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INFLUENCE OF STRAIN PATH AND TRIBO CONDITIONS ON LIMITING RELATIONSHIP IN DEEP DRAWING

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ABSTRACT

In the paper is considered the influence of the tribo conditions and the strain path on realization of limiting relations in typical stress - strain scheme of deep drawing - stretching. Investigation was performed on four materials aimed for deep drawing, out of which the two types of thin sheets have the anti - corrosion coating of zinc. Standard stretchings were realized, and as an example of non proportional strain were realized two phased trajectories with usage of different lubricants. We conclude that realized two phased forming - in the first phase uniaxial tension, in the second stretching - enables realization of greater degree of limiting strain, than in the conditions of proportional forming process. However, realized values of the greatest depths of drawing, as the key indicators of integral strain analyzis, are significantly lower.

1. INTRODUCTORY CONSIDERATIONS

Usual definition of forming limit strain assumes ability for realization of maximal strain in given machining conditions (stress - strain scheme, speed, temperature and tribo-conditions, and so on). In deep drawing of parts made of thin sheets, it is important to compare the realized values of strain with the limiting values; using of Forming Limit Diagrams (FLD) just makes possible the definition of the degree of criticality of the drawn piece. The proportionality conditions - strain path in obtaining the FLD must correspond to those in real drawing [1].

The position and shape of the FLD, which is determined experimentally, is affected by numerous factors - kind of material with basic indicators ("n" and "r" factors, strain rate, experimental methodology, criterion for existing of localization and magnitude of the measuring base - diameter of the measuring grid). The strain path is completely described by strain trajectory - the trajectory of points which are for the corresponding measuring fields entered into the system of main linear strain e_1 - e_2 for each moment of drawing. In that the realistic assumption is that each complex trajectory consists of several phases, out of which every one satisfies the proportionality conditions. The complete description of, e.g. two phased forming, can be expressed by the direction coefficient ($t = e_1/e_2$), for the first and the second phase, and by the strain degree e1 at the end of the first phase, in the form (t^I, t^{II}, e_1^I) [1,2].

Examples of different forms of strain path are given in Figure 1. Details related to the effect of strain path on the position and shape of the FLD are presented in numerous works, e.g. [3,4]. Taking into account the specific influence of the tribo-conditions in changing the strain path, for experimental work was chosen the scheme noted as C, with the uniaxial tension in the first, and stretching in the second (scheme 2). To scheme 1 corresponds the proportional stretching, for which at completely uniform forming process is valid $e_1 = e_2$, or direction "a".

