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# Shrinkage Defects Elimination Methods in the Bottom Necks of Cast Iron Rolls

**E. V. Menyailo**

*National Metallurgical Academy of Ukraine*
*4 Gagarin Ave., Dnipropetrovsk, 49600, Ukraine*

The sand mold of the bottom neck often does not provide directional solidification of cast due to accelerated solidification of the roll body when casting rolls in stationary molds. To avoid hot zones and shrinkage defects in the bottom roll necks it is reasonable to make the bottom neck in metal mold with sandy-argillaceous heat-insulation. Bottom neck molding with external chill also helps solve this problem

Keywords: SHRINKAGE DEFECTS, CAST IRON ROLLS, SAND MOLD, MOLDING, CASTING, CAST

**Introduction**

Hot zones and shrinkage defects often appear in the bottom necks when permanent-mold casting [1, 2]. They are caused by accelerated solidification of the roll body as compared to the bottom neck. In spite of the fact that the roll body diameter is 1.5-3.0 times larger than the neck one, body cooling in a metal mold leads to shrinkage feeding disturbance from the lost head. So, experimental research showed that at body diameter 450 mm solidification of iron with spheroidal graphite came to an end in approximately 70 min, and the bottom neck with diameter ~327 mm cooled in a sandy-argillaceous molding box in 130 min (**Figure 1a, b**). Therefore there are shrinkage defects in the axial zone of the bottom neck (cross-hatched zone "B" in **Figure 1 c, d**). These defects are not visible on the surface but can decrease operational durability of the roll.

Shrinkage defects in the upper neck and feeder head (cross-hatched zones "A" and “B” in **Figure 1 c, d)** are removed using method of combined arc-electroslag heating of the feeder head by not consumable electrodes. This method is developed at National Metallurgical Academy of Ukraine [3].

The task of present research is to develop the mold design providing accelerated solidification of the bottom roll neck as compared to the roll body in order to avoid the formation of hot zones and shrinkage defects.

**Results and Discussion**

We used a mathematical model of roll solidification process in the combined chill-sand mold boxes [4]. The model is based on the adjoint numerical solution of two-dimensional non-stationary thermal conductivity equation in the areas of liquid and solidifying metal, combined mold consisting of seven elements with various thermophysical properties and heat source (Q) for top feeder head heating. Also it is possible to change consequently heat source strength Q during the whole period of cast solidification.

The solidification process is explained by quasiequilibrum theory of two-phase zone. Hidden heat of crystallization is considered by effective coefficient of heat capacity. To raise accuracy of calculation it is necessary to refuse the uniform distribution of hidden heat of crystallization in the interval of temperatures liquidus-solidus corresponding to relative fraction of solid phase (φ) and, as a rule, defined from iron-carbon diagram. The interval $T_{liq}$-$T_{sol}$ was divided into three sections in which a part of precipitated solid phase was determined according to results of experimental measurements of real cast solidification (**Figure 1**). For example, it is determined that for hypoeutectic cast iron with spheroidal graphite ($T_{liq}$= 1230 ºC and $T_{sol}$=1125 ºC) calculated curves of cooling match to experimental ones if 20 % of solid phase precipitate in the interval of temperatures 1230-1210 ºC, 10 % in the interval 1209-1155 ºC and 70 % in the interval 1154-1125 ºC.

Experimental research revealed the bottom neck solidification accelerated by 20-30 % as compared to the upper neck. Besides, a correction considering phase-transition heat emission at eutectoid transformation ($\chi_e$) is introduced. Its value and temperature range are also defined taking into account experimental curves of cooling.

With account of stated above, we calculated the roll-standard (**Figure 2**) in which bottom neck solidification almost corresponds to solidification time of the experimental roll (**Figure 1b**). As modeling of feeder head filling-up with the melt is impossible, we accepted that the total time of upper neck solidification corresponded to time of experimental roll solidification.

The sand mold of the bottom neck often does not provide a directional cast solidification because of accelerated solidification of roll body (**Figure 2**). It does not make economic sense to reduce heat-removal because of decrease of wear-resistant cementite components in the working layer [5]. Therefore we investigated effect of new mold boxes of the bottom neck on metal solidification: metal mold with sand-argillaceous heat insulation 20 mm thick (**Figure 3a**) and external chill 20 mm thick in the molding box with a sandy mix (**Figure 3b**).

