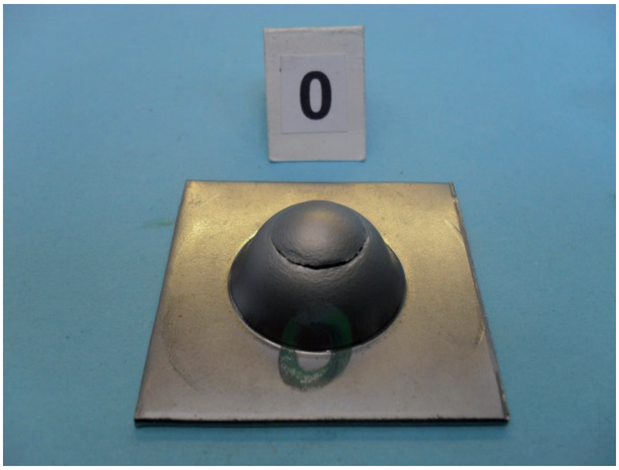

Fig. 4. Crack of steel 11 321, initial state

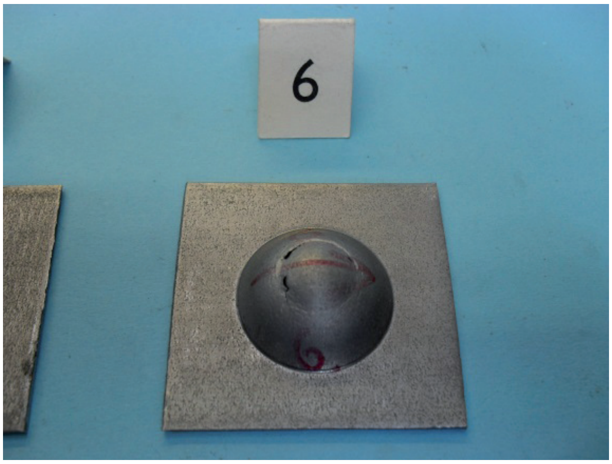

Fig. 5. Crack of steel 11 321, after DRECE 2x180°

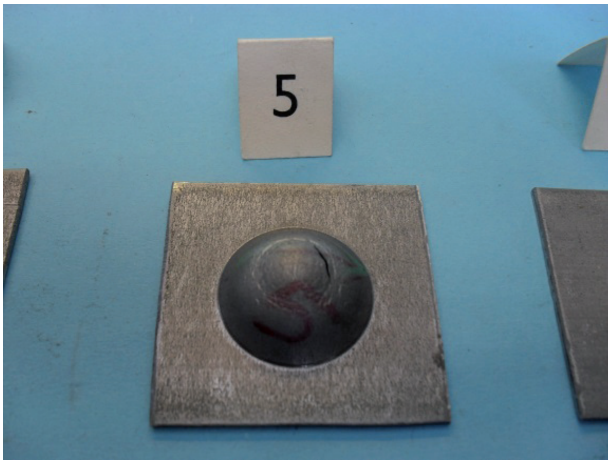

Fig. 6. Crack of steel 11 321, after DRECE 4x180°

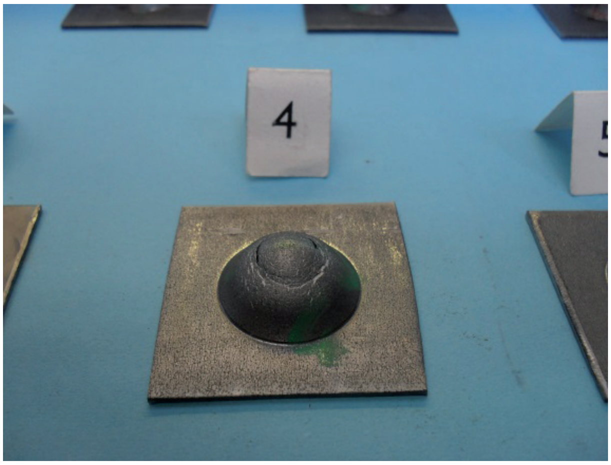

Fig. 7. Crack of steel 11 321,after DRECE 6x180°

5.2. Fukui – evaluation

The Fukui test was also performed on the BPM-TESA-Schweiz machine, with modification only of its internal configuration. The test readings were again recorded by the Tektronix TDS 2022B oscilloscope. The oscilloscope's output was also the recorded time and stressing up to the sample's failure. By adjustment, we transformed these data to a force – trajectory diagram. In addition, the coefficient η_f and indicator *MF* were determined.

In Table 4 the values of η_f, *A* and *MF* are presented for illustration. After the second pass through the DRECE tool, all three values decreased. The decreased value of *MF* indicates that the sheet metal shows better deep-drawing ability than the steel 11 321 in the initial state. However, after the fourth and sixth pass the value of *MF* increased. For better understanding of this phenomenon it is necessary to compare this parameter with the results of mechanical properties. These show that after the fourth and sixth pass the values of $Rp_{0.2}$, R_m and *HV10* continued to grow, but at the same time ductility, A_{80}, decreased significantly. This parameter has a significant effect on formability.

Table 4.
Evaluation of tests by Fukui (steel 11 321)

Steel 11 321 – Fukui			
	η_f, -	*A*, N.m	*MF*, N.m
Initial state	1.282	454.50	354.7
DRECE	1.274	433.08	340.0
DRECE	1.252	474.59	378.9
DRECE	1.244	492.83	396.2

5.3. Mechanical properties of the steel 11 321

Mechanical properties were obtained in cooperation with the VÚHŽ Dobrá a.s. research institute. These are presented mainly for better evaluation of the actual technological tests. Results of the mechanical property test are presented in Table 5.

Table 5.
Mechanical properties of the steel 11 321

Mechanical properties of the steel 11 321				
	$Rp_{0.2}$, MPa	R_m, MPa	A_{80}, %	*HV10*, -
Initial state	173	311	50.3	93
DRECE 2×180°	370	391	22.6	122
DRECE 4×180°	382	411	15.8	135
DRECE 6×180°	390	415	14.8	133

6. Conclusions

It is apparent that a contradiction exists between the two technological tests. In the Erichsen test, the deep-drawing ability indicator first dropped and then with the increasing number of passes this indicator started to grow. In the Fukui test, it was the other way round. After the second pass the deep-drawing ability indicator improved and with the increasing number of passes it started to deteriorate.

In order to establish, which of the two methods is more suitable, it will be necessary to repeat both tests on a greater number of samples, from which a standard deviation of the measurement readings will be calculated. Nevertheless, the hitherto performed tests indicate that the more suitable test for determining the deep-drawing ability of sheet metal processed by the DRECE technique is the Erichsen test.

Acknowledgements

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References

[1] G. Oehler, Sheets and their testing, SNTL Praha, 1958, 139-143.
[2] J. Petruželka, Formability and unconventional forming methods, 1st Edition, VŠB – Technical University of Ostrava, Ostrava, 2000, 148.
[3] M. Dvořák, F. Gajdoš, K. Novotný, Forming technology: Sheet metal and bulk forming, PC-DIR Real (1999) 169.