INFLUENCE OF SHEET METAL FEED SPEED ON INCREASING THE EFFICIENCY OF THE FORMING PROCESS BY THE DRECE METHOD IN INNOVATION FORMING EQUIPMENT

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Abstract

The DRECE method is a very promising method for forming sheet metal sheet using the severe plastic deformations (SPD) principle. The DRECE method is characterized by the continuous extrusion of the sheet metal strip by the forming die, which creates a forming angle of 108 ° in the deformation zone. In the case of materials formed by a given method, there is a substantial increase in the mechanical properties, in particular the yield strength, already after the first pass through the forming device, while maintaining sufficient ductility of the materials. This fact is very important for the subsequent use of the method in industrial practice. In order to study the possibility of applying the DRECE method in industrial practice, this work presents proposals for design solutions for industrial use. The proposed design solution is also supplemented by mathematical simulations of the forming process.

Keywords: Severe plastic deformation process, DRECE method, mechanical properties

1. INTRODUCTION

Severe plastic deformation (SPD) is defined as the forming process, in which an extremely large deformation stress is applied to the formed material by means of various forming methods, in order to achieve an ultra-fine-grained to nano structure (UFG and nano structure). SPD methods require significant investment in forming tools. Tools used in SPD forming must be very durable to withstand repeated extreme loads. Forming tools are constructed with a special geometry, which prevents the free flow of material, thus exerting hydrostatic pressure on the formed material. Hydrostatic pressure is necessary to achieve high stress and derive a high density of grid defects in the material which causes refinement of the microstructure [1]. Ultra fine-grained materials are defined as polycrystalline materials with very small grains. The grain size of UFG materials is less than 10 µm. In practice, the structure of UFG materials is often refined, when a grain size of less than 100 nm is achieved, due to the occurrence of precipitates at grain boundaries as well as increasing the dislocation density. Very important factors are the temperature of the forming process and speed of deformation [2].

The aim of the presented work was to monitor the influence of the number of passes of DC01 steel by forming equipment using DRECE methods at a constant extrusion speed 100 $mm \cdot s^{-1}$.

2. DRECE METHOD

The DRECE method is a promising forming technology using severe plastic deformation. The DRECE method is characterized by a combination of two SPD methods, the DCAP method and the ECAP - Conform method. During DRECE forming, the sheet metal strip is pushed into the working space and is extruded by the frictional force generated by the friction between the feed roller and the two pressure rollers over the forming tool. And it does not happen to change the cross-section or length of the sheet metal strip. In the deformation zone, the material is extruded at a suitable angle of connection of the forming tools. Correct choice of deformation angle (108° or 113°), the magnitude of which was determined by mathematical simulation, is a critical parameter influencing the resulting mechanical properties and microstructure of the formed material. The given method enables the forming of sheets with a length of 1000 to 2000 mm, a width of 58 mm and a thickness of 2 mm [3-10]. The principle of the DRECE method is shown in **Figure 1**.

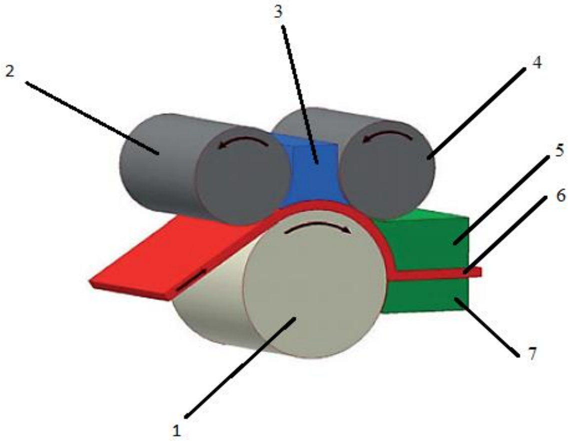


Figure 1 Schema of the DRECE method (1-feed roller, 2-rear pressure roller, 3 guide intermediate member, 4-front pressure roller, 5-upper tool holder, 6-formed material, 7-lower tool holder) [4]

Figure 2 shows a forming apparatus using the DRECE multiple plastic deformation method. The forming equipment underwent modernization, when the drive and gearbox of the forming equipment were replaced, thus increasing the extrusion speed up to v = 100 mm·s^{-1}.

