# Steady State Numerical Model of COREX Melter Gasifier

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## Salient features:

- Alternate iron making process.
- Divided into reduction shaft and melter gasifier.
- Uses non coking coal unlike conventional process which lowers the cost of production.
- Reuse of top gas for pre-reduction of ores in reduction shaft.

## Literature:

- Velocity and temperature relation, effect on coal consumption.[1]
- Mole percent of gases and temperature relation, effect of bed height.[2]
- Temperature and mole percent relation, effect of volatility of coal.[3]

## Model description:

It is a comprehensive model that tries to predicts temperature and mass flow rate at each node to optimize the input parameters for the required production rate.

- Melter Gasifier is divided into 4 zones namely:
  - Free board zone
  - Fluidized bed zone
  - Moving bed zone
  - Raceway zone
- Nine gas species : CO, $O_2$, $CO_2$, $H_2$, $H_2O$, $CH_4$, $C_2H_6$, tar, and soot.
- Ten solid species : Fe, $Fe_2O_3$, FeO, CaO $CaCO_3$, C, ash, coal moisture, coal volatile, and gangue
- Three solid phases : DRI, coke and coal.

## Inputs :

- Production rate (required)
- DRI consumption
- Coal consumption
- Coke consumption
- Oxygen consumption
- Tuyere temperature

## Calculations :

- Mass flow rate of all solid and gas species
- Mass generation rate of all solid and gas species
- Temperature of all the three phases (gas, solid, and liquid)
- Rate of reactions using mole percent of species

## Output :

- Temperature and mass flow rate at each node
- Mole percent of gaseous species.

## Assumptions :

- Raceway zone is considered to be two dimensional and rest of the gasifier is considered as one dimensional.[4]
- Fluidized bed is considered to be full of gas
- Oxygen gets consumed totally in raceway zone

## Calculations :

- Mass balance equation for solid and gas in 1D and fluidized bed zones

$$\frac{d(A_b G_i)}{dz} = A_b \dot{G}_i$$

- Heat balance equation for solid and gas in all 1D and fluidized bed zones

$$\frac{d(A_b G_i Cp_i T_i)}{dz} = \sum_{phases} A_b a_{ij} h_{ij}(T_i - T_j) + A_b \Delta H_{reac.\ or\ melt.\ i}$$

- Momentum and continuity equation for gas in 2D zone [5]

$$-\frac{\partial P}{\partial z} = (f_1 + f_2|G_g|)G^z{}_g \text{ and } \frac{\partial G^z{}_i}{\partial z} + \frac{1}{r}\frac{\partial (rG^r{}_i)}{\partial r} = A_b \dot{G}_i$$

- Chemical reaction rates :

Oxidation of carbon
Carbon gasification reaction[6]
Water-gas reaction

$$\dot{R} = \frac{A_c}{\frac{6}{d_p k_p E_f} + \frac{1}{k_f}} \times \frac{9.868 \times 10^{-6} P_{re}}{M_{wr} RT}$$

Cracking of volatiles[7]
Reduction of Fe2O3 and FeO[8]

$$\dot{R} = A_{re} e^{B_{re}/T} \chi_{re} \times \frac{P}{RT}$$

Calcination of CaCO3 [9]

$$\dot{R} = A_{re} e^{B_{re}/T}(1-\xi) \times \left(1 - \frac{\chi_{re}\xi P}{(1-\xi)K_{eqm}}\right)$$

- Notations :

