

## BLOWHOLES IN CONTINUOUS CAST BLOOMS

### MEHUR<sup>^</sup>AVOST V KONTINUIRNO LITIH BLUMIH

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In dustrial expe ri ence on the pres ence of blow holes in con tin uous cast blooms are sum ma r ised. From sta tis ti cal obser va tions the ef fect of pro cess ing pa ram e ters, such as heat re sist ing lin ing, oxy gen blow ing, tap ping tem pe ra ture and chem i cal com po si tion, es pe cially of sil i con and gas ses hy dro gen, ni tro gen, oxy gen as well as of the for ma tion of car bon monoxyde is de duced.

Key words: steel blooms, continous cast ing, blow holes, pro cess ing, gas im pu ri ties

Predstavljen e so indu strijske izku ųnje o prisotnosti meh ur-kov v kon tin uirno vlitih jek lenih blumih. Na osn ovi sta tis ti nih op azo vanj je op re deljen vpliv proces nih pa ram e trov, na pr. ognjev arna ob zidava, vpi ho vanje kisika i n tem pe ra tu ra pre bo da ter kem ijske sestave, npr. vsebnosti silicija, plinov vo di ka, du ųika i n kisika ter nastajanje ogljikove ga mono ksida.

Klju-ne besede: jek leni blumi, kon tin uirno litje, plinski meh ur-ki, procesiranje, plinske ne-isto-e

The appearance of blowholes in single charges of converter steel CC cast in sequence required one fast identification of their origins, since, they were found by use of the same raw material, additions, and production technology. Blowholes were found in some charges near the surface and in inside the blooms and billets. The content of gases: hydrogen, oxygen and nitrogen as well as of main trace and residual elements, and the examination of the parameters of melting practise did not show any statistical significance. In some cases CC blooms were rolled to products with excellent surface. In other cases blowholes were opened to the surface during the rolling, however, the final rolling surface was of acceptable quality. Some causes for the formation of blowholes were eliminated on the base of statistical investigations. It seems that no general rule is valid for all steelworks and, consequently, solution must be found considering the specific aspects of every steelwork production process.

The facts and conclusions presented here result from a long period of examinations and controls of the CC steel blooms of section 270 x 340 mm up to 10 m long. The analysis of all melts with blowholes in the period of three years showed the possibility of classification of defect melts. In this period no change of insulating plates, of tundish powder as well as of refractory materials occurred. All examined melts were cast in a two tundish on the CC machine with four strands.

By some melts blowholes were found over the whole length of all four strands, in other cases up to the third or up to the second CC bloom. Very often blowholes were found only up to the half of the first CC blooms. In some cases blowhole were observed up to a different length of the two strands cast from the same tundish and more frequently the bloom length with blowholes was very different on strands cast from both tundishes. By using only one tundish the situation was improved. Generally,

the blowholes were observed on the surface of CC blooms, while sometimes blowholes were visible after rolling or even after machining.

By increased number of tundishes by the same lining and casting powder the share of rejected CC blooms because of blowholes increased. When the lining and casting powder were substituted with other products the share of blooms with blowholes was lowered.

Detailed and examination showed that the appearance of blowhole could be connected to:

- the low silicon content in the cast steel;
- quantity of blowed in oxygen, and
- the tapping temperature.

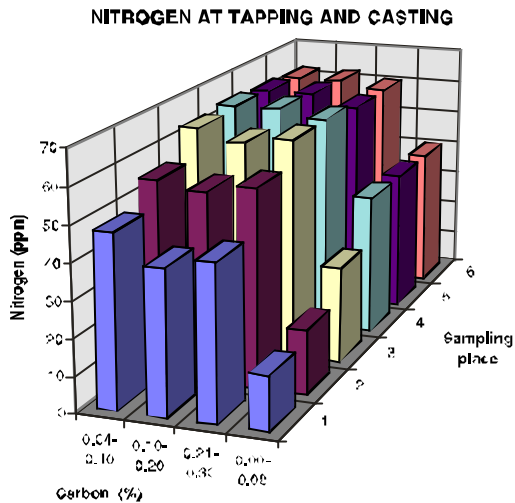
However, in no case the statistical signification was sufficient. The comparison of melts with and without blowholes shows that by melts without blowholes the average addition of FeSi (27 kg/melt) was higher and higher by 0.05% the silicon content in the final analysis. More blowholes were found in melts with higher average addition of FeMn (for 20 kg/melt), of iron ore for 20% before tapping, as well as of aluminium (26 kg/melt). In this case the aluminium content in the final analysis higher by (0.02%), the content of MnO in slag also higher and higher for 9°C the average tapping temperature.