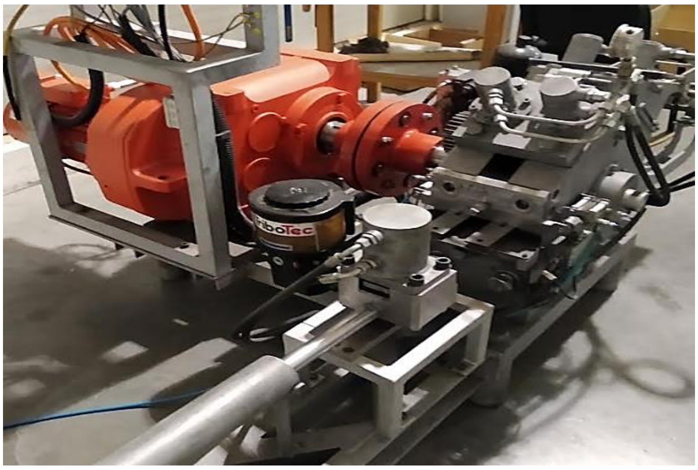


Figure 2 Forming equipment for DRECE method

3. ANALYSIS OF SPD PROCESS INFLUENCE ON MECHANICAL PROPERTIES

The aim of the work was to monitor the influence of the number of passes (1 to 3 passes) of DC01 steel by forming equipment using DRECE methods at a constant extrusion speed v = 100 mm·s^{-1}. The chemical composition of DC01 steel is given in the **Table 1**. The **Figure 3** shows the scheme of sampling samples for the tensile test. In the **Table 2** the average values of the mechanical properties of DC01 steel sheets are given.

Table 1 Chemical composition of DC01 steel (in wt. %)

C	Mn	P	S
0.12	0.600	0.045	0.045

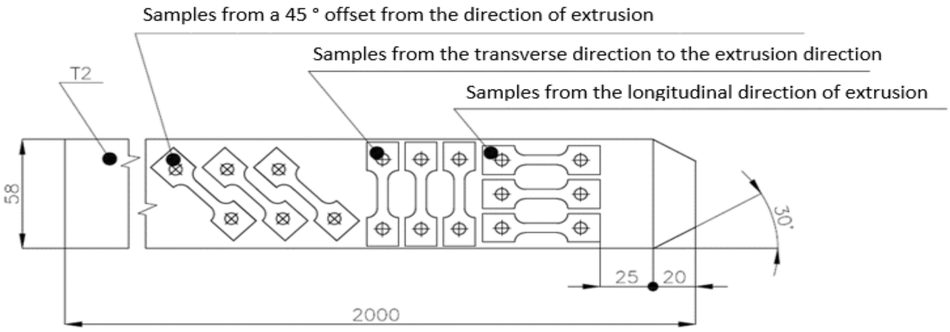
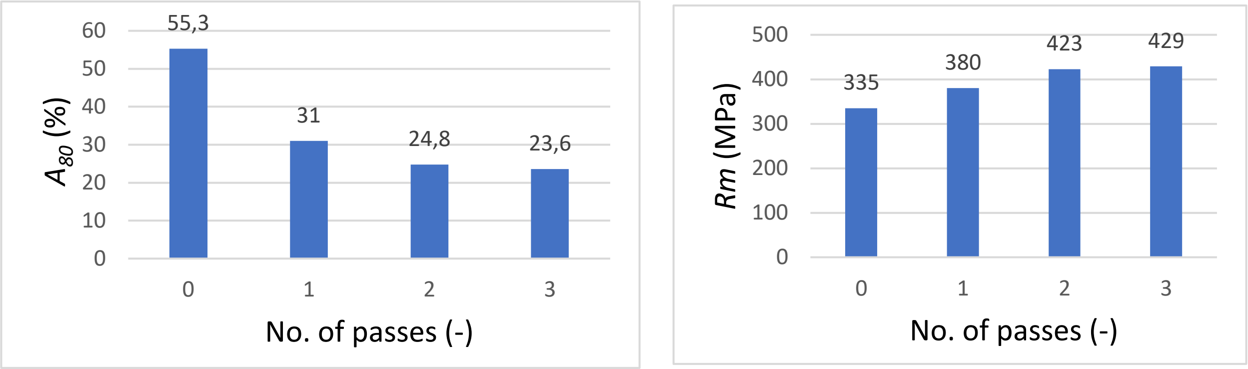


