THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 4 - 2016, ISSN 1453-083X

INFLUENCE OF REDUCTION SCHEME ON HARDNESS COLD ROLLED STRIP MARK STEEL ST 12

Marian-Iulian NEACȘU, Viorel DRAGAN
"Dunarea de Jos" University of Galati
e-mail: uscaeni@yahoo.com

ABSTRACT

The paper presents the results of the research on the influence of the evolution hardness scheme rolled steel, for the cold-rolled strip steel St 12. St 12 is intended for the manufacture of cold rolled strip stamping properties environments

We studied three variants of rolling with the same degree of deformation. The total = 60% of the samples submitted to the research were divided into 3 groups. Samples from the first group were rolled with uniform reduction coefficient increased from the first to the last pass. Samples from the second group were rolled with constant coefficients decreased from the first to the last pass. Samples of the third group were rolled with uniform reduction coefficient decreased from the first to the last pass.

By statistical processing of the experimental data was done correlation HRB = f (ε) using an equation like: $HRB = HRB_0 + a \times \varepsilon^b$ *from which the mathematical calculations specific led to obtain equations curves hardening for the three kinds of rolling schemes.*

Following research consisting in observing as steel hardening analyzed has a very high speed we can say that the limit of plasticity of the material cold rolling is more than 60% where cracks are observed.

KEYWORDS: rolling, roll, drawing, rank reduction

1. Introduction

Lamination process by passing through the space between two metal cylinders rotating met successive improvements, achieving a quantum leap after 50 years with the expansion of large-scale electrical applications [1, 2].

Consequently, it could switch to complex constructions which have increased production capacity to meet the growing requirements of the user industries of steel sheets and strips [3].

Introduction of automation and computerized techniques in metallurgy meant also an important step in the direction of the processes of plastic deformation of steel [4].

Tables and cold rolled steel strips is a staple with multiple uses in various industrial fields, working to achieve different product categories, a diverse array. Thin steel sheet and strip of low-carbon killed or semi-killed are processed in the body parts of cars, equipment and household appliances and various parts or goods obtained by die-stamping or deep drawing [3, 4].

Packaging industry is another area of using sheet and cold rolled steel strips.

A considerable proportion of the production of sheet and strip is covered by various methods (zinc plating, tinning, lacquering, painting) and is designed to create the outer shell in the construction industry.

Steel strips nickel, chromium or copper is widely used for decorative purposes. The multitude in the areas of use and processability requirements for manufactured products of cold strip mills can have different embodiments.

The machine itself is a twisting rolling stand whose construction differs from case to case, depending on the type of mill and form part of the finished product.

Lamination means not only the machine itself used for plastic deformation, but a complex of operations and production lines which, aside preparing raw material for cold rolling, after rolling is conjuring various properties and characteristics of the material that make it suitable for further processing [2, 3].

The complexity of technological lines of the composition of a polling cold rolling largely depends on the assortment of production, its destination and the conditions of the material in terms of the appearance of the surface, the mechanical and technological final of employment in tolerances imposed.

2. Materials and methods of research

Steel St 12 is a carbon steel (C = 0.1%, N = 0.007%) of general purpose and is produced according to DIN 50014 [7]. It is intended for the manufacture of cold rolled strip stamping properties environments. Strips of this steel grade are produced by DIN 1623-1.

2.1. The research method

For conducting research on the influence on the development scheme of rolled strip cold-rolled hardness, were used 12 samples of hot rolled strip with dimensions of 4 × 30 × 200 mm steel St 12. The samples were divided into three groups (each with 4 samples in each group) and were cold rolled by the rolling according to the following scheme [2, 3]:

- samples of the first group were rolled with uniform reduction coefficient increased from the first to the last pass (ε_1 = 9.55%; ε_2 = 13.07%; ε_3 = 16.60%; ε_4 = 20.12%; ε_5 = 23.64%);
- samples from the second group were rolled with constant coefficients decreased from the first to the last pass (ε1 = ε2 ε4 = = = ε3 ε5 = 16.74%);
- samples of the third group were rolled with uniform reduction coefficient decreased from the first to the last pass (ε1 = 23.64%; ε2 = 20.12%; ε3 = 16.60%; ε4 = 13.07%; ε5 = 9.55 %);

In all three variants was performed the same total degree of deformation ε_{total} = 60%.

