Structural and Mechanical Preparation of Rolled Products for Fasteners

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Abstract. Based on the analysis of quality factors of calibrated rolled products, the structural and mechanical properties of steel 20Mn2Si for cold heading of hardware products are formed. The balance is established during the preparation of gauged bars to manufacture fasteners from it. To produce gauged bars with a diameter of 7.75 mm, a new technological flow is proposed using hot rolled products with a diameter of 8.5 mm. The proposed resource-saving technology for preparing rolled steel 20Mn2Si excludes spheroidize annealing, which reduces labor and energy costs, increases the environmental friendliness of production and operational reliability of fasteners. This eliminates the possibility of quenching cracks, the need for straightening products, the risk of thread defects and reduces the cost of manufacturing long bolts. This makes it possible to significantly reduce the process chain, reduce the cost of manufacturing fasteners and meet regulatory requirements for their mechanical properties.

1. Introduction
Over the past three decades, world mechanical engineering has undergone significant changes related to reducing production costs, the negative impact on the environment, improving product quality and developing new types of products [1, 2].

The mechanical engineering state is one of the most important indicators of the economy state. Therefore, the problems of mechanical engineering are problems of the economy as a whole. No state can have an efficient economy without a modern, competitive machine-building industry.

In many branches of mechanical engineering that consume metal products, significant technical progress has been achieved in recent years [3-5]. In this regard, metals, as the main structural materials, are subject to increasing requirements in terms of strength, plastic and viscosity characteristics, stampability, corrosion resistance, durability, as well as new functional properties [6-8]. At the same time, there is a growing need to reduce costs, save material and energy resources, use them in the interests of the economy and solve increasingly major environmental problems [9, 10].
2. Immediacy of the problem
An important task is not only to ensure the metal production that meet the modern requirements of consumers [11, 12], but also to produce highly-competitive materials with better characteristics and stimulate the development of the Russian economy. This is particularly relevant for restructuring of machine-building industries, because these days much needs to be done in short time, with limited resources. Therefore, it is vital to determine the use of products, on the base of which market and technologies it is most likely to create a globally competitive production [13, 14].

3. Problem statement
One of the most important parts in mechanical engineering is fasteners made by cold heading from calibrated rolled products [15-17]. As a rule, structural carbon steels with a carbon content of up to 0.5% are used for the manufacture of fasteners produced by cold heading. All mechanical properties, chemical composition of this steel type and heading are regulated by GOST 10702-78, and deviations from dimensions by GOST 2590-88. The dimensions and mechanical properties of the initial hot-rolled products have a significant impact on the production of high-quality calibrated rolled products with certain specifications [18, 19]. These requirements include: the optimal quality level of finished rolled products in terms of mechanical properties, profile accuracy, surface quality condition, coil mass, high yield of the material during processing, and much more.

The existing technology for manufacturing calibrated rolled products includes a greater number of alternating operations of cold plastic deformation, heat treatment (recrystallization annealing) and preparatory (related to deformation) operations. Long-term manufacturing technology of calibrated rolled products increases its cost, and in some cases reduces the quality of products (increases the grain size, the depth of the decarbonized layer of medium and high-carbon steel qualities, reduces the level of mechanical properties).

The implementation of a resource-saving technology for obtaining long steel products for cold-heading production of automobile plants, spheroidized directly from the rolling heating in the conditions of mill 350 of OAO “Oskolsky electrometallurgical work”, allows to obtain rolled products with a fine pseudo-spheroidized structure. In terms of mechanical properties, it does not differ from rolled metal subjected to traditional furnace spheroidizing annealing. The use of high-quality hot-rolled products with specified mechanical properties and high accuracy of rolled products allows to provide metal savings and reduces the cost of calibrated rolled products by 13% [20].