Figure 3 Schematic representation of sampling samples for tensile tests from sheet metal DC01

Table 2 Average values of mechanical properties of DC01 steel sheets

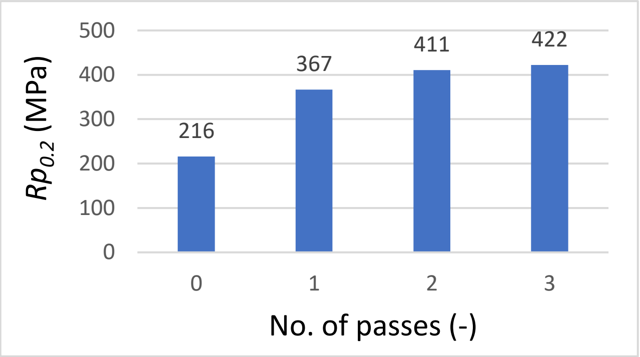
		$Rp_{0.2}$ (MPa)	Rm (MPa)	A_{80} (%)	Z (%)
Default state	**Longitudinal direction**	216	335	55.3	70
	Transverse direction	203	338	51.2	66
	Deviated direction	228	346	49.2	64
1st pass	**Longitudinal direction**	367	380	31.0	55
	Transverse direction	345	367	38.3	52
	Deflected direction	379	389	33.0	49
2nd pass	**Longitudinal direction**	411	423	24.8	54
	Transverse direction	351	382	32.1	59
	Deflected direction	403	418	23.5	50
3rd pass	**Longitudinal direction**	422	429	23.6	51
	Transverse direction	356	392	33.0	51
	Deflected direction	422	437	22.9	47

A graphical representation of the course of basic mechanical properties ($Rp_{0.2}$, Rm, A_{80}) for samples from the longitudinal direction is shown in **Figure 4**. **Figure 4** shows a significant increase in the value of the contractual yield strength $Rp_{0.2}$, which was achieved after the 1st pass, when there was an increase from 216 MPa to 367 MPa, an increase of 70 %. The value of the strength limit Rm increased from the initial value of 335 MPa to 380 MPa after the 1st pass (increase by 13%). Due to the initiation of strain hardening in the extruded sheet, the ductility A_{80} decreased from the initial value of 55.3 % to 31%, after the 1st pass, which is a decrease of 44 %. A graphical representation of the course of basic mechanical properties ($Rp_{0.2}$, Rm, A_{80}) for samples from the transverse direction is shown in **Figure 5**. The nature of the changes in the values of the mechanical properties is the same in the transverse direction as in the case of the results from the longitudinal direction. As the number of passes increases, the values of the contractual yield strength $Rp_{0.2}$ and the strength limit Rm increase and at the same time the ductility A_{80} decreases due to the decrease in the movement of dislocations. Compared to the initial state, the value of the contractual yield strength $Rp_{0.2}$ increased by 70 % and the yield strength Rm by 9 %. The value of ductility of A_{80} decreased after the first pass to 38.3 %, which is a decrease of 25.2 %.