Rolling mill was made irreversible in an experimental type of lamination technology laboratory of the Department of Materials Processing and faculty Ecometallurgy SIM - UPB having the following characteristics [2]:

- diameter cylinders: 200 mm;
- rolling speed: 1 m/s;
- drive motor power: 40 kW.

Of the four samples in each group, the first sample was used to adjust the rolling stands while the other three were laminated under the same lamination as shown in the repeatability of results and for monitoring eventual elimination of disturbing factors. Before the first pass and after each pass, HRB hardness was measured under standard conditions (ball 1/16" and load 100 kg) device from the laboratory TDP. For each sample, determinations were made in May and was calculated arithmetic average of the three of these determinations eliminating outliers.

After each run was measured sample thickness (Hi) and calculated the relative reduction in that passage (ε_i) and total relative reduction to the passage in question (ε_{toti}) relations:

$$\varepsilon_i = \frac{\Delta h_i}{H_{i-1}} = \frac{H_{i-1} - H_i}{H_{i-1}} \times 100 \quad [\%] \tag{1}$$

$$\varepsilon_{tot_i} = \frac{\Delta h_{tot_i}}{H_0} = \frac{H_0 - H_i}{H_0} \times 100 \quad [\%] \tag{2}$$

In these relationships:

- H_{i-1} is the thickness of the sample before passage i;
- H_i is the thickness of the sample after passing;
- H_0 is the initial thickness of the sample (prior to the first pass).

3. Results obtained

After performing experiments, the results are summarized in Tables 1, 2, 3.

Table 1. *Get the HRB hardness as planned rolling with increasing relative reductions*

No. of pas.	ε_i proposed %	H_i proposed mm	Sample no.	H_{i-1} mm	H_i mm	Δh_i mm	ε_i realiz. %	Δh_{toti} mm	ε_{toti} realiz. %	HRB					
										1	2	3	4	5	Average
0	-	-	-	-	4.00	-	-	-	-	66.6	69.8	66.9	65	70.2	67.7
1	9.55	3.6	**1**	4.00	3.67	0.33	8.25	0.33	8.25	76.4	75.9	75.0	77.2	75.5	76.0
			2	4.00	3.73	0.27	6.75	0.27	6.75	70.9	72.3	72.5	69.1	69.5	70.9
			3	4.00	3.67	0.33	8.25	0.33	8.25	75.4	74.7	73.8	72.9	72.1	73.8
2	13.07	3.1	**1**	3.67	3.09	0.58	15.80	0.91	22.75	88.9	89.8	88.2	84.7	87.0	87.7
			2	3.73	3.10	0.63	16.89	0.90	22.50	87.2	87.4	85.5	84.8	85.2	86.0
			3	3.67	3.18	0.49	13.35	0.82	20.50	86.7	87.0	85.0	86.0	84.7	85.9
3	16.60	2.6	**1**	3.09	2.60	0.49	15.86	1.40	35.00	89.1	86.6	89.0	90.4	90.8	89.2
			2	3.10	2.59	0.51	16.45	1.41	35.25	90.0	88.3	89.0	89.2	89.5	89.2
			3	3.18	2.63	0.55	17.30	1.37	34.25	87.7	91.4	89.7	91.0	89.1	89.8
4	20.12	2.1	**1**	2.60	1.94	0.66	25.38	2.06	51.50	91.1	86.6	91.2	89.6	87.2	89.2

			2	2.59	2.16	0.43	16.60	1.84	46.00	86.8	85.5	89.8	88.7	88.5	87.9
			3	2.63	2.15	0.48	18.25	1.85	46.25	86.1	86.0	89.4	88.7	87.6	78.6
5	23.64	1.6	**1**	1.94	1.55	0.39	20.10	2.45	61.25	86.4	90.0	90.5	90.2	89.0	89.2
			2	2.16	1.63	0.53	24.54	2.37	59.25	87.7	87.5	90.0	86.5	85.0	87.3
			3	2.15	1.59	0.56	26.05	2.41	60.25	86.4	88.0	85.5	87.7	86.3	86.8