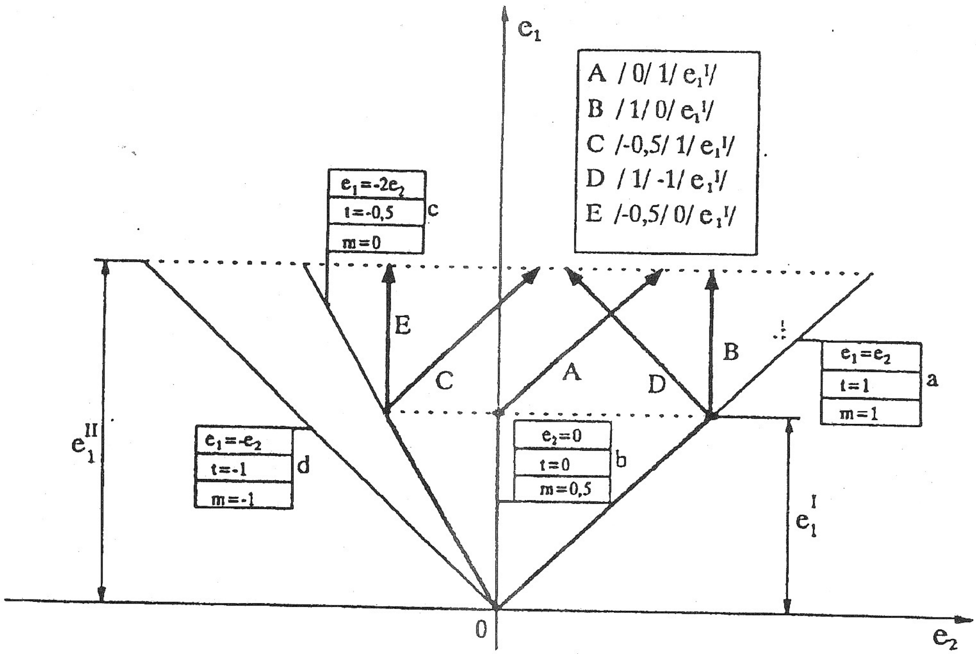

Figure 1. Possible forms of the strain path

In previous investigations of authors it was shown that the points which correspond to different contact conditions lie on the same forming limit curve. In Figure 2 is shown the position of points in the FLD obtained by applying different lubricants, [5].

In deep drawing by the solid punch, in the area of $e_2>0$, larger values of main strains are realized in conditions of lowered friction; by increasing the friction the metal flow is blocked in the tangential direction, by what the conditions of strain are worsen (limiting case is the planar strain, at $e_2=0$). In the paper [6] is stated, imprecisely, that the position of the FLD depends on contact conditions, namely that the high distribution gradient enables reaching of larger values of maximal strain.

2. EXPERIMENTAL PROCEDURE

Tested materials belong to the group of low carbon steel thin sheets, aimed for obtaining parts of passenger car bodies. Two materials, in the C0148P5 class, marked as (1) and (2) are thin sheets with common surfaces of two different manufacturers. Materials

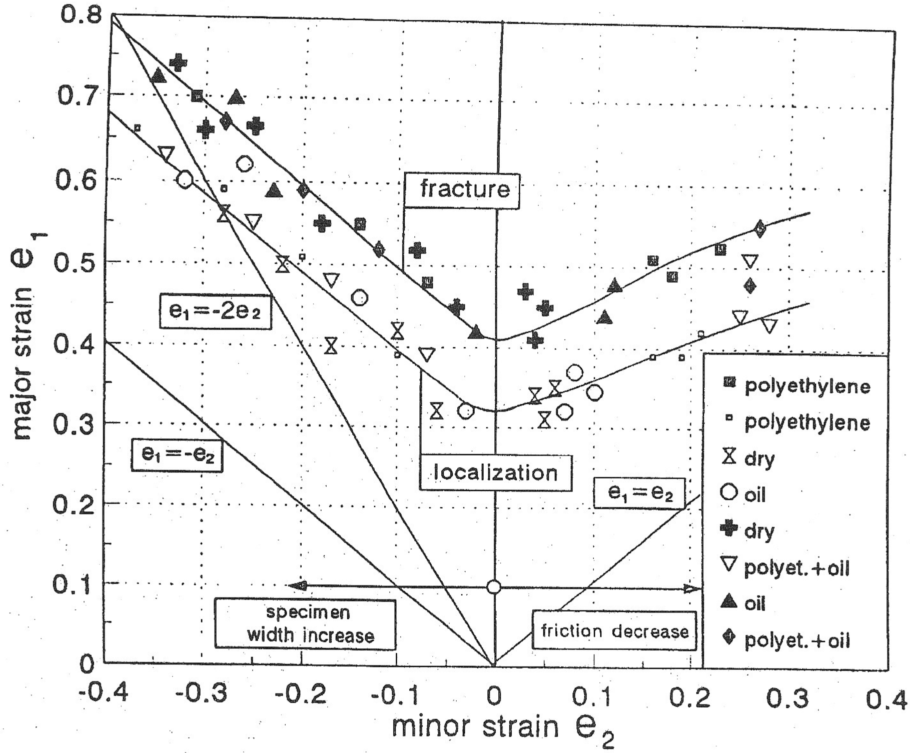

Figure 2. FLD obtained for different contact conditions

C0148 (Zn1) and (Zn2) have the anti-corrosion coating of zinc on one and both sides. Characteristics and basic parameters of formability of these materials are given in Table 1.