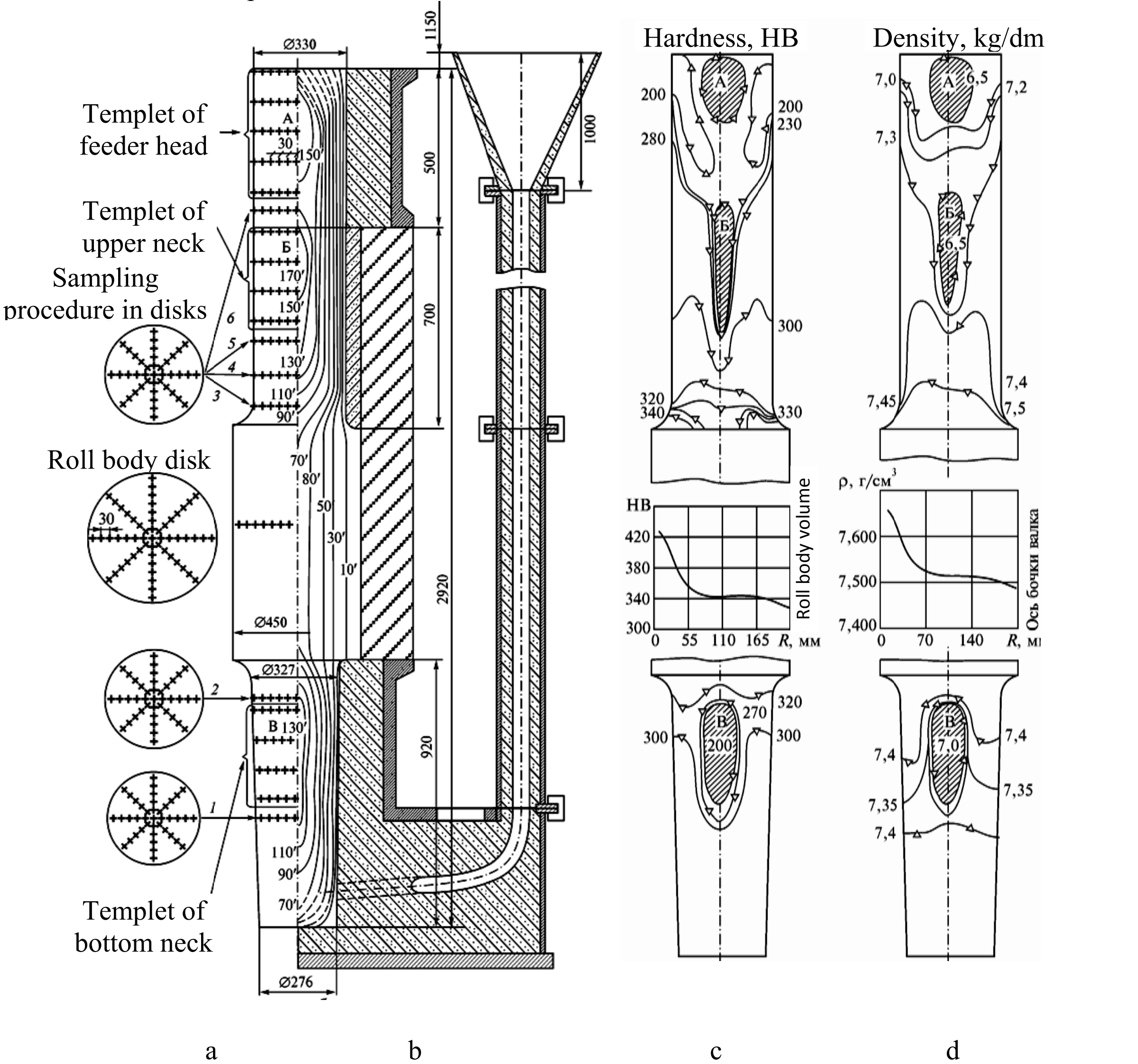



**Figure 1.** Template and disk cutting, sample taking (*a*) from 2200 kg roll made of cast iron with spheroidal graphite, isosolidus front at solidification and mold (*b*), change of hardness (*c*) and density (*d*) across the thickness and height of the cast