***Table 2.** Get the HRB hardness as planned rolling with constant relative reduction*

No. of pas.	**ε_i proposed %**	**H_i proposed mm**	**Sample no.**	**H_{i-1} mm**	**H_i mm**	**Δh_i mm**	**ε_i realiz. %**	**Δh_{toti} mm**	**ε_{toti} realiz. %**	**HRB**					
										1	**2**	**3**	**4**	**5**	**Average**
0	-	-	-	-	4.00	-	-	-	-	66.6	69.8	66.9	65	70.2	67.7
1	16.74	3.3	**1**	4.00	3.31	0.69	17.25	0.69	17.25	83.9	82.3	85.8	86.3	79.9	83.6
			2	4.00	3.45	0.55	13.75	0.55	13.75	84.8	85.8	81.3	86.5	85.3	84.7
			3	4.00	3.35	0.65	16.25	0.65	16.25	84.7	85.3	85.7	86.8	86.4	85.8
2	16.74	2.8	**1**	3.31	2.82	0.49	14.80	1.18	29.50	88.5	89.3	88.8	89.9	87.5	88.8
			2	3.45	2.78	0.67	19.42	1.22	30.50	89.0	90.3	89.4	86.9	90.5	89.2
			3	3.35	2.75	0.60	17.91	1.25	31.25	87.5	86.4	86.1	87.3	87.2	86.9
3	16.74	2.3	**1**	2.82	2.36	0.46	16.31	1.64	41.00	87.5	87.1	86.7	90.5	90.5	88.5
			2	2.78	2.23	0.55	19.78	1.77	41.25	90.0	88.0	91.1	91.5	88.0	89.7
			3	2.75	2.28	0.47	17.09	1.72	43.00	88.5	89.7	88.2	87.8	89.0	88.6
4	16.74	1.9	**1**	2.36	1.84	0.52	22.03	2.16	54.00	90.4	89.4	91.3	91.8	90.0	90.6
			2	2.23	1.85	0.38	17.04	2.15	53.75	87.0	91.0	90.6	90.0	89.0	89.5
			3	2.28	1.87	0.41	17.98	2.13	53.25	85.0	85.0	86.3	89.3	89.5	87.0
5	16.74	1.6	**1**	1.84	1.58	0.26	14.13	2.42	60.60	86.1	90.4	88.3	84.0	88.0	87.4
			2	1.85	1.53	0.32	17.30	2.47	61.75	90.8	90.8	90.0	88.4	90.8	90.2
			3	1.87	1.57	0.31	16.04	2.43	60.75	88.2	88.8	84.5	83.4	87.2	86.4