The increase of number of melts cast in sequence from only one tundish lowered the share of rejected CC blooms because of blowholes by appr. 35%.

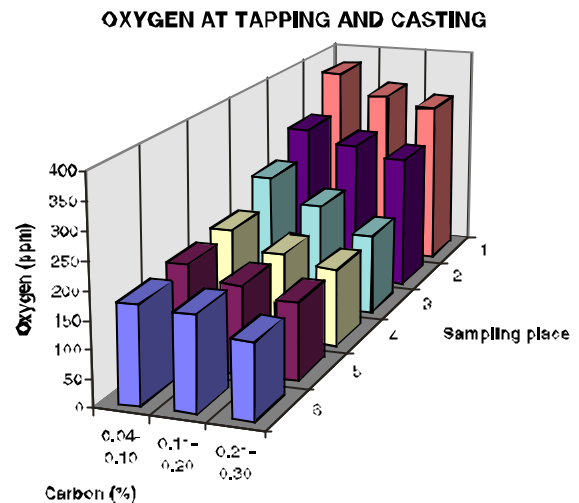
On the base of the equation:

$$p = p_a + h\gamma + 2\sigma/t \quad (1)$$

it was assumed that by low hydrogen content in melt, the reaction with moisture during the casting increased the hydrogen content in the steel. The heterogeneous reaction of carbon monoxide gas bubbles formation and growth was by higher gases content and diffusion.



**Figure 1:** Change of the nitrogen content from tapping to casting of different steel grades with carbon content between 0.04 and 0.30%; 1 - converter, 2 - ladle before treatment, 3 - ladle after treatment, 4 - after casting 25% of melt, 5 - after 50% and 6 - after casting 75% of melt



**Figure 2:** Change of the oxygen content from tapping to casting of different steel grades with carbon content between 0.04 and 0.30%

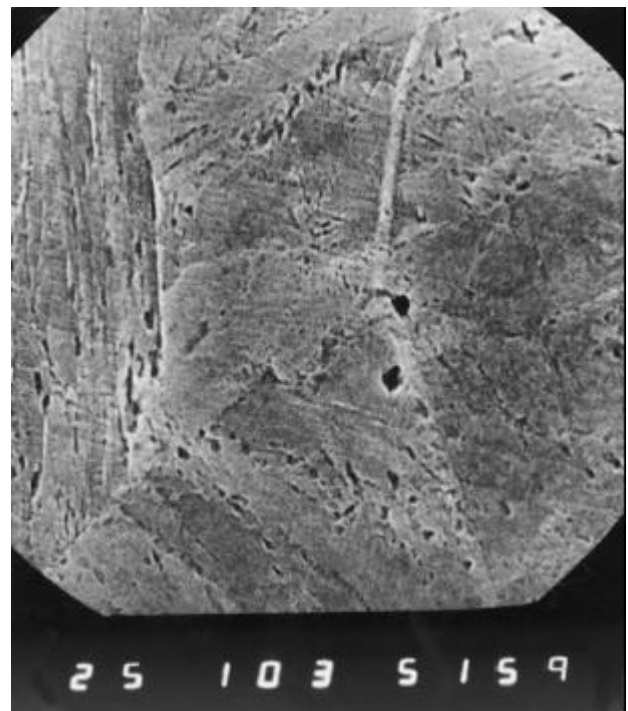
The average content of nitrogen in the melt was of  $42 \pm 20$  ppm (**Figure 1**), of hydrogen of promoted  $3.08 \pm 0.36$  ppm and of oxygen of  $395 \pm 200$  ppm (**Figure 2**). The content of nitrogen increased during the recarburisation because of the addition of petrolcoke with on average  $50 \pm 11$  ppm of nitrogen and from electrode crumbles with on average  $14 \pm 10$  ppm of nitrogen. The average hydrogen content increase in non-carburised melts during the tapping reached  $0.60 \pm 0.44$  ppm and in carburised melts  $0.71 \pm 0.14$  ppm. During the ladle treatment of melts the content of hydrogen decreased by  $0.62 \pm 0.31$  ppm.

