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# Development of nitrogen prediction model for 320-tonne converter

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## 1 INTRODUCTION

Nitrogen(N) is widely known as would be controlled in various levels for different steel grades production. Specially, ultra-low carbon(ULC) steel requires extremely low N level in steelmaking.

However, it is difficult to prevent N pick-up from Atm. and raw Mats., because the N is one of the interstitial elements is easily absorbed into molten Fe.

Moreover, in the converter process which is N removal is occurred by CO gas formed during de-carburization, the demand to reduce carbon emission(Carbon neutral) would force an unfavourable environment for N control by reducing hot metal ratio (HMR) in the converter.

Thus, a **nitrogen prediction model**(NPM) has been developed based on thermodynamic and kinetic approaches using FactSage™ 8.3. In addition, in present study, it was tuned through simulation of key reactions combined with time series data in the converter.

## 2 MODEL DESCRIPTION

### ▶ Important variables of the NPM

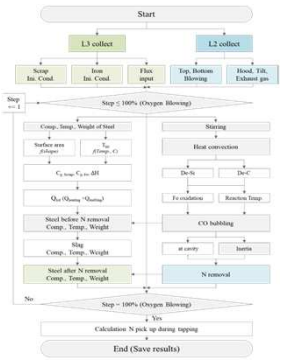
| Source | Input | | | | Removal |
|---|---|---|---|---|---|
| 1st Variable | Molten Iron | Solid Scrap | purity of gas | Leakage in hood | $CO_{(g)}$ evolution |
| 2nd Variable | Temp., Comp., Time, ... | Length, Grade, Density, Comp., ... | Gas flow ($O_2$, Ar , $N_2$, ...) ... | Hood press., Comp. of outgas, ... | Flow rate, Stirring, DeC Rxn., Temp., Comp., ... |

**① Initial condition**
- N content in Molten iron → Thermodynamic Calc.

**② During oxygen blowing**
- N pick-up: Scrap melting/impurity of gases/leakage
- N removal: Decarburization
  → **Converter Simulation**: Real time Calc. of N content

**③ Tapping** (N pick-up from atm.: Kinetic Calc.)

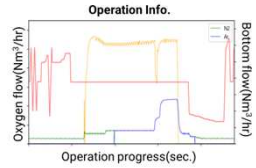
### ▶ Outline of the NPM



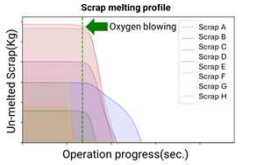

## 3 R&D(I. Converter simulator)

### ▶ Main modules for converter simulation

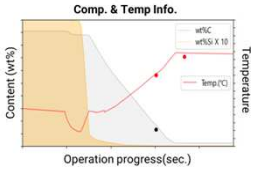
① Operation data load & pre-processing
- Load Lv.3(processed) & Lv.2(time series)
- Improve data readability for Python
- Convert to thermodynamic & kinetic data




② Scrap melting module
- Specification of each scrap
  (Specific length(L), apparent density($\rho$), ...)
- Melt Calc. by heat & mass transfer model




③ Oxidation & Heat balance module
- Calc. the oxidation reaction at each stage
  (Stage order: Si(~15%)→C(~75%)→Fe(~100%))
- Calc. the temperature of molten Fe
  (Factors: Oxidation, Scrap, Slag making,...)
- Verification: comparison with operation results




## 4 R&D(II. N prediction)

### ▶ The nitrogen prediction model(NPM) for converter process

**Classic model**

Fruehan's kinetic based Mathematical N Calc. model

$$\text{pct N}_{bulk}^{(t+1)} = \text{pct N}_{bulk}^{(t)} + \left(\frac{d\ \text{pct N}}{dt}\bigg|_{removed}\right)\cdot\Delta t + \sum_{n}\left(\frac{d\ \text{pct N}}{dt}\bigg|_{source}\right)^{n}\cdot\Delta t$$

kinetic reaction of N in Converter

$$\frac{d\ \text{pct N}}{dt}\bigg|_{removed} = \frac{m\cdot A\cdot\rho}{W_m}\cdot(\text{pct N}_{surf} - \text{pct N}_{bulk})$$

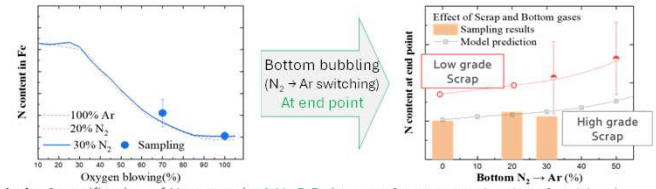
Goldstein & Fruehan, MMTB, 1999
Fruehan, Lally and Galws, Trans. ISS, 1987

**Modification**

| Model based on SIMULATION (FactSage) | | Automation by Python programming (python) | |
|---|---|---|---|
| Scrap melting interpretation | Thermodynamic data using FactSage™ 8.3 | Real-time processing (≤10Sec. for 1Ht. Calc.) | Hyper param. tunning (Empirically optimization) |

**Calc. results I (End point)**

▷ N content at end point of oxygen blowing(Effect of bottom blowing gases)




**As is**: Quantification of N content by $\%N_2$ B.B. ($N_2$ B.B. after 50%: acceleration of N pick-up)

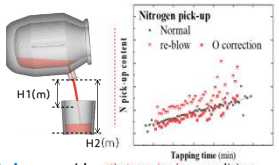
**To be**: Improvement of interpretation of scrap melting and grade effects

**Calc. results II (Tapping)**

▷ Calc. N pick-up during tapping

N pick-up $\Delta\left[\frac{P_{steel}}{100\cdot MW_N}\right][k_R]\left[(\%Ni)^2 - (\%Neq)^2\right]\cdot t_{tapping}$

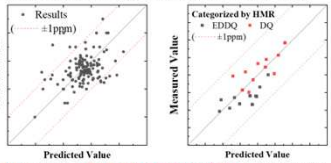
Jung and Ende, MMTB, 2020




**To be**: consider tilt/tap hole condition

▷ Effect of hot metal ratio(HMR) on N content

**As is**: Quantification of N by HMR(80~90%)
- Pred. vs. Meas. results with categorized by HMR




**To be**: Predict EAF-BF combined Proc.(HMR≤70%)

## 5 CONCLUSION

A **nitrogen prediction model**(NPM) for converter process has been developed based on thermodynamic and kinetic approaches combining with operational data. Since this NPM was modified based on the converter simulation, it has various advantages in terms of versatility and expandability.

(1) It is possible to predict removal and distribution for each component by adding calculation module using python script.

(2) It can provide prediction results about N for high-difficulty trial production such as EAF-BF combined Process(HMR ≤ 70%).

In verification through comparison with about 18,000 production results, the accuracy of the NPM's nitrogen prediction was found to be over 90%(±1ppm).

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