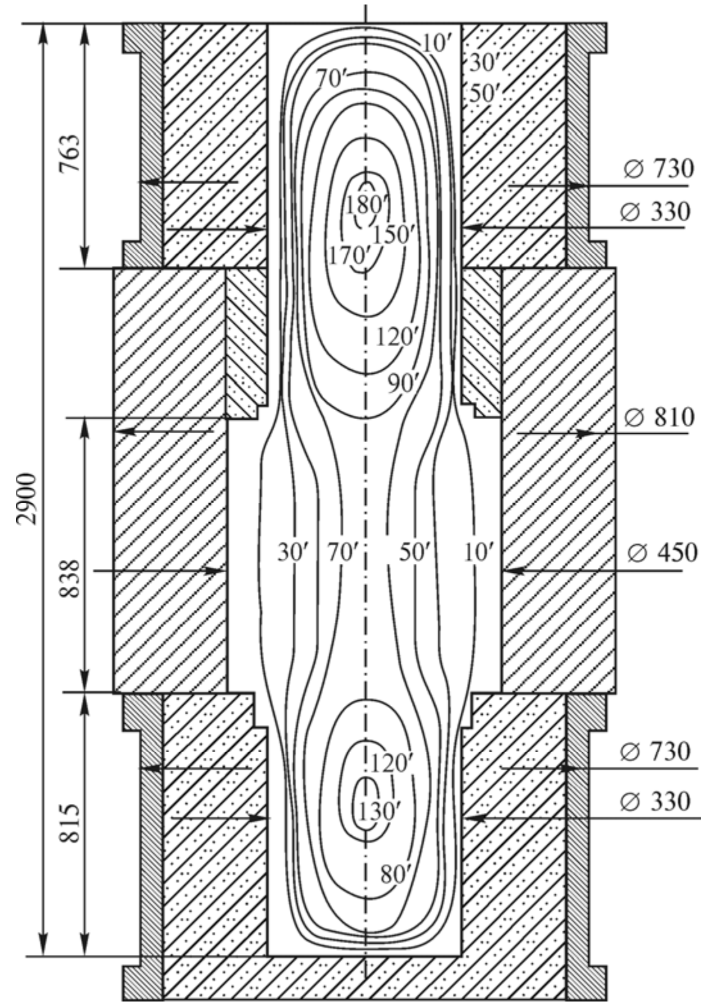


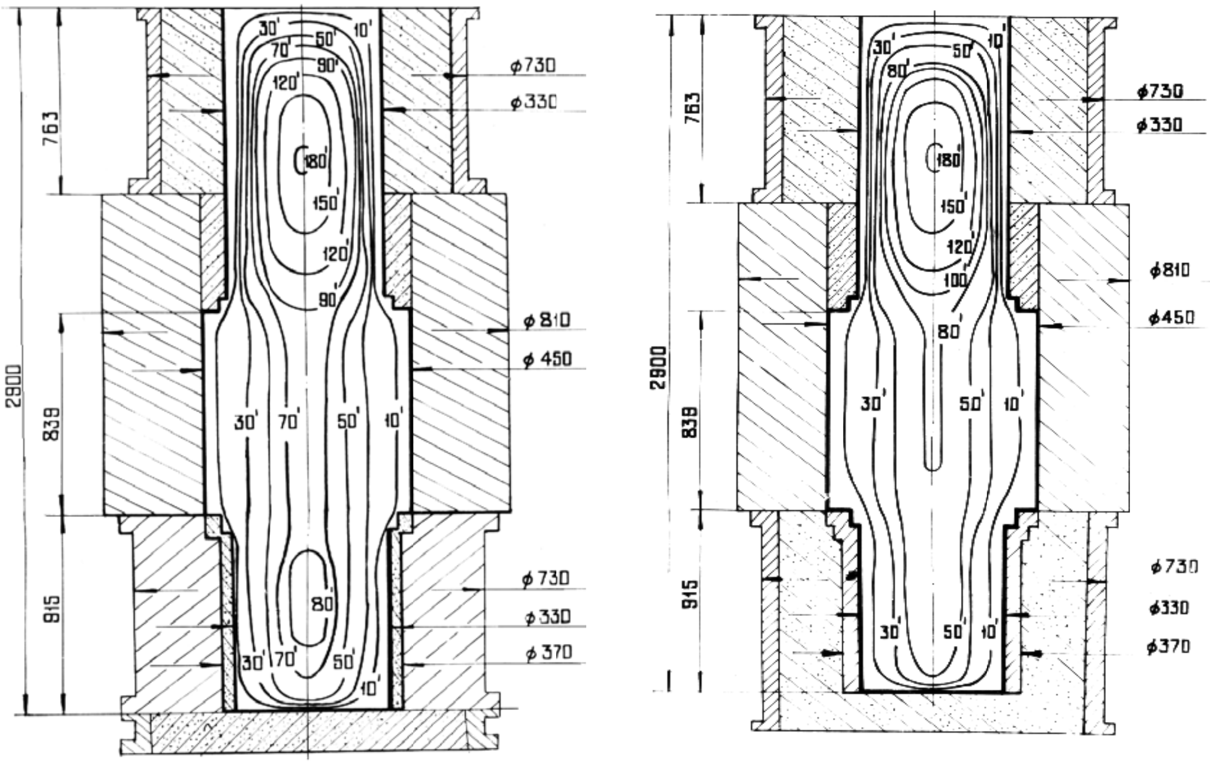

**Figure 2.** Calculated curves of solidification front isosolidus in cast iron roll with spheroidal graphite at pouring temperature 1320 °C: 10 ′, 30 ′, 50 ′, 70 ′, 80 ′, 90 ′, 120 ′, 130 ′, 150 ′, 170 ′, 180 ′ - time, min

Analysis of isosolidus curves shows that both options are acceptable for reduction of heat zone dimensions though in the first case metal mold with heat insulation does not exclude the formation of enclosed volume of the melt isolated from the feeder head (**Figure 3a**). However it occurs at the last stages when the main part of the cast has already solidified. Therefore the bottom neck chill molding really provides reduction of hidden shrinkage defects as compared to the roll-standard (**Figure 2**).

The second option of casting with external chill 0.7 mm thick paint sheeted and external heat insulation (**Figure 3b**) makes it possible not only to produce the bottom neck almost with no heat zones and shrinkage defects but also at low cooling rate. So, calculations showed that cast surface temperature was 859 °C in 210 minutes when casting with external chill, and in the axial zone - 872 °C. When chill casting with heat insulation 20 mm thick these values are 763 °C and 804 °C respectively, which is worse as compared to the first option because of increase of temperature difference and thermal stress.

Neck production in the mold box (**Figure 3a**) reduces labor content of forming works. Neck hardness grows slightly as experimental research of similar design of roll body showed small depth of chill at metal mold wall thickness 25 mm [5].