Tests by stretching were performed in machine tool with semi spherical drawing tool of 50 mm diameter, with speed of 0.333 mm/s. Methodology of strain fields determination is described in papers [3, 7]. In realization of the two phased forming, in the first phase specimens of 130 mm width were uniaxially extended until the values $e_1=0.135 - 0.2$, and then the stretching was done. In each phase of forming the condition t^{I}=const., t^{II}=const. was satisfied (until the moment of localization).

In testing are realized limiting lubrication conditions - as the lubricant was used the polyethylene (P), and the contact surfaces were technically dry (D).

	s mm	R_n MPa	R_m MPa	ε %	n	r
C0148.P5(1)	0.8	180.0	314.6	36.2	0.235	1.51
C0148.P5(2)	0.8	178.1	326.5	35.2	0.226	1.32
C0148(Zn1)	0.7	176.5	311.4	36.2	0.220	1.37
C0148(Zn2)	0.7	177.4	290.9	38.6	0.217	1.45

Table 1

3. RESULTS AND DISCUSSION

Effects of the tribo - conditions and realized strain histories are shown in figures 3 - 6. Distributions of the major natural strain e1 are presented in meridian cross section of the piece; to point 1 corresponds the middle - the pole of the piece, and to point 10 the zone at the rim in which the tangential strain is equal 0.

In Table 2 are given values of greatest depths in schemes 1 and 2 and amounts of major deformations realized in the first phase of deformation e_1^I).

Material	Scheme 1		Scheme 2			
	Lubr. D	Lubr. P	Lubr. D	Lubr. P	Lubr. D	Lubr. P
	h_M, mm	h_M, mm	e_1^I	h_M, mm	e_1^I	h_M, mm
C0148.P5 (1)	22.0	28.0	0.135	17.0	0.135	22.0
C0148.P5(2)	23.9	26.9	0.172	16.3	0.200	21.0
C0148 (Zn1)	21.3	25.7	0.200	15.7	0.170	21.3
C0148 (Zn2)	22.3	25.7	0.170	17.8	0.185	20.9

Table 2

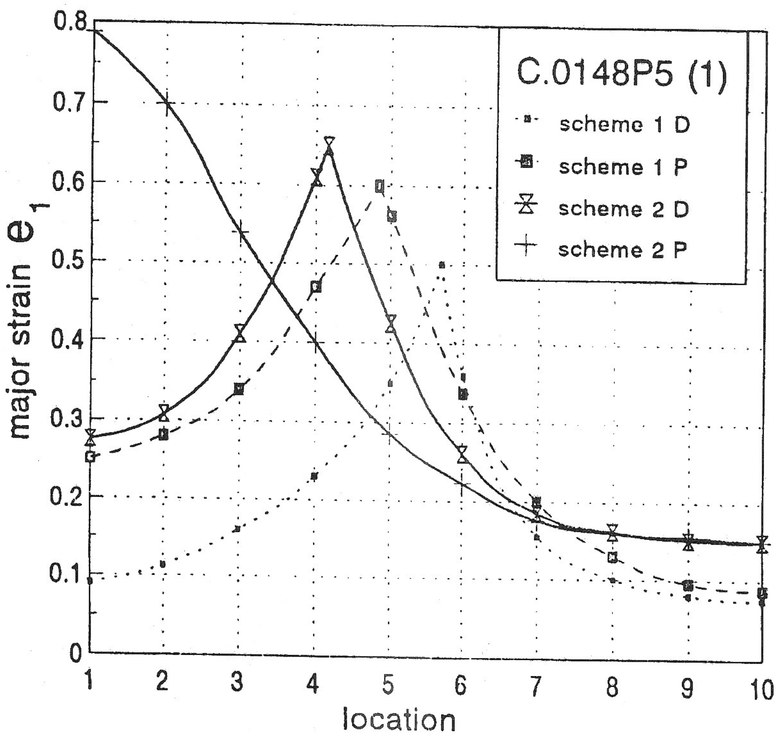

Figure 3. Strain distribution for material C0148P5(1)

