Resource efficient preparation of high quality rolled stock for motor vehicles’ fastening

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Abstract. At the present moment the top priority issues are becoming the aspects of resource and utility saving in the process of manufacturing of gauged bars for upsetting of fastening for motor vehicles while providing its better quality and competitive ability. The dominating factor in this direction is the enhancing of efficiency of the full process chain by means of cost saving for both metal and energy. This paper is presenting the results of research of the method for preparation of 38XA steel that has proved itself good for manufacturing of fastening elements in the car industry. It has been proved that drawing of the rolled stock with optimal drafting ensures absence of ellipticity and scale. The available light oxide coating has been removed by etching during some seconds. The resource saving rolled stock processing method is ecologically friendly, causes formation of highly dispersed equally spaced structure and increases the capacity to metal forming. Thereby this increases the upsetting tools service life. At the same time, the absence of the decarburization layer enables to reduce the number of transitions in the process of upsetting of metal articles.

1. Introduction

At the present moment [1-3] the top priority issues are becoming the aspects of resource and utility saving [2-4] in the process of calibration of gauged bars for upsetting of fastening for motor vehicles while providing its better quality and competitive ability [5,6]. The dominating factor in this direction is the enhancing of efficiency of the full process chain [7,8,17] by means of cost saving both for metal and for energy [9,10,18].

The quality of metal articles may be provided by using of corresponding materials or technological processes [11]. For upsetting, it is necessary to use the metal which corresponds to the highest standards of strength, plasticity and compression.
The rolled stock quality parameters are related to a range of its structural and mechanical properties [12,13], which are formed by metal drawing through the die. The rolled stock shall ensure the compression without defects [14] (the optimal compression shall be not more than 1/3 of its height).

The rolled stock drawing quality is determined by the frames of discrepancy of the speeds and of the time required for operations of preparation, reducing and thermal treatment. Electrical heating or warming up in the gas heaters lasts for 10-36 hours, and the warming up by high frequency currents (HFC) - up to 6 minutes with further cooling for about 6 hours. While doing so, it is important to ensure the required measure of dispersion of the metal grains and structure, which provide the required properties.

The most widely spread method is the rolled stock bell-furnace annealing, after which apart from the granular perlite, the elements of lamellar perlite may appear, which cause the mechanical properties dispersion along the scope of the full strip.

In the rolled metal used for critical bolts production, the presence of decarburized layer, grooves and scores, etc. is excluded [15]. That is why the inadmissible defects shall be removed by a harmful procedure of etching or by turning, which increase the cost of the finished articles.

In the process of work it is proposed to perform the warming up for annealing in induction block, which excludes the decarburization of the rolled metal surface due to guaranteed temperature stability. This increases the rolled metal quality, the productivity and economic efficiency of the process, enables to carry out its automation and ensures the lack of toxic discharges into atmosphere.

2. Materials and research methods
In this paper the 38XA steel has been studied (Table 1) that has proved itself to be good for manufacturing of the fastening elements for car industry.

| No | Process diagram | Rolled stock diameter, mm | Content of elements, % |
|----|----------------|--------------------------|------------------------|
| 1  | 1              | 12.0                     | C 0.39 Mn 0.62 Si 0.18 P 0.009 S 0.015 Cr 0.87 |
| 2  | 2              | 14.0                     | C 0.40 Mn 0.64 Si 0.19 P 0.021 S 0.017 Cr 0.9 |

The method used for rolled stock processing from a diameter of 12.0 mm to 9.65 mm at production facilities is: furnace annealing (750°C, 24 h); etching; drawing (from 12.0 mm to 11.0 mm); furnace annealing; etching; drawing (from 11.0 mm to 10.2 mm); turning (from 10.2 mm to 9.97 mm); drawing (from 9.97 mm to 9.65 mm); lubrication.

During removal of the defects by turning, about 55 kg of metal chips is obtained per each ton of metal (5.5%). In case of scale removal by etching some additional time would be required, ecologically toxic solutions will be involved, requiring expensive utilization.

The authors have studied two methods of rolled stock processing using HFC as follows:

- Method 1. Rolled stock Ø 12, mm: etching; drawing (reducing by 15.9%); annealing (760-780°C); etching; drawing (reducing by 23%); annealing (760-780°C); etching; drawing (reducing by 0%).

