The Influence of the Initial Billet on the Mechanical Properties of Pipes

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Abstract. The article researched the influence on the pipes mechanical properties initial billet obtained by the traditional method and the proposed method, in which the piercing process is excluded. The proposed method involves casting the initial billet for the production of seamless pipes with a cavity obtained on a continuous casting machine. The production of hot-rolled seamless pipes from a hollow billet is an urgent issue today, since central porosity and axial segregation after casting are excluded, affecting the quality of the pipes obtained in the subsequent stages of production: rolling on a mandrel mill and reducing. The result is a minimal deviation of the mechanical properties of steel samples obtained by double deformation of a hollow continuously cast billet from samples obtained according to the traditional scheme, including the piercing process.

1. Introduction
At the present stage of steel production development, the most rational way to obtain steel billets for the production of seamless pipes is the continuous casting process, due to its technical and economic advantages: productivity, product yield, etc. Solid billets are characterized by axial segregation heterogeneity with any manufacturing methods, therefore, removing metal from the axial zone of the billet is advisable [1–4]. The authors of [5–7] propose to use a hollow continuously cast billet instead of a sleeve pierced on a cross-helical mill as the initial billet for pipe production. However, the pipe obtained by rolling from a hollow cast billet undergoes lesser degrees of deformation and in this regard, experimental researches and mechanical properties analysis of the obtained products from a hollow cast billet and a pierced sleeve are necessary [8–11].

2. Object and research methods
For the research, templates with a length of 150 mm were selected from a continuously cast billet with a diameter of 210 mm from steel grade 09Mn2Si and from a sleeve obtained after piercing from this billet. The experimental scheme is shown in Figure 1. The casting of a continuously cast billet was carried out in the electric steel melt shop of the LLP “KSP Steel”, and the billet was pierced in the pipe rolling shop of the same plant on a two-roll cross-helical mill with mushroom-shaped rolls.

Upset of samples with a diameter of 30 mm and a length of 75 mm was carried out on a hydraulic press at the laboratory of S. Toraighyrov PSU to ensure a compression equal to 30%, which is similar...
to the total compression of the rolling process on a continuous mill and reducing on a reduction mill. Heat treatment of the upsetted samples was carried out in the furnace SNOL 7.2/1300 at the laboratory of S. Toraighyrov PSU.

The mechanical properties determination of the initial billets, upsetted and heat-treated samples was carried out according to GOST 1497-84 “Metals. Tensile test methods” in the laboratory of LLP “KSP Steel”.

Samples for testing were taken in the transverse \( T \) and longitudinal \( L \) directions, three units from each template, as shown in Figure 2 for a solid billet and in Figure 3 for a hollow billet.
3. Research results and discussion

In the production of seamless hot-rolled pipes according to GOST 632-80 “Casing pipes and couplings to them”, GOST 633-80 “Tubing and couplings to them” and similar foreign API 5CT “Casing and tubing” only mechanical properties are standardizing indicators, namely, tensile strength, yield strength and elongation.

The initial mechanical properties and density of the cast hollow billet are similar to the properties of a solid continuously cast billet, since at this stage the product does not yet undergo deformation. In this regard, the conditional initial values of the mechanical properties of the hollow billet are taken from the test results of tensile tests of samples taken from solid continuously cast billets. Table 1 shows the test results in comparison with samples cut from a pierced sleeve [12–15].

| Type of billet | Test sample | Tensile strength, MPa | Yield strength, MPa | Elongation, % |
|---------------|-------------|-----------------------|--------------------|---------------|
| Cast          | transverse  | 437;445;41            | 415;435;36         | 6.2;5.2;6.4   |
|               |             | 432                   | 406                | 5.9           |
|               | longitudinal| 478;455;45            | 424;448;39         | 5.5;6.9;7.6   |
|               |             | 463                   | 421                | 6.7           |
| Pierced       | transverse  | 596;538;63            | 517;485;50         | 9.1;10.5;8.1  |
|               |             | 589                   | 502                | 9.2           |
|               | longitudinal| 689;666;53            | 457;525;54         | 11.5;10.5;10  |
|               |             | 631                   | 510                | 10.8          |

As can be seen from the data in table 1, the values for all indicators of the pierced billet are significantly higher than that of cast.

