# The control of volume flow heating gases oh coke plant

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***Riadenie objemového toku vykurovacích plynov koksovne***

*The contribution deals with mixture and coke gases volume quantity determination for coke battery in term of their optimal redistribution at single blocks in consideration of accurate observance of corresponding technological temperature.*

***Key words:*** *volume flow, gas losses, coke – oven battery.*

## Actual control system of gas volume flow

Heating coke battery (HCB) is mixture gas (MG) – fired, that rise of blast – furnace (BFG) and coke – oven gas (COG) at mixture gas station (MGS). At single battery blocks (A, B and C) are gases distributed by system of regulation flaps (Fig. 1).

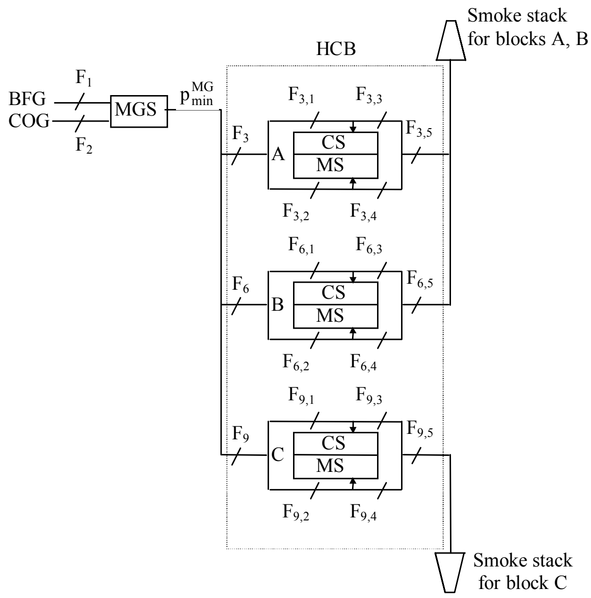


*Fig.1. Scheme of MG – pressure control by regulation flaps system.*

The sum of flaps is 20: two for gases admission ($F_1$, $F_2$), three for blocks ($F_3$, $F_6$, $F_9$), by twos at sides – coke and machine (e.g. $F_{3,1}$) and the like for combustion products ($F_{3,5}$). The battery have two smoke stacks – for blocks A, B and for C. In term of volume flow control is fundamental pressure behind MGS - $p^{MG}_{min}$. Value of this actual control pressure is 2,5 kPa. At blocks are maximal pressure values behind regulation flaps 2 kPa and at the sides around 1,5 kPa. The ultimate influence at gas distribution hat input pressure and flow of gases, because he is much oscillated, mainly at blast – furnace gas. This unstableness is due to pressure changes at main gases transport. It is negative also for stationary caloric value conservation.

## The proposal of volume flow control

Mathematical model is created on the base of pressure – losses calculating in tube system with choices input parameters - pressure and amount of gases.

$$\begin{aligned}
&pBF - X_1 - \Delta_{BF} - \Delta_1 - \Delta_2 - X_3 - \Delta_3 - \Delta_4 - X_4 - \Delta_5 - CC_1 = 0 \\
&pBF - X_1 - \Delta_{BF} - \Delta_1 - \Delta_2 - X_3 - \Delta_3 - \Delta_6 - X_5 - \Delta_7 - CC_2 = 0 \\
&pBF - X_1 - \Delta_{BF} - \Delta_1 - \Delta_8 - \Delta_9 - X_6 - \Delta_{10} - \Delta_{11} - X_7 - \Delta_{12} - CC_3 = 0 \\
&pBF - X_1 - \Delta_{BF} - \Delta_1 - \Delta_8 - \Delta_9 - X_6 - \Delta_{10} - \Delta_{13} - X_8 - \Delta_{14} - CC_4 = 0 \\
&pBF - X_1 - \Delta_{BF} - \Delta_1 - \Delta_8 - \Delta_{15} - \Delta_{16} - X_9 - \Delta_{17} - \Delta_{18} - X_{10} - \Delta_{19} - CC_5 = 0 \\
&pBF - X_1 - \Delta_{BF} - \Delta_1 - \Delta_8 - \Delta_{15} - \Delta_{16} - X_9 - \Delta_{17} - \Delta_{20} - X_{11} - \Delta_{21} - CC_6 = 0 \\
&pBF - X_1 - \Delta_{BF} - pCO + X_2 + \Delta_{CO} - CC_7 = 0 \\
&-\sqrt{\xi_1}\cdot V_{BF} - \sqrt{\xi_2}\cdot V_{CO} + \sqrt{\xi_3}\cdot V_A + \sqrt{\xi_6}\cdot V_B + \sqrt{\xi_9}\cdot V_C - CC_8 = 0 \\
&-\sqrt{\xi_3}\cdot V_A + \sqrt{\xi_4}\cdot V_{A,MS} + \sqrt{\xi_5}\cdot V_{A,CS} - CC_9 = 0 \\
&-\sqrt{\xi_6}\cdot V_B + \sqrt{\xi_7}\cdot V_{B,MS} + \sqrt{\xi_8}\cdot V_{B,CS} - CC_{10} = 0 \\
&-\sqrt{\xi_9}\cdot V_C + \sqrt{\xi_{10}}\cdot V_{C,MS} + \sqrt{\xi_{11}}\cdot V_{C,CS} - CC_{11} = 0
\end{aligned} \quad (1)$$

