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COLD DRAWING SCHEDULES FOR RST 34-2 (1.0034) STEEL WIRE FOR CORRECTION OF OVERHEATING DEFECTS AND BREAKLESS ENSURING

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The analysis of wire drawing current state and prospects shows [1] that in the world there is a tendency to expand the range of materials by chemical composition, initial state, finishing mechanical properties and the attendant decrease in production. Development of drawing in small batches complex technologies allows making wire and deformed semi-finished products from operational properties and schedules, which are inaccessible to the multihole drawing machine. Achieving these goals is facilitated by the increasing use of mathematical modeling to assess the stress-strain and thermal state of materials, taking into account their plastic and thermophysical properties, accumulated damage and cracks, followed by assessment of their healing properties. Such materials to some extent reduce the stability of dies, but this is quite acceptable with low series and frequent changes in the range of forgings. Recycling of worn or defective wire is increasingly used. In particular, defects can occur when drawing steel wire with intermediate annealing, when it is possible to overheat individual wire coils. Due to the deterioration of mechanical properties, its further processing by pressure is almost impossible. Overheating defects are usually eliminated by additional heat treatment [2], which increases the cost of the wire.

The purpose of this work is to develop cold drawing schedules of superheated wire, which ensure the metal continuity in the deformation process while increasing its strength.

The research included the RSt34-2 (EN 1.0034) steel wire with an initial diameter $D = 4$ mm, wound in coils weighing 1 ton each, which at 1140 – 1160 °C and exposure at this temperature for 3 hours were overheated. Cold drawing schedules were tested at drawing speeds from 2.25 m/s in the first pass to 0.086 m/s in the last passes. Annealing of the samples was performed in an electric furnace at 900 - 930 °C for 2 hours. The mechanical properties of the wire were researched according to DIN EN ISO 6892-1-2020 on a machine P-0.5 with a force of 5 kN. Metallographic studies have shown that in the longitudinal and transverse

sections of the wire, grains formed after overheating at 1140 - 1160 °C are small and equilibrium. Their diameter ranges from 6 to 24 μm in the transverse and from 5 to 70 μm in the longitudinal section of the wire, which indicates overheating of the metal under study. Thermomechanical processing (TMP) of the wire was conducted by the following schedules: (1) Cold drawing (properties correspond with DIN EN ISO 6892-1-2020); (2) Cold drawing + annealing (properties correspond with DIN EN ISO 6892-1-2020); (3) Cold drawing + overheating; (4) Cold drawing + overheating + cold drawing; (5) Cold drawing + overheating + cold drawing + annealing.

Overheating of the wire sharply reduces its yield ability: the drawing ratio of the samples is reduced by 4.5 - 10 times compared to the limit value regulated by DIN EN ISO 6892-1-2020. Due to the thick layer of scale on the surface, ultimate strength and yield strength low values with abnormally low yield ability, the use of wire is impossible even as a binding material. The existing technological processes for drawing carbon steels turned out to be unacceptable: the wire could not be cleaned of scale, as repeated bending between the rollers of the machine led to its breakage. Etching of large coils in sulfuric acid did not remove scale on the turns of the wire located in the coils central part. The most acceptable option for cleaning the surface of the wire was to pull it before entering the die holder through five worn wires with the initial working channel diameter equal to the wire diameter. In this case, the main layer of scale was lost in worn drawing die, and its remnants in the form of small grains fell off during the first drawing pass into the soap box when the wire entered the deforming die.

Cold drawing of superheated wire in standard schedules was accompanied by frequent breaks, especially in the first pass. The frequency of breaks did not depend on the lubricant used. Considering this, the drawing on the first pass was later conducted without lubrication, and starting from the second pass, during the drawing of wire virtually clean from scale we used household soap dry powder.

Wire breaks during drawing occurred between the deforming die with the wire coil placed on it, in the tong jaws and between tongs and the deforming die. The reasons of wire breaks at its entrance to the deforming die were increased drawing speed, large coil mass and low yield strength of the wire material. At the initial moment of wire deformation at a drawing speed of 0.418 m/s, the back-pull load Q required to unwind the coil on the support bearing, exceeded 2.5 kN. The back-pull stress, $\sigma_Q = Q/F_0$ (here F_0 is the cross-sectional area of the wire at the entrance to the deforming die) exceeded the yield strength of superheated steel. This caused wire plastic deformation before its drawing and subsequent breakage due to low yield ability ($\delta = 2.0 - 4.6\%$). The continuity of the metal was preserved by reducing the drawing speed to 0.245 m/s and dividing the wire coil after the first drawing pass into coils weighing 60 – 80 kg, which did not cause a significant surge of back-pull load in subsequent passes, even with a twofold increase in drawing speed.

Wire breaks in the tongs at the exit of the deforming die were eliminated by experimental selection of the optimal drawing speed V and drawing ratio on the i -

i-th pass ($\mu_i = d_{i-1}^2 / d_i^2$, where d_{i-1} and d_i are wire diameters before and after drawing on the *i*-th pass), taking into account the allowable wear of the die: the first pass – $V = 0.245$ m/s, $\mu = 1.27 - 1.34$; the second pass – $V = 0.418$ m/s, $\mu = 1.29 - 1.52$; the following passes – $V = 0.518$ m/s, $\mu = 1.20 - 1.38$.

