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THE HARDENING OF CARBON STEELS IN PLASTIC COLD DEFORMATION THROUGH COGGING OF ROLLED EDGE

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ABSTRACT

The cogging of steels on rolled edge has as effect the increased growth of the resistance characteristics and especially that of the flow limit, due to the hardening. The paper presents the results obtained through establishing the non-uniformity of the deformation on steel samples, in plastic cold underlined by analyzing the hardness distribution HV_5 *and the microstructure in the section of some steel samples, with 0,02…0,33 % C, deformed with 3…40 % degree of deformation.*

The performed analysis and the processing of experimental data leads to a personal interpretation of the hardening evolution, in the case of this deformation type.

1. INTRODUCTION

One of the ways of increasing the resistance characteristics of construction unalloyed, low carbon steels, is hardening by plastic cold deformation.

Industrial bar hardening is achieved at present by means of two technological processes namely:

- by drawing;
- by twisting.

The authors of this paper also took into consideration a third means of hardening, i.e. a plastic deformation by rolling round sections along a generatrix, method witch presents several advantages both concerning the investment costs and its turning account on building sites, especially for concrete steels.

In following this target, we analyzed the influence of the deformation degree of round sections rolled along the generatrix, upon resistance properties and the formation of distortion areas.

The research is based on values of Vickers hardness determined in the samples cross-sectionally deformed and cut.

Unlike the data given by the literature, referring to forging elongation, where the unitary degree of deformation is 8 % at most, this study contains data concerning the degree of unitary deformation of up to 40 %.

2. EXPERIMENTAL DATA

In order to achieve the objectives of the experiment, we deforms by pressure along the generatrix bar samples having the diameter of 25 – 30 mm which, after deformation have been cut at half length, the surface being prepared by metalographic polishing in view of determining its Vickers hardness.

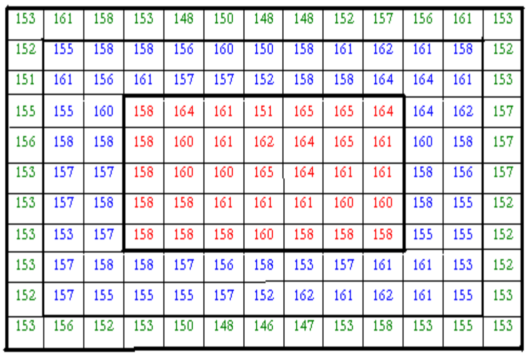
The Vickers method has been chosen as it is largely used in research works and it supposes a continuous hardness scale – for the given strain - starting with soft materials (HV = 4,9 daN) up to extremely hard materials (HV= 1500 daN).

In order to determine the hardness in cross-section of the plastic deformed samples, we used a portable device, type HPO –10, with the strain of 4,9 daN (HV_5).

At a first stage, since the upsetting deformation zones and the elongation deformation ones are accepted as similar, we deformed and analyzed round and square section samples having the same cross-sectional surface, the same deformed volume and acted upon with the same force.

We present as examples in figures 1 and 2, schemes of the hardness obtained after cutting two samples of carbon steel, having 0,12 % C and in fig. 3 and fig. 4 the distribution of same-hardness areas.

Further on, we determined the Vickers hardness of round extrasoft steel samples (0,02%C) and then steel with 0,12 % C and 0,22 % C. Figures 5 and 6 render the results obtained after analyzing the extrasoft steel samples compressed along the generatrix to a deformation degree of 10, 20, 30 and 40 % across the diameter.