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where: pBF, pCO – pressure of admission gases [Pa], $X_i$ – regulation flaps pressure losses, $\Delta_{BF}$, $\Delta_{CO}$, $\Delta_i$ – losses at single tube system sections, $CC_i$ – corrective coefficients, $\xi_i$ – pressure loss coefficient at flap [-], $V_i$ – gas volume flow at single blocks and block sides

Model calculated all fixed gas pressure losses and with system of not – linear equations find regulation flaps possible swing out. Competent pressure losses are divided at linear, at height reduction, flow route and tube cross – section change, change of gas flow rate in mixture gas separation channels and combustion gases accumulating channels, regulation flaps resistance and absorption of combustion air at elbow rack. All thinking losses are the functions of geometric system parameters, born – mediums properties, as is for example – density, temperature, viscosity and their amount, eventual velocity in given cross – section.

The pressure loss at flap is calculated by formula

$$X_i = \xi_i \cdot \frac{w_{0,i}^2}{2} \cdot \rho_{0,i} \cdot \frac{T_i}{273} \quad (2)$$

and according literary sources

$$\xi_i = 0{,}1382 \cdot e^{0{,}1156 \cdot \alpha_i} \quad (3)$$

where: $w_{0,i}$ – gas flow velocity [$m.s^{-1}$], $\rho_{0,i}$ – gas density [$kg.m^{-3}$], $T_i$ – gas temperature [K] $\alpha_i$ – flap angular displacement [°]

Equation system (1) calculated with corrective coefficients, at that are represented measurements errors (as flow, as pressure) and alike shadowy losses. The coefficients are rated from historical measurement dates. First 6 equations are the loss of pressure formulation from gas admission to smoke reverse at single block side. The seventh its' a deal for gas mixture and others reflect gas distribution from blocks at sides. The result are asked pressures behind regulation flaps :

$$\begin{aligned} p_j &= p_{BF} - X_1 - \Delta_{BF} - \Delta_{j,1} - \Delta j,_2 - X_j - CC_{i,1} \\ p_{j,MS(CS)} &= p_j - \Delta_{j,3} - \Delta_{j,4} - X_{j,1} - CC_{i,2} \end{aligned} \quad (4)$$

where: $p_j$, $p_{j,MS}$ – asked pressure at block (j = A, B, C) and side, $CC_{i,1}$, $CC_{i,2}$ – proportions of corrective coefficients

## Evaluation of obtain results

In table 1 are presented asked pressures at blocks and sides and differences their values opposite measured values.

*Tab.1. Asked pressure values.*

| N. | $p_A$ | $d_A$ | $p_{A,MS}$ | $d_{A,MS}$ | $p_{A,CS}$ | $d_{A,CS}$ | $p_B$ | $d_B$ | $p_{B,MS}$ | $d_{B,MS}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1812 | -436 | 1454 | -594 | 1346 | -463 | 1756 | -315 | 1169 | -197 |
| 2 | 2204 | -204 | 1517 | 483 | 1386 | 614 | 2338 | -404 | 1368 | -160 |
| 3 | 2381 | -821 | 1651 | -574 | 1503 | -287 | 2148 | -282 | 1227 | -209 |
| | $p_{B,CS}$ | $d_{B,CS}$ | $p_C$ | $d_C$ | $p_{C,MS}$ | $d_{C,MS}$ | $p_{C,CS}$ | $d_{C,CS}$ | | |
| 1 | 29 | 912 | 1516 | 74 | -117 | 730 | 1257 | -7 | | |
| 2 | 937 | 133 | 2004 | -98 | 246 | 385 | 1414 | 7 | | |
| 3 | -422 | 1362 | 963 | 681 | 47 | 556 | 1361 | -83 | | |

These differences are mainly consequence of input pressures variation and volume flow slump. The calculation of flaps pressure losses rise from general formula (3). It is therefore needed application on specif. technological equipment. At figure 2 is exponential dependency coefficient $\xi$ of flap angular displacement for block A. Below are mathematical formulations for all blocks and sides.