***Table 3.** Hardness HRB obtained as planned rolling with decreasing relative reductions*

No. of pas.	**ε_i proposed %**	**H_i proposed mm**	**Sample no.**	**H_{i-1} mm**	**H_i mm**	**Δh_i mm**	**ε_i realiz. %**	**Δh_{toti} mm**	**ε_{toti} realiz. %**	**HRB**					
										1	**2**	**3**	**4**	**5**	**Average**
0	-	-	-	-	4.00	-	-	-	-	66.6	69.8	66.9	65	70.2	67.7
1	23.64	3.1	**1**	4.00	3.14	0.86	21.50	0.86	21.50	84.6	88.0	87.6	87.7	90.4	87.7
			2	4.00	3.06	0.94	23.50	0.94	23.50	88.4	89.8	90.8	89.5	88.9	89.5
			3	4.00	3.15	0.85	21.25	0.85	21.25	88.0	88.5	88.0	88.8	88.0	88.3
2	20.12	2.4	**1**	3.14	2.55	0.59	18.79	1.45	36.25	88.6	90.8	92.5	90.4	91.3	90.7
			2	3.06	2.58	0.48	15.69	1.42	35.50	91.7	90.1	90.8	89.0	90.8	90.5
			3	3.15	2.45	0.70	22.22	1.55	38.75	90.3	85.9	89.4	90.2	89.3	89.0
3	16.60	2.0	**1**	2.55	2.05	0.50	19.61	1.95	48.75	88.6	85.8	86.0	89.5	88.7	87.7
			2	2.58	2.12	0.46	17.83	1.88	47.00	89.0	88.7	88.2	88.5	91.2	89.1
			3	2.45	2.13	0.32	13.06	1.87	46.75	89.2	86.1	87.4	88.2	87.0	87.6
4	13.07	1.8	**1**	2.05	1.77	0.28	13.66	2.23	55.75	86.7	91.5	89.5	91.6	87.0	89.3
			2	2.12	1.8	0.32	15.09	2.20	55.00	90.6	88.7	85.8	85.0	84.0	86.8
			3	2.13	1.75	0.38	17.84	2.25	56.25	89.5	89.5	91.5	88.0	91.3	90.0
5	9.55	1.6	**1**	1.77	1.60	0.17	9.60	2.40	60.00	86.0	86.4	85.0	86.3	86.2	86.0
			2	1.8	1.50	0.30	16.67	2.50	62.50	89.0	89.6	89.0	91.0	88.4	89.4
			3	1.75	1.65	0.10	5.71	2.35	58.75	88.5	84.8	86.8	90.0	87.3	87.5

Based on data in Table 1 was built variation diagram (Fig. 1) depending on the degree of hardness reduction.

Figure 2 shows the variation HRB hardness depending on the degree of reduction in total under the scheme rolling with constant relative reduction.

Figure 3 shows the variation in hardness depending on the degree of reduction based on the data in Table 3.

The correlation HRB = f (ε) was obtained by statistical processing of the experimental data using an equation of the type [5, 6]:

$$HRB = HRB_0 + a \cdot \varepsilon^b \quad (3)$$

The equation was linearized as follows:

$$HRB - HRB_0 = a \cdot \varepsilon^b \quad (4)$$

$$\log(HRB - HRB_0) = \log a + b \cdot \log \varepsilon \quad (5)$$

The change of variables was made:

$$Y = \log(HRB - HRB_0) \quad (6)$$

$$X = \log \varepsilon \quad (7)$$

$$A = b \quad (8)$$

$$B = \log a\, a \quad (9)$$

and there was obtained a linear equation of the type:

$$Y = A \cdot X + B \tag{10}$$

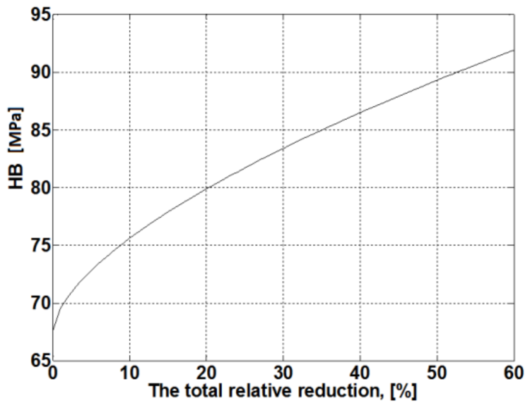

Fig. 1. *HRB hardness grade 1 for total variation reduction as planned rolling with increasing relative reductions*

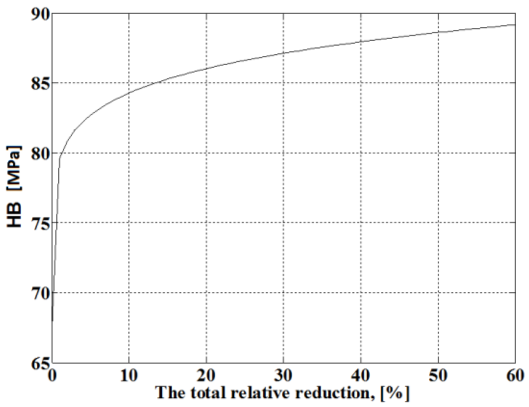

Fig. 2. *HRB hardness grade 2 for total variation reduction as planned rolling with constant relative reduction*