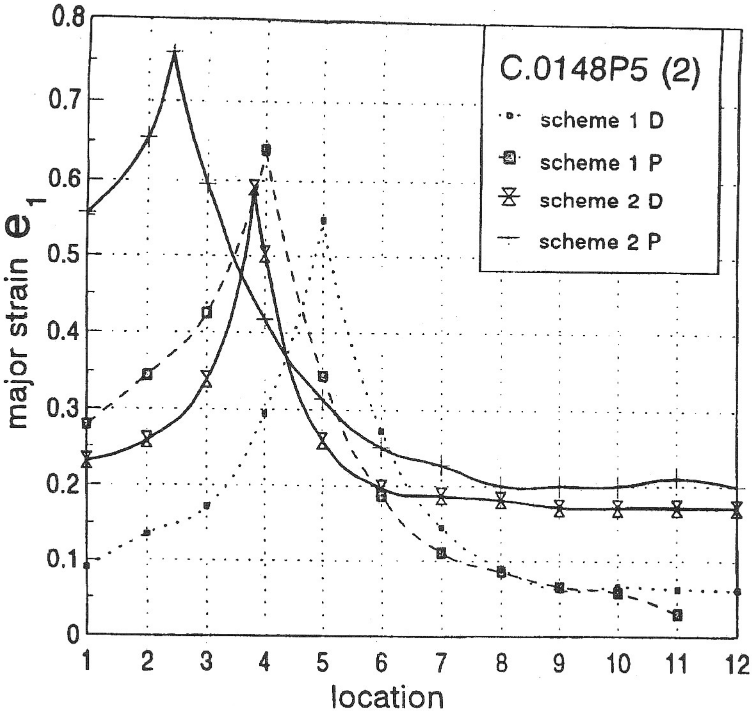

Figure 4. Strain distribution for material C0148P5(2)

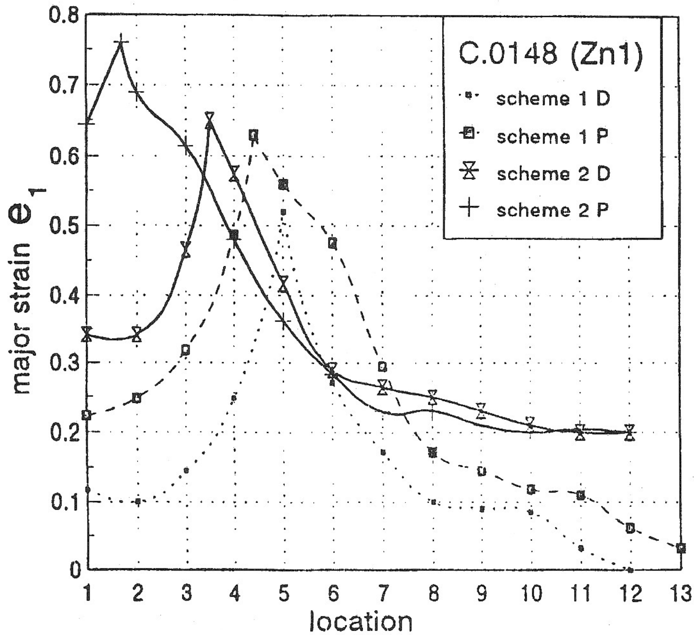

Figure 5. Strain distribution for material C0148(Zn1)

