Introduction of Wheel Production on a New Pressing and Rolling Line

A. V. Kushnarev*, A. A. Kirichkov*, V. D. Shestak*, V. V. Timofeev*, and A. A. Bogatovb

*OAO Nizhnetagil’ski Metallurgicheskii Kombinat (NTMK), Nizhnii Tagil, Russia
bEl’tsin Ural Federal University, Yekaterinburg, Russia

Abstract—A new pressing and rolling line with high levels of mechanization and automatic control has been introduced for wheel production at OAO Nizhnetagil’ski Metallurgicheskii Kombinat, because the new product range required improved production technology. This line incorporates new designs and permits the production of high-quality cast-iron wheels at high speed.

DOI: 10.3103/S0967091210120181

The new pressing and rolling line at OAO Nizhnetagil’ski Metallurgicheskii Kombinat (NTMK) includes a system for hydraulic scale removal; three stamping presses; a wheel-rolling mill; a marking machine; and a laser instrument for measurement of the cast-iron wheels. Six gantry-type robot manipulators are used for transportation, with computerized automatic control. High product quality and productivity depends on the production technology: the calibration of the deformation tool; the methods of hydraulic scale removal, cooling, and tool lubrication; and the deformation conditions in the presses and rolling mill.

Initially, the SMS Eumoco equipment increased the rejection rate of the cast-iron wheels (from 20.4 to 68%); the debugging period lasted 1.5 years. The stamping method proposed by SMS Eumoco was nonoptimal, on account of the nonuniform metal distribution over the perimeter of the forging [1]. (The radius and height fluctuated from the rated values by as much as 14 and 21 mm, respectively.) The solution was to stamp the blanks on a 50-MN press with plane-parallel dies and a self-centering calibration wheel [2]. As a result, the rejection rate declined to 1.43% in 2008, and the quantity of wheels with inadequate diameter to 1.66%.

On introducing the new product range, the tool calibration recommended by SMS Eumoco proved unsatisfactory. Therefore, the production equipment was selected on the basis of [1, 2]. Thus, in rolling experimental batches of blanks 010, 073B-1, 077A-2, 097-1, and 097A-1 with a large hub diameter and projection of the hub by relative to the rim, the rejection rate was considerable, on account of cutting of the edges of the hub, disruption of the fixed roller attachment in the mill, and hence fluctuation in the blank’s internal diameter. The rolling process was stabilized without wheel rejection by changing the design of the edger rollers and their attachment to the shafts.

On introducing the production of wheel blank 010 (diameter 710 mm), the front and wear edging rollers are outside the space bounded by the external diameter of the hub and the internal diameter of the rim in the final stamped forging. This problem is addressed by introducing the optimal roller design. On introducing wheel blank 010, the design of the tension beam was modified and hence the reach was increased. This
ensured rolling of the crest over the whole perimeter of the blank.

In the production of wheel blanks 077A-1 and 127 with a cylindrical rolling-wheel surface, in the absence of a crest, the rolling mill is not turned on, since the control program has been developed and adapted for the manufacture of one-piece forged railroad wheels with a crest. This problem has also been successfully solved by plant specialists.

In the manufacture of blank 126-1, a wheel hub with the disk on the same side of the rim, the formation of depressions on the disk with annular buildup is prevented by changing the rolling conditions.

In rolling blank 127 (a wheel hub), an elliptical rolling-wheel surface must be formed in the second half of the rolling process. This entails correcting the cross section of the rim by final stamping.

These examples indicate that existing design programs for the calibration of the stamping presses and the wheel-rolling mills cannot react to problems that arise in the introduction of new profiles and the expansion of the product range. It is clear that calibration must involve simulation of the pressure treatment of the metals so as to verify the effectiveness of the design solution and identify the optimal calibration of the instrument and rolling conditions. Without provision for simulation, experience in calibration is invaluable.

The program for the production process and calibration of the deformation instrument requires determination of the final wheel mass, the technological losses of metal, and the optimal mass of the initial continuous-cast billet. Appropriate selection of the initial billet mass improves the precision of the iron wheels, facilitates the adjustment of the pressing and rolling line and also the control of the process, and ensures stable and rhythmical production. In the initial stage of the calculation, the cross-sectional contour of the final machined wheel is constructed in a CAD program, in the light of the mean dimensional tolerance field mandated in the standards or technical specifications. The most necessary tolerances and the metal losses $g_1$ in machining are established so as to obtain the specified geometry of the finished wheel within the tolerance field and also to remove the surface defects. In the next stage of the calculation, we determine the optimal production-tolerance field ensuring stable stamping and rolling. The rated wheel-blank contour is found by calculating half production tolerances, and the metal losses $g_2$ are established by calculating the mass of the wheel blank bounded by the minimum and rated contours. The need to plot the minimum and limiting contours of the wheel blank in the CAD program is explained in that the software of the laser measurement system within the pressing and rolling line constructs the actual contour of the wheel blank by scanning its surface and superimposes the result on the calculated contour. This permits not only monitoring of the wheel-blank dimensions but also visual assessment of its overall precision. This facilitates the ongoing correction of system setup by the operators in the pressing and rolling line. The extruded mass $g_3$ obtained in piercing a hole in the wheel hub is calculated after determining the dimensions of the upper and lower mandrels of the deforming tool in a 90-MN stamping and press and the broaching tool in a 50-MN press. The mass loss $g_4$ corresponding to metal wastage depends on the size of the blank, the furnace design, the heating conditions, the burner design, and the control system for fuel combustion. The metal losses are clearly evident in the figure.

The next step is to design the stamping system for a K5000 press, responsible for disk bending, wheel calibration, and hole piercing in the hub. First, the hub blank is placed on the outer end of the piercing bush. As it is lowered, it is centered relative to the axis of the lower die. The following dimensions are necessary for calibration of the wheel shape: the hub length; the thickness, position, and shape of the disk; the rim width; and the rim’s internal diameter. All the dimensions of the deformation tool must correspond to the dimensions of the hot wheel; precise determination of the linear-expansion coefficient of the metal is important. In addition, we must take account of the displacement of the hub relative to the rim due to the thermal stress induced by heat treatment. The working-surface contour of the upper deforming tool is determined by the rated minimum wheel dimensions on the inside; the working-surface contour of the lower deforming tool is determined by the rated minimum wheel dimensions on the outside. Thickness calibration of the rolled blank’s disk may increase the rim’s internal diameter. Therefore, the external diameter of the bending dies must be less than the rated internal diameters of the rim by the negative production tolerance on these dimensions.

The position of the working surfaces in the centering unit and the piercing bush that ensure length calibration of the hub is determined by the calculated projection and deadhead of the hub. In determining the cavity depth and the height of the die space, the base surfaces are the working surfaces of the repair rings; in