From the standpoint of the theory of metal forming, longitudinal rolling is now presented as a “regular upsetting”, with a continuous supply of metal under the peens. The processes of upset and longitudinal rolling are studied in detail in the works of S. I. Gubkin, I. M. Pavlov, A. I. Tselikov, Ya. M. Okhrimenko and A. A. Presnyakov [16–20]. On the basis of these research and work, the rolling and reducing processes were modeled by another type of metal forming – upsetting. To determine the mechanical properties after rolling and reduction processes, cylindrical samples were taken with pierced and solid cast billets. To provide 30% compression samples 75 mm long upsetting to achieve equal 52.5 mm in length. Regarding the size of the compression, a pipe with a wall of ~ 10 mm, rolled from a sleeve with a wall thickness of 33 mm, was taken as an example, and a total compression of 30% was achieved. Before upsetting, the samples were heated in an electric furnace to 1000 °C, providing better deformation conditions and simulating factory technological parameters. Time in the furnace at this temperature was calculated on the basis of 1.0–1.5 minutes per 1 mm section, which, respectively, for samples with a diameter of 30 mm was 30–45 minutes.

After upsetting, standard specimens for testing were made from these samples. The test results are shown in table 2.

Analyzing the results of table 2, it is seen that the deviation of the mechanical properties values practically decreased to 3%.
To ensure a smaller discrepancy between the values for each sample and to obtain a more accurate averaged value, all samples were heat-treated in an SNOL 7.2/1300 electric furnace. The heat treatment mode, based on the chemical composition of the steel and the resulting strength group:

- heating temperature – 880–890°C;
- heating rate ~10 °C/min;
- heating time – 1.0 min per 1 mm section;
- cooling rate ~ 100 °C/c;
- tempering temperature – 600–620 °C;
- holding time at tempering – 2.0 min per 1 mm section.

Table 2. The mechanical properties of the upsetted samples.

| Type of billet | Test sample | Tensile strength, MPa | Yield strength, MPa | Elongation, % |
|----------------|-------------|-----------------------|--------------------|--------------|
| Cast           | transverse  | 767;808;78 9          | 643;622;62 0       | 14.3;14.9;14.8 |
|                |             | 788                   | 628                | 14.7         |
|                | longitudinal| 802;809;78 1          | 623;635;65 9       | 14.8;14.8;15.1 |
|                |             | 797                   | 639                | 14.9         |
| Pierced        | transverse  | 817;792;79 9          | 625;651;64 6       | 14.9;15.0;14.9 |
|                |             | 803                   | 641                | 14.9         |
|                | longitudinal| 821;814;79 8          | 640;635;66 5       | 15.3;15.1;14.8 |
|                |             | 811                   | 647                | 15.1         |

Table 3 shows the results of the final mechanical properties obtained after heat treatment.

Table 3. Mechanical properties of heat-treated samples.

| Type of billet | Test sample | Tensile strength, MPa | Yield strength, MPa | Elongation, % |
|----------------|-------------|-----------------------|--------------------|--------------|
| Cast           | transverse  | 790;801;786 792       | 633;642;629 635    | 14.8;14.9;15.1 |
|                | longitudinal| 793;799;794 795       | 636;640;645 640    | 15.5;14.8;15.0 |
|                |             | 799                   | 640                | 15.1         |
| Pierced        | transverse  | 807;793;796 799       | 650;641;649 647    | 14.4;15.3;15.3 |
|                |             | 808;810;797 805       | 651;653;644 649    | 15.0;15.4;15.6 |
|                |             |                       |                    | 15.3         |
| GOST 632-80,   |             |                       |                    |              |
| GOST 633-80    |             |                       |                    |              |
| API 5CT        |             |                       |                    |              |

GOST 632-80, GOST 633-80

API 5CT

not less than 689

not less than 13

not less than 13 (for a sample with a cross section of 70-80 mm²)
According to the results of heat treatment, the discrepancy between the values decreased, which indicates the alignment of the mechanical properties and structure along the cross section of the samples. The values of the indicators are within the permissible limits of mechanical properties according to GOST 632-80, GOST 633-80 and API 5CT, and corresponds to strength group E (according to GOST) or N80 (according to API).

4. Conclusion

The possibility of producing seamless hot-rolled pipes from a hollow billet is substantiated, providing the necessary set of mechanical properties that are regulated by the standards GOST 632-80, GOST 633-80 and API 5CT. The deviation of the mechanical properties of products obtained from cast and pierced billets is less than 3%. The results of casting, deformation and subsequent heat treatment of the researched pipe samples correspond to the standardized indicators of the standards GOST 632-80, GOST 633-80 and API 5CT, which confirms the feasibility of producing pipes from a hollow billet, considering improving the quality of the structure.

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