Change of mold box design of the bottom neck has small effect on solidification of upper neck and feeder head (**Figure 3a, b**). However as mentioned above the directional solidification of upper neck and feeder head provides combined arc-electroslag heating of bath level of feeder head by not consumable graphite electrodes.




a b

**Figure 3.** Calculated curves of solidification front isosolidus in cast iron roll with spheroidal graphite at pouring temperature 1320 °C: *a* – bottom neck is produced in the chill mold with sand- argillaceous heat insulation 20 mm thick; *b* - bottom neck is produced from external steel chill 20 mm thick in the molding box with a sandy mix; 10′, 30′, 50′, 70′, 80′, 90′, 100′, 120′, 130′, 150′, 170′, 180′ — time, min

## Conclusions

To avoid heat zones and shrinkage defects in the bottom roll necks it is necessary to produce bottom neck in a metal mold with sand-argillaceous heat insulation 20 mm thick. Bottom neck molding with external chill 20 mm thick helps solve this problem.

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## Методы устранения усадочных дефектов в нижних шейках чугунных прокатных валков

Меняйло Е.В.

Песчаная форма нижней шейки при литье прокатных валков в стационарные формы часто не обеспечивает направленное затвердевание отливки из-за ускоренного затвердевания бочки. Для исключения образования тепловых узлов и усадочных дефектов в нижних шейках прокатных валков целесообразно нижнюю шейку выполнять в кокиле с песчано-глинистой теплоизоляцией. Равноценным вариантом решения поставленной цели является формовка нижней шейки с наружным холодильником.