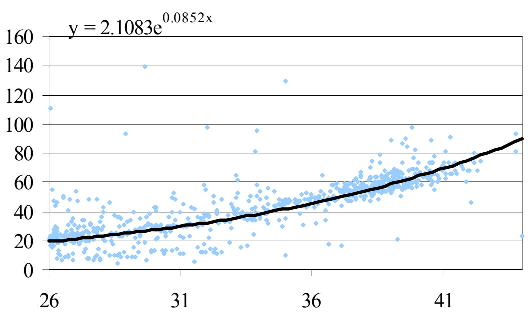


*Fig.2. Coefficient $\xi$ for block A.*

$$\begin{aligned} &\xi_1 = 0{,}1689 \cdot e^{0{,}092 \cdot \alpha_1} \quad \xi_2 = 0{,}0502 \cdot e^{0{,}0989 \cdot \alpha_2} \\ &\xi_3 = 2{,}1083 \cdot e^{0{,}0852 \cdot \alpha_3} \quad \xi_4 = 11{,}934 \cdot e^{0{,}0283 \cdot \alpha_4} \quad \xi_5 = 1{,}5666 \cdot e^{0{,}0765 \cdot \alpha_5} \\ &\xi_6 = 0{,}9513 \cdot e^{0{,}1015 \cdot \alpha_6} \quad \xi_7 = 5{,}3061 \cdot e^{0{,}0309 \cdot \alpha_7} \quad \xi_8 = 0{,}6073 \cdot e^{0{,}0669 \cdot \alpha_8} \\ &\xi_9 = 0{,}118 \cdot e^{0{,}1035 \cdot \alpha_9} \quad \xi_{10} = 0{,}2829 \cdot e^{0{,}0978 \cdot \alpha_{10}} \quad \xi_{11} = 2{,}0876 \cdot e^{0{,}0821 \cdot \alpha_{11}} \end{aligned} \quad (5)$$

Following this new formulations were calculated asked pressures (Table 2). Improvement is by blocks and by bulk sides. For this formulation upgrading is needed apply input gas pressure ahead of accurate standing.

*Tab.2. Asked pressure values after flaps relation modification.*

| **N.** | $p_A$ | $d_A$ | $p_{A,MS}$ | $d_{A,MS}$ | $p_{A,CS}$ | $d_{A,CS}$ | $p_B$ | $d_B$ | $p_{B,MS}$ | $d_{B,MS}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1478 | -102 | 1036 | -176 | 1068 | -185 | 1658 | -217 | 914 | 58 |
| 2 | 2044 | -44 | 1268 | 732 | 1329 | 671 | 2232 | -298 | 1118 | 90 |
| 3 | 1680 | -121 | 1226 | -149 | 1361 | -144 | 2041 | -175 | 1110 | -92 |
| | $p_{B,CS}$ | $d_{B,CS}$ | $p_C$ | $d_C$ | $p_{C,MS}$ | $d_{C,MS}$ | $p_{C,CS}$ | $d_{C,CS}$ | | |
| 1 | 429 | 512 | 1537 | 53 | 63 | 551 | 1147 | 103 | | |
| 2 | 1004 | 67 | 2004 | -99 | 350 | 280 | 1346 | 75 | | |
| 3 | 306 | 633 | 1637 | -13 | 200 | 403 | 1271 | 7 | | |

## References


KOSTÚR, K.: Control System of Coking Plant. *Metallurgy*, 2/2002, 2002. pp. 121-124. ISSN 0543-5846

PÁSTOR, M. and KOSTÚR, K.: Modelling flow in industry furnace. In: Proceedings of ŘÍZENÍ PROCESU 2002, pp. 182. ISBN 80-7149-452-1

PÁSTOR, M. and KOSTÚR, K.: Gas flow modelling in tube system of coke-oven battery. *Acta Metallurgica Slovaca,* 4/2002, 2002. pp. 129-134. ISSN-1335-1532.