153	161	158	153	148	150	148	148	152	157	156	161	153
152	155	158	158	156	160	150	158	161	162	161	158	152
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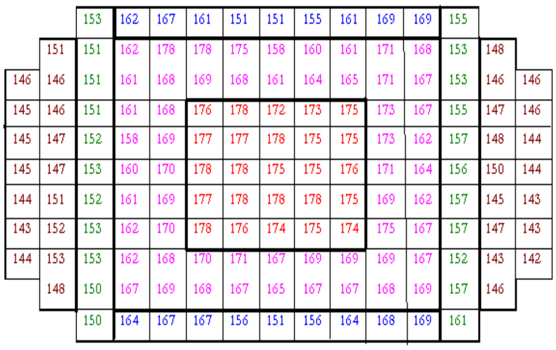
155	155	160	158	164	161	151	165	165	164	164	162	157
156	158	158	158	160	161	162	164	165	161	160	158	157
153	157	157	158	160	160	165	164	161	161	158	156	157
153	157	158	158	158	161	161	161	160	160	158	155	152
153	153	157	158	158	158	160	158	158	158	155	155	152
153	157	158	158	157	156	158	153	157	161	161	153	152
152	157	155	155	155	157	152	162	161	162	161	155	153
153	156	152	153	150	148	146	147	153	158	153	155	153

FIGURE 1. C = 0,12 %; ε = 12 %



		153	162	167	161	151	151	155	161	169	169	155		
	151	151	162	178	178	175	158	160	161	171	168	153	148	
146	146	151	161	168	169	168	161	164	165	171	167	153	146	146
145	146	151	161	168	176	178	172	173	175	173	167	155	147	146
145	147	152	158	169	177	177	178	175	175	173	162	157	148	144
145	147	153	160	170	178	178	175	175	176	171	164	156	150	144
144	151	152	161	169	177	178	178	178	175	169	162	157	145	143
143	152	153	162	170	178	176	174	175	174	175	167	157	147	143
144	153	153	162	168	170	171	167	169	169	169	167	152	143	142
	148	150	167	169	168	167	165	167	167	168	169	157	146	
		150	164	167	167	156	151	156	164	168	169	161		

FIGURE 2. C = 0,12 %; ε = 25

In the same mode, we determined the Vickers hardness of round extrasoft steel samples (0,02%C) and then steel with 0,12 % C and 0,22

% C compressed along the generatrix to a deformation degree of 10, 20, 30 and 40 % across the diameter.

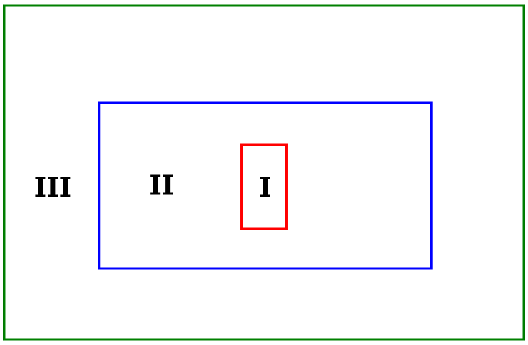


FIGURE 3. DEFORMATION ZONES ON SQUARE SAMPLES

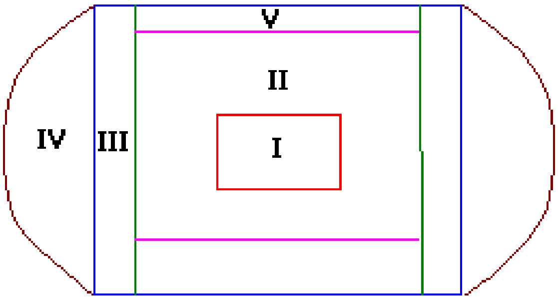


FIGURE 4. DEFORMATION ZONES ON ROUND SAMPLES

	120	123	121	120	123	121	121	123	120	121	120	
116	120	114	113	116	120	118	118	118	114	120	114	116
118	116	106	107	108	118	116	115	108	111	107	106	116
116	107	107	110	107	115	118	114	108	107	107	110	114
103	106	109	109	111	117	120	112	110	111	106	110	108
108	105	110	109	112	124	127	125	110	108	109	107	105
107	118	104	113	110	122	129	123	111	113	110	116	108
110	104	104	116	116	126	127	124	121	115	116	110	110
	115	120	126	120	125	125	125	124	121	120	121	

FIGURE 5. C = 0,02 %; ε = 10

148	158	157	161	158	162	165	163	161	158	158	157	144
144	153	165	167	167	169	175	168	168	167	161	152	143
143	148	165	168	168	168	177	168	168	167	163	151	144
147	153	162	175	172	173	177	172	173	171	163	154	148
146	152	167	167	178	175	178	175	177	165	169	154	147
148	155	169	167	167	175	172	171	168	169	167	153	147
148	158	165	160	160	161	164	161	162	162	165	157	148

FIGURE 6. C = 0,02 %; ε = 30

3. INTERPRETATION OF THE EXPERIMENTAL DATA

Figure 1 represents the scheme of the resulting Vickers hardnesses determinated on the cross section of square sample.