The mechanical properties of the wire with a diameter of 2.55 mm and 2.05 mm, obtained by cold drawing in selected schedules, were acceptable for its further processing into nails or usage as a binding material. The increase in strength during cold drawing of wire with overheating defects was much more intense than during cold rolling of the same steel. The equations for dependence of wire ultimate strength and yield strength from the drawing ratio were obtained.

An equation that allows to predict the acceptable cross-sectional area of the wire end sections during drawing has been devised. An inequation has been created that connects the parameters of the Korber - Eichinger equation and the sharpening of the wire ends with burrs and reductions in the cross-sectional area due to the deepening of the tongs jaws when clamping the wire ends. The authors experimentally proved that the design of drawing overheated wire technology taking into account the conditions of this inequation guarantees the elimination of breaks both at the end sections of the wire (at the beginning of drawing) and at a stable stage of the process. In particular, it was possible to develop technologies for drawing overheated wire made of RSt 34-2 steel with abnormally low mechanical properties and thus to abolish additional heat treatment that eliminates overheating defects.

The results show that when the drawing speed is reduced from 0.418 m/s to 0.245 m/s, the back force stress decreases from 203 MPa to 163.8 MPa, the limit drawing ratio increases per pass from 1.025; 1.05 and 1.108 to 1.09; 1.11 and 1.17, i.e. the diameter of the wire at the die exit can be reduced by 0.10-0.12 mm. Qualitatively the same result can be obtained by reducing the difference between the diameter of the wire pointed (sharpened) end and the diameter of the die from 0.5 mm to 0.1 mm. In this regard, to prevent wire breaks, it is advisable to choose the drawing routes, taking into account the available die of the rolls in the grinding machine. The diameter of the wire in each pass must be selected so that it does not exceed the diameter of its end section after sharpening in the appropriate die by more than 15%. If it was possible to eliminate the crumpling and cutting of burrs on the wire ($p_i = 0$), the limit drawing ratio on the first pass would increase from 1.05 to 1.135 ($\sigma_Q = 203$ MPa), as the route of drawing 4 mm \rightarrow 3.9 mm could be replaced by 4 mm \rightarrow 3.75 mm.

Practical verification of the strength criterion showed its acceptability for the development of technology for drawing superheated wire. In particular, the drawing ratio in one pass can be significantly increased by reducing the back force by forcibly untwisting the coil with a linear speed 20 - 30% smaller than the drawing speed ($V = 0.245$ m/s). In this case, the surge of the back force disappears, which allows to use deforming die with a diameter of 3.45 mm at $\Delta_1 = 0.25$ mm at the first pass. Wire drawing in the second pass takes place in changed conditions.

During rolling in the grinding machine, the diameter of the wire end is reduced to 2.52 mm. Lubrication with soap powder helps to reduce the coefficient of friction from 0.5 to 0.1 at the drawing steady stage. With a lighter shape with a coil which does not weigh more than 80 kg, at a drawing speed of $V = 0.418$ m/s, the back force is reduced to 46 MPa. Under these conditions, the calculation according to the strength criterion provides a limit drawing ratio on the second pass $\mu_2 = 1.52$ along the route of drawing 3.45 mm \rightarrow 2.80 mm. On the third pass it is necessary to make a wire with a diameter of 2.55 mm, which is carried out with a drawing speed of 0.518 m/s. Under drawing conditions, it is allowed to reduce the diameter of the deforming die to 2.32 mm. On the fourth pass it was impossible to draw the wire along the route 2.55 mm \rightarrow 2.05 mm, because due to the sharpening of the wire end with a diameter of 1.67 mm, it broke in the tongs at the drawing initial moment. Verification of this experimental fact by analytical calculations for inequality confirmed the probability of wire breakage: $(\sigma_U^e)_i / (\sigma_U^d)_i = 0.88$. In this regard, the drawing routes on the fourth and fifth passes 2.55 mm \rightarrow 2.32 mm \rightarrow 2.05 mm were chosen based on the presence of a deforming die with a diameter of 2.32 mm. It should be noted that the fifth pass could be avoided if the grinding machine had a caliber with a diameter of 1.8 mm.

[1]. Radionov A. A. and Radionova L. V. 2013 Russian Internet Journal of Industrial Engineering 1 3-11

[2]. Totten G. E. 2006 Steel Heat Treatment: Metallurgy And Technologies (Taylor & Francis Group)

РЕЖИМЫ ХОЛОДНОГО ВОЛОЧЕНИЯ СТАЛЬНОЙ ПРОВОЛОКИ RST34-2 (1.0034) ДЛЯ ИСПРАВЛЕНИЯ ДЕФЕКТОВ ПЕРЕГРЕВА И ОБЕСПЕЧЕНИЯ БЕЗОБРЫВНОСТИ

Разработана технология рециклинга проволоки из стали RSt34-2 (EN 1.0034) с дефектом «перегрев» способами холодного волочения. При степени вытяжки 1,20–1,52 за один проход и скоростях волочения от 0,245 м/с до 0,518 м/с технология обеспечивает повышение прочности до уровня, достаточного для использования проволоки в качестве обвязочного, армирующего материала или материала заготовок для изготовления гвоздей. Получены аналитические зависимости предела прочности и предела текучести перегретой проволоки от степени её вытяжки при волочении. Предложено неравенство, связывающее напряжение, возникающее в начальный момент волочения в поперечном сечении заостренного участка конца проволоки, и напряжение среза заусенцев, возникающих при заточке, с пределом прочности стали. Неравенство позволяет рассчитывать предельную степень вытяжки на каждом переходе.

Наукове видання

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