- Method 2. Rolled stock Ø 14 mm: etching; drawing (reducing by 13.7%); annealing (760-780°C); etching; drawing (reducing by 14.8%); annealing (760-780°C); etching; drawing (reducing by 15.9%); annealing (760-780°C); etching; drawing for Ø 9.65 mm.

3. Investigation results
Statistical analysis of results of the existing process scheme of 38XA steel showed increase of rolled stock hardness by 50% above the admissible HB >207, the decarburized layer of the rolled metal is higher than the norm (over 0.05 mm) for 20% of rolled metal. For the major part of the metal Ψ < 60%, what is below the admissible value. The surface quality parameter satisfies the GOST 14955-77
requirements only for 50% of the rolled stock. As a result only 50% of metal corresponds to the requirements.

It has been established that the rolled stock properties in the strip have been distributed in an uneven manner. In this way, the microstructure of external ends is more finely dispersed than that of the internal ends. This is caused by a higher speed of the strip external sides’ cooling comparing to the internal ones. In case of rolled metal annealing, a finely dispersed microstructure equally distributed along its full length is formed in the HFC inductor. That leads to the drop in hardness (HB by 30-31 units) and to the drop in strength (strength limit by 70-90 MPa; of yield strength – by 40-70 MPa), but also leads to increase of plastic properties (contraction ratio – by 11-13%). With the increase of the number of HFC annealings as a result of further cold calibration, the change of the microstructure is observed. For example, sorbitic perlite acquires a less dispersed form. As such type of rolled stock Ø11.0 mm annealing leads to emerging of perlite with small grains, the Ø9.65 mm rolled metal already forms the uniformly distributed structure along the section of the rolled stock, which consists of dotted finely grained perlite with evenly distributed ferrite.

Furthermore, the hardness does not increase HB 194, and decarburized layer and scale are missing, what testifies about high quality of the surface layer of the rolled stock. At the same time this method eliminates the ellipticity of the finished rolled metal. The applicability factor of the finished rolled stock for cold pressing is rather high and amounts to $\sigma_0.2 / \sigma_{upst} = 41/68 = 0.6$.

Earlier [16] a process scheme for rolled stock preparation for cold upsetting of metal items had been patented, which included the coil annealing with HFC warming up, that guarantees together with the system of control and monitoring a high ($\pm 3\, ^\circ$C) accuracy of maintaining of the temperature conditions, and fractional deformation in dies with different degree of drafting. Bars Ø8.0 mm from steels of different grades (10, 20, 20Г2P, 30Г1P, 38ХГ1М) have been subjected to calibration with different degree of drafting. The strength and plastic properties of rolled stock calibrated after fractional deformation have been studied (8.0 – 7.6 – 6.88 – 6.23 – 5.10 – 4.39). Analysis of study results of spheroidizing (723-750°C) and recrystallization annealing conditions of the steels, which have been studied in this paper with HFC warming up and temperature ranges have shown that using of HFC warming up during steel annealing in comparison with annealing in bell furnaces provides increase of the structure dispensability and absence of the decarburized layer. At the same time the strength and plasticity parameters do not practically differ.

However, in case of making deformations before the annealing with HFC warming up in unwound state, the microstructure is observed with full spheroidization. However, this process diagram [16] differs from the one proposed by us by a considerably longer process cycle and is rather a labor and energy consuming. For example, the process of unwinding of the coil upstream of the HFC induction box and its back winding requires availability of special equipment and is rather labor consuming. Besides, in case of the metal warming up in the coils, the uniformity of properties shall not be guaranteed for the full scope of rolled metal. In order to exclude this negative feature, the production engineers have to do a short-time spheroidizing and recrystallization annealing in the furnaces after winding of the bar into the coil. And this leads to increasingly greater extension of the technological process and in any case it would not always lead to achieving of the uniformity of properties both along the length and for the cross section of the rolled stock.

4. Conclusions
Based on study results of methods for preparation of the 38XA steel rolled stock using the high frequency current warming up, it has been established that drawing with optimum drafting in three steps ensures the absence of ellipticity and scale of the finished rolled metal. The available light oxide coating is removed by etching during some seconds.

The resource saving method 2 for the rolled stock processing is ecologically friendly, causes the formation of the finely dispersed uniformly distributed structure and increases the capacity to form shaping, resulting in the increase of the service life of the upsetting tools. At the same time the absence
of decarburization layer enables to reduce the number of transitions in the process of upsetting of metal articles.

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