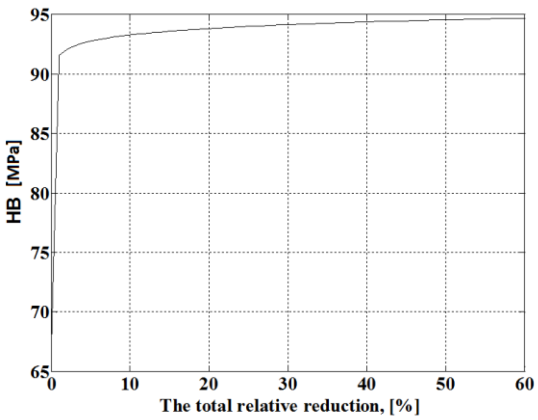

Fig. 3. *HRB hardness variation with the total degree reduction as planned rolling with decreasing relative reductions*

The coefficients A and B are determined by the relationship:

$$A = \frac{n \cdot \sum_{i=1}^{n} X_i \cdot Y_i - \sum_{i=1}^{n} X_i \cdot \sum_{i=1}^{n} Y_i}{n \cdot \sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2} \tag{11}$$

$$B = \frac{\sum_{i=1}^{n} Y_i \cdot \sum_{i=1}^{n} X_i^2 - \sum_{i=1}^{n} X_i \cdot Y_i \cdot \sum_{i=1}^{n} X_i}{n \cdot \sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2} \tag{12}$$

After calculating the coefficients, it returns to initial variables:

$$a = 10^B \tag{13}$$

$$b = A \tag{14}$$

After the calculations, there result specific equations hardening curves (15, 16, 17) for the three kinds of rolling regimens studied.

For the scheme rolling, coefficient reduction breeders:

$$HRB = 66.7 + 1.8757 \times \varepsilon^{0.623} \tag{15}$$

For the scheme in order to reduce rolling with constant coefficients:

$$HRB = 67.7 + 11.8957 \times \varepsilon^{0.14} \tag{16}$$

For the scheme of rolling coefficient, it reduces to the lower value:

$$HRB = 67.7 + 23.85 \times \varepsilon^{0.03} \tag{17}$$

4. Conclusions

Analyzed steel has a very high work-hardening rate, the area of the gliding limited degree of deformation is up to about 15% and occurs after the linear sliding. Over 40% of the total grade material deformation from the zone where the speed of hardening is greatly decreasing is tending to zero.

For proper technological behavior in the cold rolling, rolling the most appropriate scheme is the scheme with coefficients relative reduction breeders. Since entry into the dish to this type of scheme rolling is done at a relative reduction of approximately 40%

it is recommended for the line rolling from MITTAL STEEL (lamination line with five stands arranged in tandem to work continuously) to use a rolling scheme with discounts increasing relative to the passage III after the reduction coefficients will be descending.

As the experimental tests were made to a total level of 60% relative reduction, no cracks were observed in the material, it can be appreciated that the plasticity limit of the material of cold rolling is 60%.

References

[1]. Banaba D., Dorr R. I., *Process modeling plastic deformation of sheet metal*, Press Publisher Transylvania, Cluj-Napoca, 1995.

[2]. Cazimirovici E., *Fundamentals of plastic deformation*, Editura Bren Bucharest, 1999.

[3]. Cananau N., Tănase D., *Plastic deformation technology*, Galati University Press, 2010.

[4]. Ciucă Dumitriu I. S., *Metallurgical Processes Modeling and Optimization of Plastic Deformation and Heat Treatment*, Didactic and Pedagogic Publishing, Bucharest, 1998.

[5]. Popescu D., Ionescu F., Dobrescu R., Stefanoiu D., *Modeling in industrial process engineering*, AGIR Publishing House, Bucharest, 2011.

[6]. Talo D., *Optimizing processes - applications in metallurgy*, Publishing House, Bucharest, 1987.

[7]. ***, DIN 50014 and DIN 1623-1.