Settling the boundaries of deformation zones according to the scheme accepted at present, the average hardness of each zone is:

- zone I – 156,0 HV;
- zone II – 160,7 HV;
- zone III – 155,2 HV.

The average hardness differences, respectively, the deformation degree differences are far from those considered as normal, especially in zone I where the spherical component of strain is taken as dominant, with slight, or null differences between σ_1 and σ_3. We can notice in zone I an increase of hardness as we depart from the main axis, towards the edge of the sample, while in zone II, hardness decreases from the center towards the edge of the sample.

With the round sample (Figure 2), pressed along a generatrix, we distinguish several zones of different hardness, of deformation respectively, according to figure 4 namely:

- zone I – a restricted central zone with individual and average hardnesses maximum;
- zone II- going round the central zone, having a more reduced hardness than zone I;
- zone III – passage between central zones I and Ii and the area of the material which is outside the compression zone;
- zone IV – outside the compression zone;
- zone V – of slight deformation.

In order to exemplify the variation of average hardnesses in the five zones, table 1 includes the values obtained when pressing extrasoft carbon steel samples (0,02% C) and steel having 0,22 % C.

Data in table 1 lead to the following conclusions:

- the variation of average hardness in each zone is similar both for extrasoft steel and that of 0,22 % C, the highest values to be found in zone I, followed by a decrease following the scheme: zone I – zone II – zone V – zone III - zone IV;
- all zones present deformations, irrespective of the position inside the sample;
- for deformation degrees along the diameter of over 30 %, we noticed decreases of average hardness both per sample and per zone.

TABLE 1. AVERAGE HARDNESSES OBTAINED FOR ROUND, UNALLOYED STEEL SAMPLES DEFORMED BY COMPRESSING ALONG A GENERATRIX

Carbon content %	Deformation degree %	Average hardness, HV					
		by sample	Zone I	Zone II	Zone III	Zone IV	Zone V
0,02	10	125	147	137	137	120	113
	20	149	165	156	156	141	138
	30	162	175	168	168	153	146
	35	161	173	166	166	151	145
	40	156	176	165	165	144	124
0,22	10	162	168	166	161	161	156
	20	191	228	207	172	172	166
	30	198	231	209	186	186	172
	40	196	222	209	182	182	169

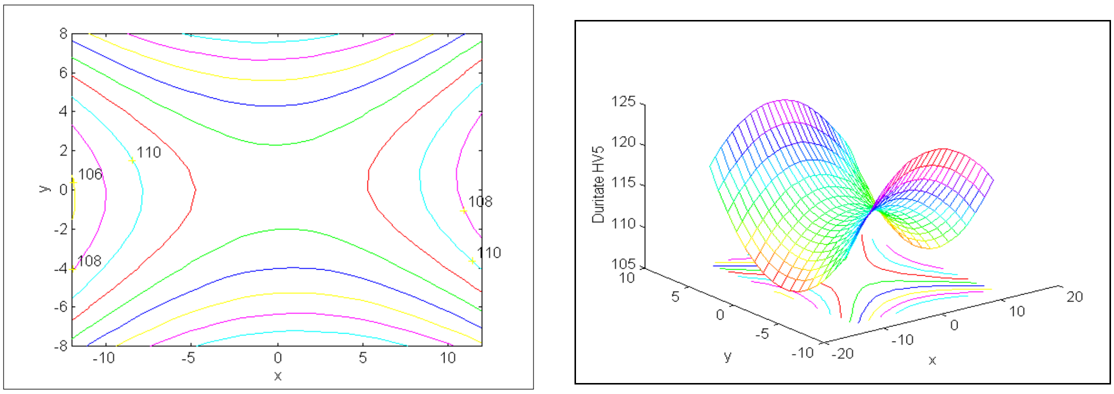


FIGURE 7.

a. SAME-HARDNESS CURVES – 0,02 % C ; ε= 2 %.

b. AVERAGE HARDNESS FOR 0.02% C STEEL: ε= 2 %

Hardness decrease for deformation degrees stirpassing 30 %may be due to a Bauschinger effect when compression strains turn into elongation ones, or vive-versa.