4. Study materials
All metallurgical plants produce hot-rolled products mainly according to dimensions in accordance with GOST 2590-88 standard rolling accuracy. This standard regulates the deviation of the usual accuracy in the range of 0.3...0.5 mm. The ovality of rolled products should not exceed 50% of the maximum deviations in diameter. At a number of metallurgical plants and industries, such as OAO “Beloretsky metallurgical plant” in Beloretsk, RUE “Belorussky metallurgical plant” in the Republic of Belarus, OAO “Magnitogorsk iron and steel works” in Magnitogorsk, OAO "Oskol electrometallurgical combine” in Stary Oskol, the mills are equipped with multistand finishing blocks and two-stage cooling lines for wire rod. This allows one to get a ready-made profile with a size accuracy of ±0.15 mm with an ovality of up to 0.2 mm. Rolled metal is characterized by a high quality level.

In some metallurgical plants, controlled rolling is used to produce wire rods on wire mills from structural steels with improved mechanical properties. Controlled rolling allows to produce hot rolled products with optimal strength and viscosity indicators. Accelerated cooling of the wire rod up to 650°C after the finishing stand of the rolling mill provides this. The use of this rolled product type allows to exclude subsequent heat treatment during further technological conversion of the wire rod.

The existing production technology of calibrated rolled steel 20Mn2Si with a diameter of 7.75 mm² involves drawing a wire rod with a diameter of 9.0 mm on mill VS-16, spheroidizing annealing in a furnace with a shielding atmosphere and final drawing. The preparation procedure of wire rod before
the first drawing and after annealing before the second drawing includes etching, washing and phosphate treatment.

The heat treatment before cold deformation is aimed at creating a certain structure that can perceive large plastic shifts. In this case, the microstructure of the metal reaches the proportion of granular perlite up to 80-90%. Although the required technological plasticity is provided by having the granular perlite more than 60%.

Obtaining a wire rod with highly precise specified mechanical properties from metallurgical enterprises allows to solve the problem of the manufactured hardware quality and expand production opportunities [21-23]. This allows us to create resource-saving technologies for the production of metal products.

Practical significance. A new technology using hot rolled steel with a diameter of 8.5 mm has been proposed to produce calibrated rolled steel 20Mn2Si with a diameter of 7.75 mm. The original rod was produced with size precision for diameter ±0.2 mm, the ovality of 0.25 mm, upsetting group 1-66, there could be cracks not more than 0.1 mm deep, the rupture strength of not more than 550 MPa, relative narrowing of not less than 60%.

The chemical composition of hot rolled products is presented in table 1.

**Table 1. Chemical composition of hot rolled steel 20Mn2Si Ø8.5 mm**

| Chemical composition of hot rolled steel, % |
|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| C    | Si | Mn | S  | P  | Cr | Mo | Cu | Al | B  | N                        |
| 0.20-0.23 | 0.10 | 0.85-0.10 | 0.015 | 0.015 | 0.10 | 0.20 | 0.10 | 0.02-0.20 | 0.002-0.005 | 0.01 max |

**Current technology**

- Hot-rolled steel Ø9.0 mm
- Surface preparation for calibration
- Calibration Ø8.10 mm
- Spheroidize annealing
- Surface preparation for calibration
- Calibration Ø7.75 mm
- Quality control test

**Proposed technology**

- Hot-rolled steel Ø8.5 mm
- Surface preparation for calibration
- Calibration Ø7.75 mm
- Quality control test

**Figure 1.** The current and proposed manufacturing technology for calibrated rolled steel 20Mn2Si Ø7.75mm.
Figure 1 shows the current and proposed manufacturing technology for calibrated rolled steel 20Mn2Si.

Hot rolled steel 20Mn2Si, which was used for simplified manufacturing technology of calibrated rolled products, passed a thorough input control for mechanical parameters and dimensions, sample upsetting up to 1/3H, and the values were put in table 2. All values were compared to the acceptable values of GOST 10702-78.