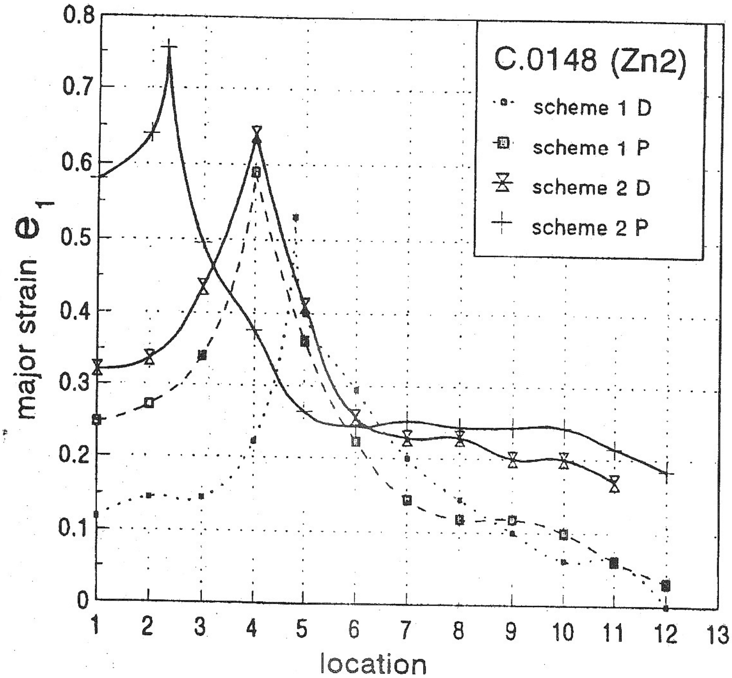

Figure 6. Strain distribution for material C0148(Zn1)

The basic characteristics of shown distributions is realization of limiting deformations in conditions of two - phased forming and improved conditions of lubrication. It is known that in stretching decrease of friction moves the zone of localization towards the center of the half - piece and enables the realization of greater depths of damage. In comparing distributions of same depth, realized degree of deformation and distribution and distribution gradient are lower at lower friction. Quantitative indicators of deformation distribution (uniformity, gradient in critical zone) can be defined according to methodology described in [8].

In stretching of the C0148.P5(1), according to scheme 2P, the failure will occurred in the middle of the piece, with distribution very similar to the distribution in hydraulic forming, Figure 3. However, deformation e_2, is significantly lower, so the deformation is expressed non-uniformly (t=1), Figure 7.

By changing the strain path the greater amount of local deformations can be realized, but at the cost of decreasing of forming ability of the whole piece (see Table 2). The basic deficiency in considerations of shown distributions is not taking into account the second major deformation, which significantly affects the character of failure. In Figures 7 to 10 are shown deformation distributions in the system e1 - e2, with drawn in the FLD (failure zone), for the described deformation schemes.

Final distributions are presented; if the distributions are formed for several consecutive phases, the so called constitutive diagrams are obtained, in which, for the corresponding measuring fields, is possible to enter also the trajectories of deformations.

Deformation in two phases does not have the characteristic distribution loop, since the failure zone is moved towards the fiels "1". The sudden increase of deformation e_1 at e_2 = const. occurs in the field of localized deformation, and it is more expressed at increased friction.

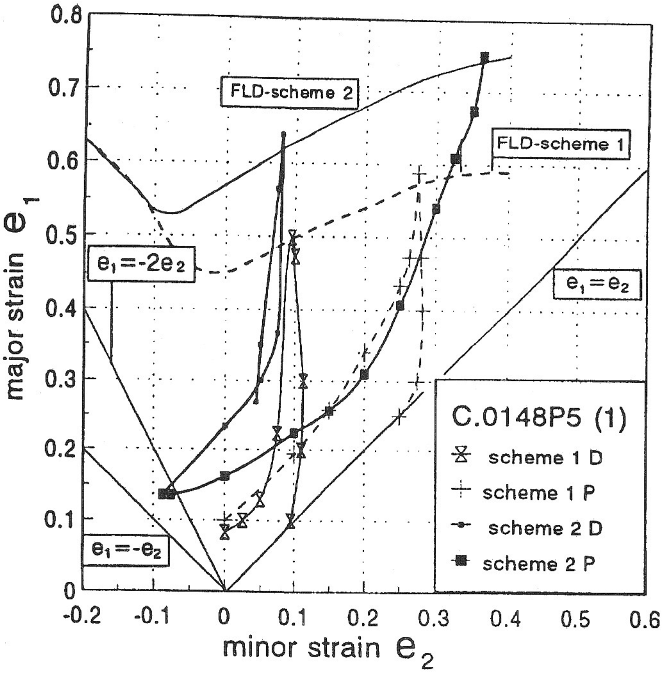

Figure 7. Strain distribution in FLD for material C0148P5(1)