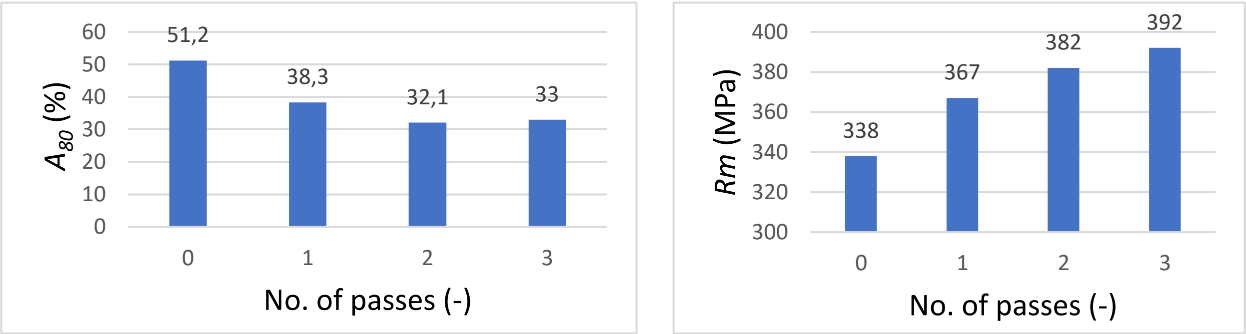
a) Ductility

b) Tensile strength



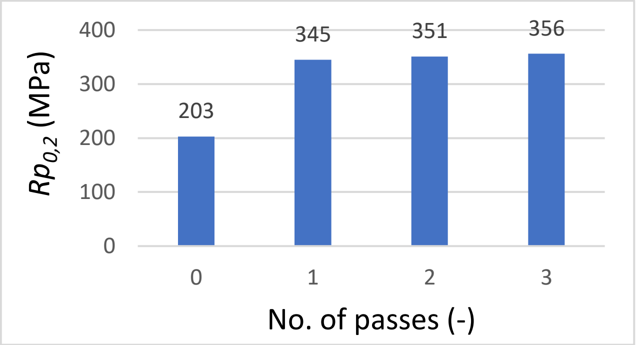
c) Yield strength

Figure 4 The course of mechanical properties of DC01 steel in the longitudinal direction



a) Ductility

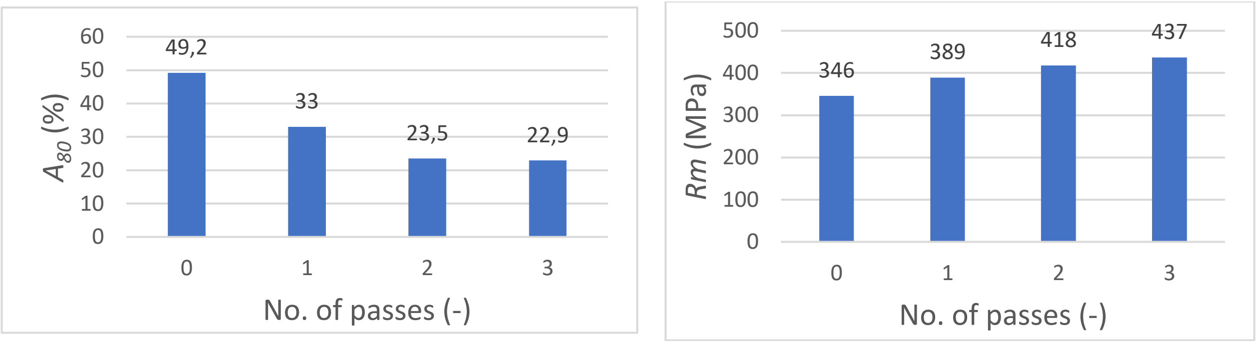
b) Tensile strength



c) Yield strength

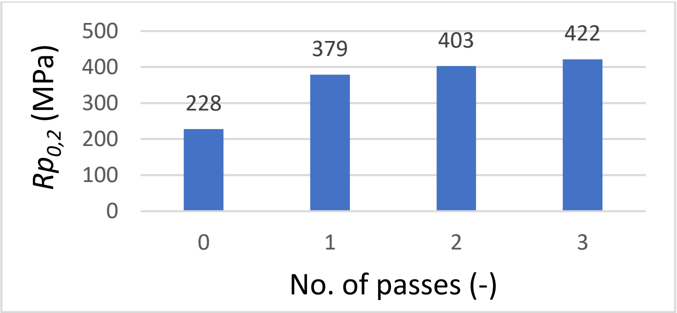
Figure 5 The course of mechanical properties of DC01 steel in the transverse direction