After calibration for the size of 7.75 mm in diameter, the calibrated rolled products were also checked for mechanical properties, sample upsetting up to 1/3H, and the values obtained were also put in table 2. The results were compared to acceptable values of GOST10702-78.

Table 2. Quality characteristics of the hot rolled steel Ø8,5 mm and calibrated rolled steel Ø7.75 mm 20Mn2Si.

| No | Temporary tear resistance of hot rolling Ø 8,5 mm, kgf/mm² | Relative reduction of hot rolling Ø 8,5 mm, % | Temporary tear resistance of a calibrated rolling Ø 7,75 mm, kgf/mm² | Relative narrowing of a calibrated rolling Ø 7,75 mm, % | Upsetting up to 1/3H of hot rolled products Ø 8,5 mm | Upsetting up to 1/3H of gauged bars GOST 10702-78 Ø 7,75 mm | Temporary tear resistance of hot rolled products Ø 8,5 mm, kgf/mm² | Relative narrowing of hot rolled products Ø 8,5 mm, % | Temporary tear resistance of a calibrated rolling stock Ø 7,75 mm, kgf/mm² | Relative narrowing of the calibrated rolling stock Ø7,75 mm, % according to GOST 10702-78 |
|----|--------------------------------------------------------|---------------------------------|---------------------------------------------------------------|-----------------------------|-----------------------------|--------------------------------|---------------------------------------------------------------|-----------------------------|---------------------------------------------------------------|--------------------------------|
| 1  | 52,3                                                   | 63,8                            | 64,4                                                           | 59,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 2  | 51,6                                                   | 64,2                            | 62,9                                                           | 59,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 3  | 51,7                                                   | 66,8                            | 63,1                                                           | 59,9                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 4  | 49,8                                                   | 65,5                            | 63,2                                                           | 59,5                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 5  | 50,3                                                   | 65,9                            | 64,0                                                           | 57,8                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 6  | 56,0                                                   | 59,9                            | 69,2                                                           | 54,8                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 7  | 49,8                                                   | 63,1                            | 64,7                                                           | 55,2                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 8  | 51,2                                                   | 65,8                            | 65,1                                                           | 59,5                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 9  | 50,0                                                   | 65,6                            | 63,6                                                           | 59,6                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 10 | 50,3                                                   | 64,5                            | 64,3                                                           | 56,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 11 | 50,1                                                   | 62,9                            | 62,4                                                           | 58,0                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 12 | 51,3                                                   | 64,1                            | 64,9                                                           | 58,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 13 | 52,8                                                   | 63,0                            | 66,8                                                           | 56,6                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 14 | 53,8                                                   | 59,7                            | 68,7                                                           | 57,7                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 15 | 53,4                                                   | 64,3                            | 68,3                                                           | 56,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 16 | 53,6                                                   | 64,4                            | 66,3                                                           | 58,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 17 | 50,4                                                   | 64,4                            | 63,6                                                           | 58,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 18 | 53,9                                                   | 62,9                            | 66,9                                                           | 54,7                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 19 | 53,7                                                   | 64,4                            | 68,7                                                           | 58,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 20 | 54,0                                                   | 63,3                            | 65,5                                                           | 58,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 21 | 53,1                                                   | 65,8                            | 66,6                                                           | 58,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
| 22 | 50,6                                                   | 64,5                            | 64,3                                                           | 58,3                        | pass                        | pass                          | 55                                                            | 60                          | 70                                                            | 55                           |
5. Conclusions
All samples of hot rolled steel 20Mn2Si made according to the proposed technology, after calibration Ø7.75 mm, passed the test for an upsetting of up to 1/3H and were recognized as suitable.

The mechanical properties of the calibrated rolled steel Ø7.75 mm correspond to GOST 10702-78. Hot rolled steel 20Mn2Si Ø8.5 mm is suitable for the production of calibrated rolled steel Ø7.75 mm according to the proposed technology.

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