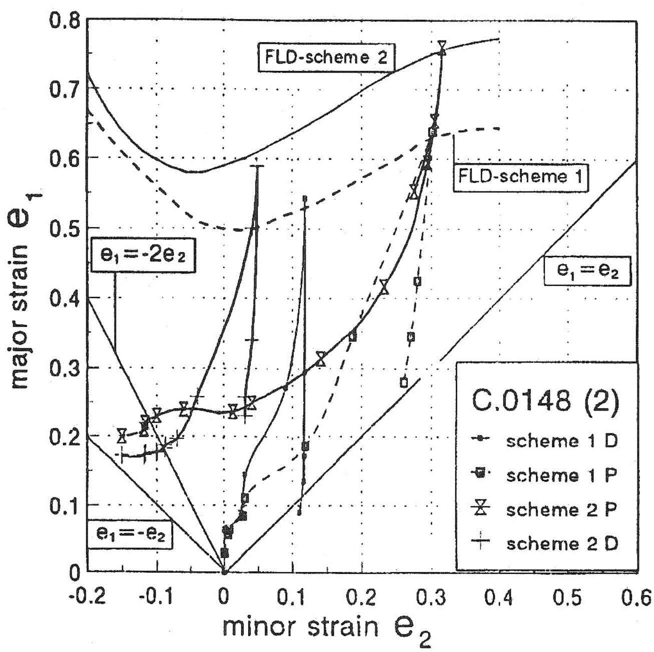

Figure 8. Strain distribution in FLD for material C0148P5(2)

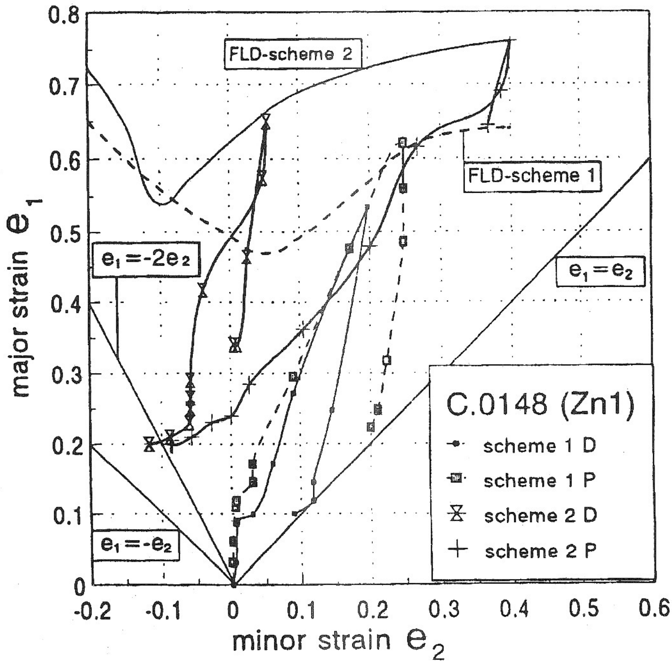

Figure 9. Strain distribution in FLD for material C0148(Zn1)