A graphical representation of the course of basic mechanical properties (*Rp*$_{0.2}$, *Rm*, *A*$_{80}$) for samples from the deviated direction is shown in **Figure 6**. A similar nature of changes in the mechanical properties of the DC01 steel sheet depending on the DRECE extrusion at a constant speed of 100 mm·s^{-1}, which was evident in the longitudinal and transverse directions (see **Figure 4** and **Figure 5**), can also be observed on the samples in tilted direction 45 °. Substantial changes in the values of the contractual yield strength *Rp*$_{0.2}$, the tensile strength *Rm*, the ductility *A*$_{80}$ were already achieved on the samples after the 1st pass. The contractual yield strength *Rp*$_{0.2}$ reached the value of 379 MPa, which is an increase of 66 % compared to the initial state. The value of the strength limit *Rm* reached the value of 389 MPa (increase by 12.5 %). Due to strain hardening, the plastic properties decreased. Elongation *A*$_{80}$ decreased from the original value of 49.2 % to 33 %, that is, a decrease of 33 %.



a) Ductility

b) Tensile strength



c) Yield strength

Figure 6 The course of mechanical properties of DC01 steel in the deviated direction

4. CONCLUSION

It can be stated that the extrusion of DC01 low-carbon steel sheet by the DRECE method using the maximum speed has a significant share in increasing the values of strength characteristics while decreasing the plastic properties. The values achieved after the 1st pass appear to be interesting for the subsequent processing, when the values of the contractual yield strength *Rp*$_{0.2}$ and *Rm* increased significantly in all directions with the current low decrease in the ductility values *A*$_{80}$. The achieved values allow the next forming process to be performed.

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REFERENCES

[1] ESTRIN, Y., VINOGRADOV, A. Extreme grain refinement by severe plastic deformation: A wealth of challenging science. *Acta Materialia*. 2013, vol. 61, no. 3, pp. 782-817.

[2] SYLWESTROWICZ, W., HALL, E., O. The Deformation and Ageing of Mild Steel. *Proceedings of the Physical Society. Section B*. 1951, vol. 64, no. 6, pp. 495-502.

[3] RUSZ, S., KŁYSZEWSKI, A., SALAJKA, M., HILSER, O., CIZEK, L., KLOS, M. Possibilities of Application Methods Drece in Forming of Non-Ferrous Metals. *Archives of Metallurgy and Materials*. 2015, vol. 60, no. 4, pp. 3011-3016.

[4] RUSZ, S., HILSER, O., OCHODEK, V., CADA, R., SVEC, J., SZKANDERA, P. Influence of SPD process on low-carbon steel mechanical properties. *MM Science Journal*. 2019, no. 2, pp. 2910-2914.

[5] CADA, R., PEKTOR, T. Development of a low-cost drawing tool for a press brake. In: *Metal 2021, 30th Anniversary International Conference on Metallurgy and Materials*. Ostrava: TANGER. 2021, pp. 241-246.

[6] CADA, R., FRYDRÝŠEK, K., SEJDA, F., DEMEL, J., PLEVA, L. Analysis of Locking Self-Taping Bone Screws for Angularly Stable Plates. *Journal of Medical and Biological Engineering*. 2017, vol. 37, no. 4, pp. 612-625.

[7] SEGAL, V., M. Deformation mode and plastic flow in ultra fine grained metals. *Materials Science and Engineering: A*. 2005, vol. 406, no. 1-2, pp. 205-216.

[8] FURUKAWA, M., IWAHASHI, Y., HORITA, Z., NEMOTO, M., LANGDON, T., G. The shearing characteristics associated with equal-channel angular pressing. *Materials Science and Engineering: A*. 1998, vol. 257, no. 2, pp. 328-332.

[9] LUIZ PÉREZ, C.J., BERLANGA, C., PÉREZ-ILZARBE, J. Processing of aluminium alloys by equal channel angular drawing at room temperature. *Journal of Materials Processing Technology*. 2003, vol. 143-144, pp. 105-111.

[10] HUANG, Y., LANGDON, T., G. Advances in ultrafine-grained materials. *Materials Today*. 2013, vol. 16, no. 3, pp. 85-93.