The theoretical explanation is based on the fact that for a given tangent strain, a dislocation line will move in the sliding plan until it meets a row of obstacles strong enough to resist sliding.

When the sense of the strain is reversed, the dislocation line may move an important amount, for a smaller tangent strain, because the obstacles behind the dislocation are not so strong.

By processing all data in MATLAB program, we determinate a new type of distribution, like a "hardness wave", presents in figures 7 and 8.

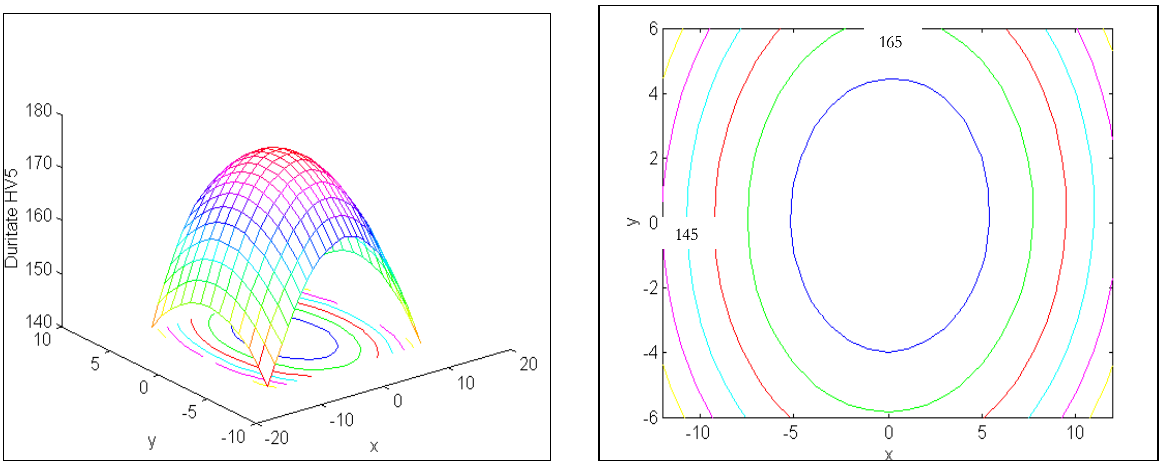


FIGURE 8.
a. SAME-HARDNESS CURVES – 0,02 % C ; ε= 30 %.
b. AVERAGE HARDNESS FOR 0.02% C STEEL: ε= 30 %

4. CONCLUSIONS

- When pressing round sections along the generatrix, five deformation zones can be established, the highest values to be found in the central part of the cross-section, where the deforming pressure has a direct action;
- In the light deformation zones, when forging or compressing round sections along the generatrix, important plastic deformations take place at the very contact between the deforming tools and the material;
- With deformation along diameter of over 30 %, which corresponds to a ratio h / l < 1, we noticed a decrease of hardnesses as a result of reversing the sense of strain;
- The study of the hardening degree by means of the Vickers hardness in the cross-section of deformed samples, can be considered an efficient quantitative method of research.
- Due to the quantitative character of the hardness research method, we suggest its use in determining the variations of deforming degree, with soft. analloyed steels, both at samples lever and with

respect to small volumes, by applying the calculation formula for the real flow strain:

$$\sigma_{real} = k\varepsilon^{n}$$

where

σ_{real} - the real strain for a certain degree of deformation;

k - the plastic moment of strength, obtained from logarithmic curve;

n – hardening coefficient

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