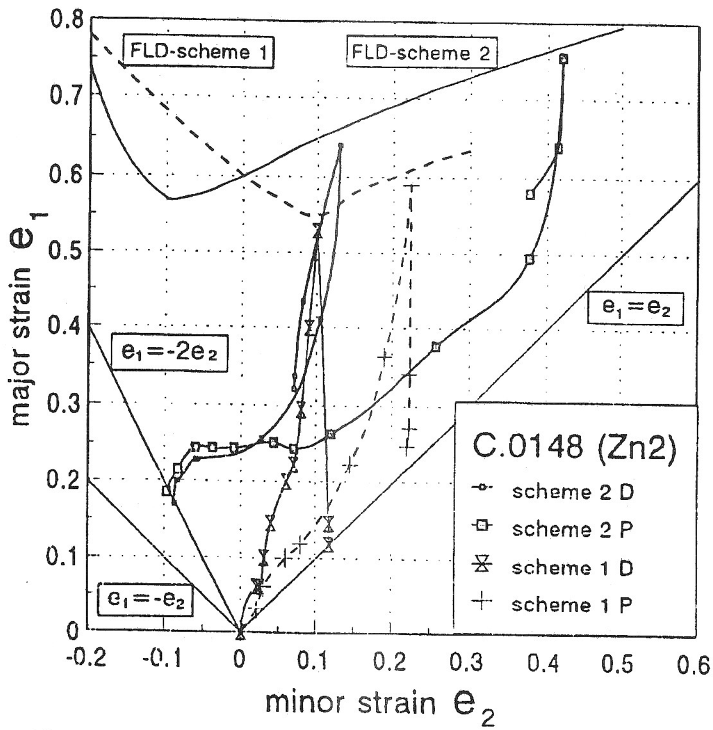

Figure 10. Strain distribution in FLD for material C0148(Zn2)

In diagrams the origin of the coordinate system for the two - phased forming is moved to the point, which denotes the end of the first phase - uniaxial tension.

4. CONCLUSION

In forming by stretching, regardless to the realized deformation schemes, by decrease of friction are realized the greater limiting degrees of strain and greater depths of failure. Tribological conditions, in the field of experimental velocities, do not affect the position of FLD, but they determine the position of points on the common curve of FLD.

Realized scheme of two - phased forming (uniaxial tension and stretching) enables realization of greater limiting degrees of strain, but with lower fracture depths. Prior deformation do not change essential relations in realized strain, but changed is the character of fracture with regard to the complex phenomena in metal structure of material.

Performed analysis on several materials shows that in conditions of non - proportional forming process, it is not possible, in considerations of deformability, to use exclusively indicators of local strain analysis, but also the parameters which describe the ability of the whole piece to be formed (realization of given geometry and so on).

5. REFERENCES

[1] Rasmussen S.J., "Theoretical Prediction of Strain Path Dependence of Limit Strains in Sheet Materials", Annals of the CIRP, Vol. 30, 1, 1981, pp. 179 - 184.

[2] Devedzic B., Aleksandrovic, S., "Influence of Non Monotonous Two Phased Processes on Forming Limit of Thin Sheets", (in Serbian), XXV SPMJ, Belgrade 1994., Proceedings, pp. 95 - 100.

[3] Stefanovic M., "Importance of Tribological Conditions in Non Proportional Forming Process of Thin Sheets", (in Serbian), XXV SPMJ, Belgrade 1994., Proceedings, pp. 185 - 191.

[4] Aleksandrovic S., "Forming Limit of Thin Sheets in Conditions of Non Monotonous Plastic Forming", (in Serbian), S.M. Thesis, Faculty of Mechanical Engineering, Kragujevac, 1993.

[5] Stefanovic M., "Tribology of Deep Drawing", (in Serbian), Yugoslav Committee on Tribology, Kragujevac, 1994.

[6] Gronostajski J., W.J. Ali, M.S. Ghatas, "Analysis of the Limit Strains of Coated Sheet Steels for Different Strainf Path, "Journal of Materials Processing Technology", 22 (1990), pp. 137 - 145.

[7] Devedzic B., M. Stefanovic, "Effects of Friction and Strain Path on Stretch - Formability of Sheet Metal", 2nd Int. Conf. of Plasticity, Stuttgart, 1987, Proceedings, pp. 437 - 444.

[8] Devedzic B., Effects of Lubrication on Sheet Metal Forming, Second Int. Conf. Lubric. in Metalworking and processing, Chicago, 1979, Proc. 27-29.