i,j : phases
re : reaction
eqm : equilibrium
ξ : conversion
χ : mole fraction

## Flow chart of the simulated process

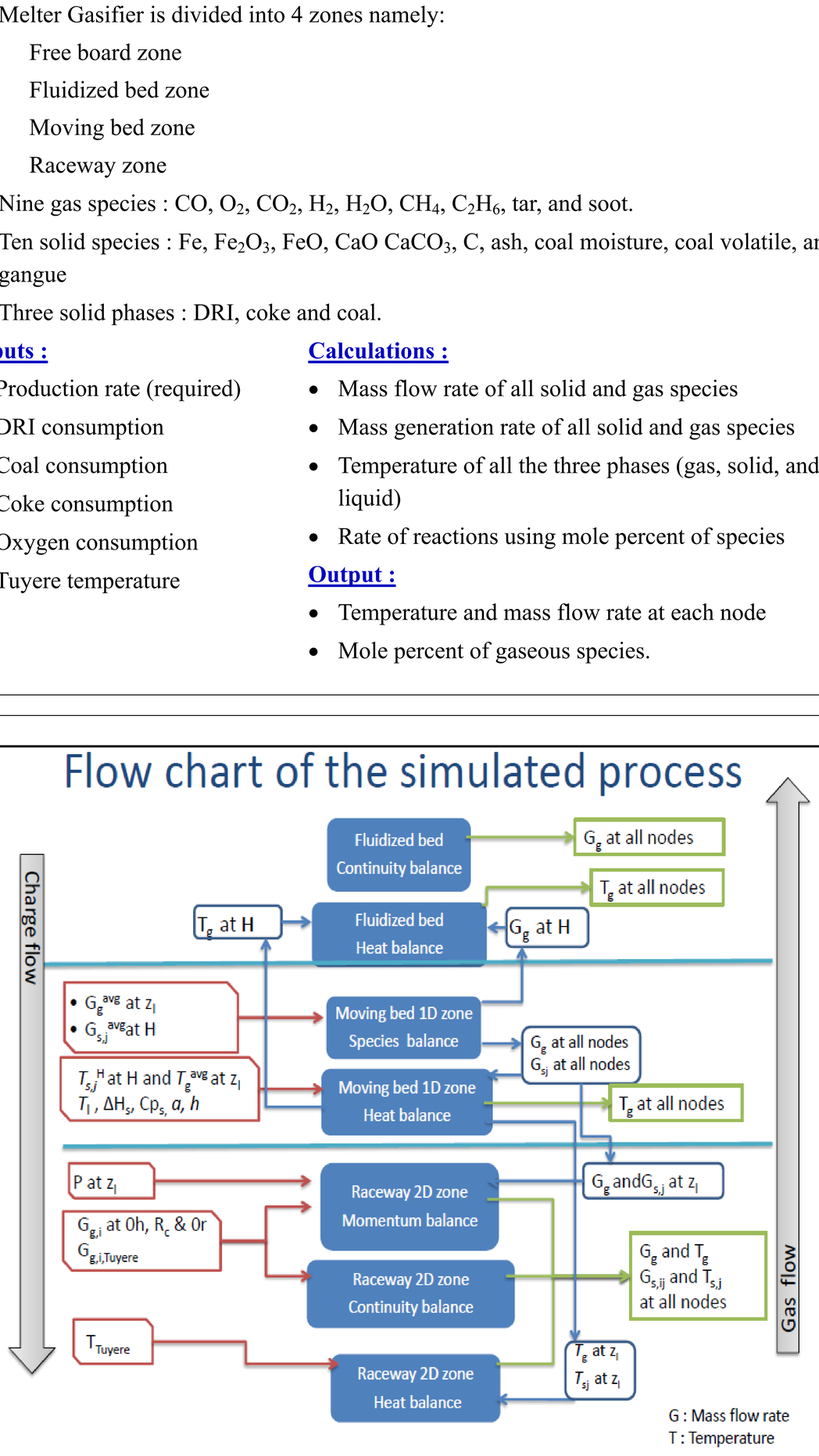


Figure 1 : Flow chart of calculated variables in this model

## Computational domain

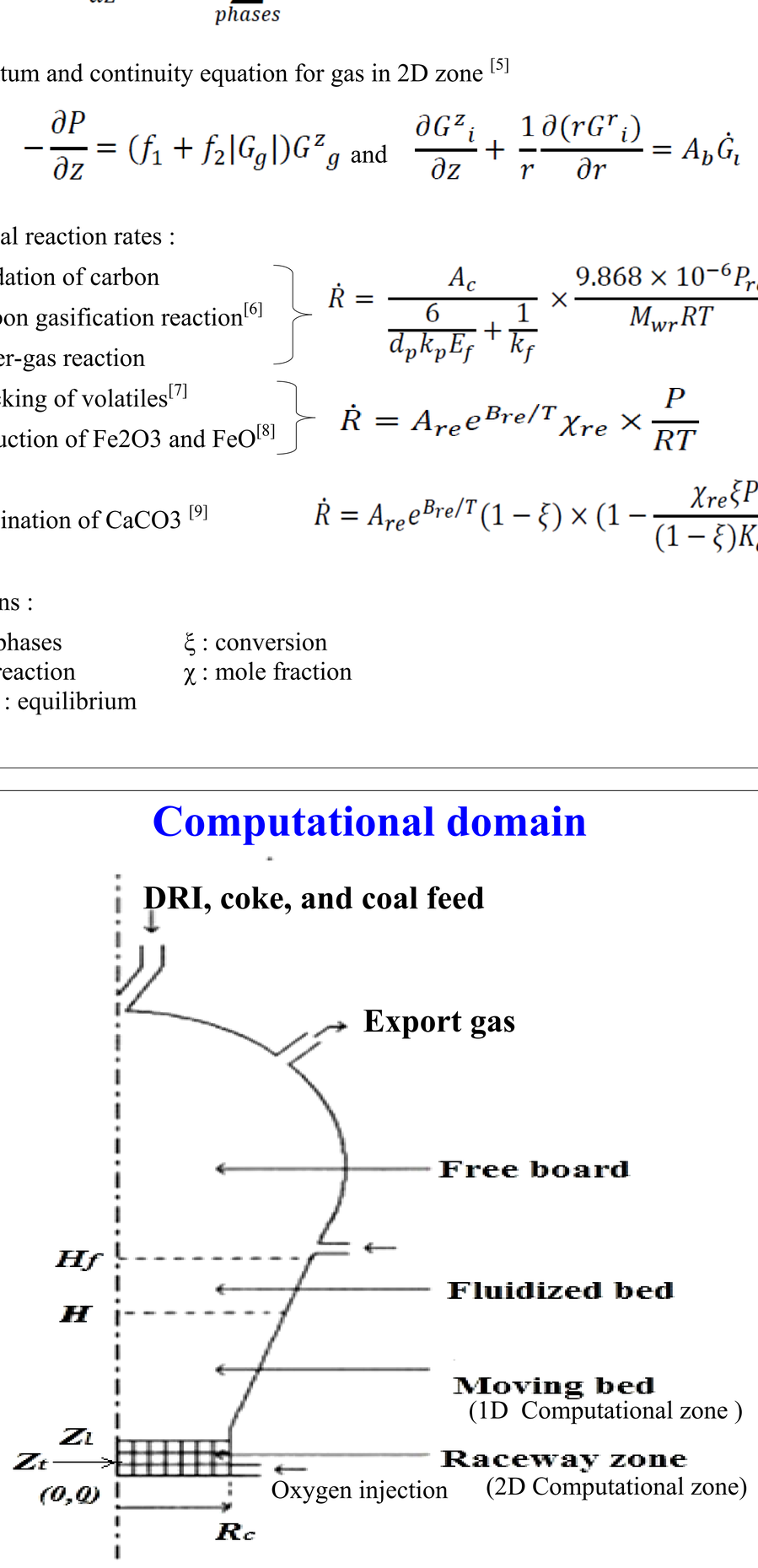


Figure 2 : Schematic of computational domain, cylindrical coordinate is used for 2D zone

Reference :

[1] Shin et. al. , ISIJ Int., 1993
[2] Lee et. al., ISIJ Int., 1999
[3] Pal et. al., Met. and Mat. Trans. B, 2003
[4] Viswanathan et. al., ISIJ Int., 1998
[5] Ergun, Chem. Eng. Process, 1952
[6] Yagi et. al., Trans. ISIJ, 1970
[7] Mori et. al., ISIJ Int. 1999
[8] Morell et. al. Chem. Eng. Sci. 1990
[9] Tsay et. al., AIChe J., 1976

## Conclusion :

The above steady state numerical model of COREX melter gasifier is developed.

## Future work:

Verification with industrial data.