About 10% of all examined melts with blowholes, were completely rejected after rolling because of blowholes in all four strands. 8% of all examined melts with blowholes were found free of defects after rolling. By 10% of melts the reason of rejection cause was an insufficient steel deoxidisation if the silicon content was below 0.14%. No connection was found between the presence of blowholes and the content of oxygen in the solidified steel. Blowholes are fragmentary found in case of presence of tapped slag inclusions rich on MnO and FeO.

Calculations show that blowholes appear by increased content of gases nitrogen, hydrogen and carbon monoxide. The actual nitrogen and hydrogen pressure in the melt is not sufficiently high to produce blowholes through homogenous reaction. In general, the controlled increase of hydrogen and nitrogen because of additions does not cause blowhole. However, blowholes could form because of the absorption of hydrogen and oxygen from moisture and the uncontrolled quality of additions. The nitrogen content in the steel during the casting has a very low influence. It seems, however, that the effect is changed by the increase of nitrogen content over 50 ppm, especially in the case when the ratio

between the contents hydrogen and of nitrogen is not about 1:2, but it is 1:10 or more.

It seems that the presence of blowholes in solidified CC blooms over the full length of each strand is connected to the insufficient deoxidisation and to the quality of tundish lining. In the analysed period of a few years the consumption of tundish lining increased by 50%. Paralelly the share of rejected material because of blowhole defects increased for 25%. The change of tundish lining decreased by 38% the quantity of blowhole defects in comparison to the total quantity of rejected CC blooms.



**Figure 3:** Blow holes on the section of solidified CC bloom

The presence of blowholes defects in the first CC blooms up to one half of their length by all strands could indicate that the reason for blowhole formation could be in the higher ferrostatic pressure ( $h\gamma$ ), according to equation (1). This explanation was checked on melts with weight greater up to 21 t, than the average weight of the examined melts and it means that the ferrostatic pressure must not be neglected. The appearance of blowholes depends on the content of hydrogen.

The appearance of blowholes up to the second or third CC bloom of each strand indicates to a notable formation of blowholes because of the influence of local peaks of the total pressure of all present gases. By oversaturation of the melt bubbles with optimal size are formed from the gas above the solubility content (**Figure 3**). From the shape, it is possible to conclude that by the formation of blowholes, low viscosity silicate slag rich in manganese oxide reacts with carbon during CC. The formation of blowholes is connected with diffusion of the dissolved hydrogen and nitrogen. By present solid MnO subsurface blowholes appear at a considerable

lower of gas in solution in the melt pressure. This occurs in the second or in the third CC bloom of the strand and it depends on the stage of casting and solidification when elements, such as aluminium and silicon begin to lose their beneficial influence. It occurs especially if by lower temperature the distribution coefficient is changed. There is no impairing effect of higher aluminium, because aluminium decreases the surface tension, which prevents the formation of blowholes. It was found that by higher aluminium the content of hydrogen is increased by the reaction of aluminium with water vapour. This occurs because the product  $[C] \cdot [O]$  changes toward the equilibrium in the process from tapping to casting for middle carbon steel. The product  $[Mn] \cdot [Al]$  is higher for steel grades with manganese content up to 1.25%, in spite of its weaker deoxidising effect. The product  $[Mn] \cdot [Al]$  is much higher than 0.20 for these steel grades. For low carbon steel grades product of  $[Mn] \cdot [Al]$  is much lower than 0.10.