NUMERICAL ANALYSIS TECHNOLOGY TO EVALUATE COKE DEGRADATION BEHAVIOR IN BLAST FURNACE[1]

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Abstract

From the viewpoint of the improvement of reaction efficiency in the blast furnace, a trial of the use of the high reactivity coke into the blast furnace was carried out as one of the technologies to realize the low reducing agent operation. In addition to the evaluation of the effect of coke reactivity on the reaction efficiency in the blast furnace, it is also important to establish the technology which predicts the coke strength after the gasification reaction in the blast furnace in order to evaluate the effect of coke quality on the blast furnace operation. However, the effect of coke reactivity index called CRI or the coke strength index after the gasification reaction called CSR on the blast furnace operation has not been clarified quantitatively yet. In this study, in order to evaluate the effects of coke quality indexes of CRI and CSR on the degradation behavior of coke in the blast furnace, a numerical analysis method based on the simultaneous analysis by a three dimensional mathematical model for the blast furnace and a solid flow model which can describe the stress field in the blast furnace was developed.

Key words: Blast furnace; Reaction efficiency; High reactivity coke; Coke degradation; CRI; CSR; Numerical analysis

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1 INTRODUCTION

It was decided that 6 % of the total carbon dioxide emission in 1990 in Japan would be reduced by 2010 at "Kyoto conference (COP3)" held in 1997. In the same way, it was decided to target 11.5 % reduction of energy consumption of steel industry in Japan. Since about 70 % of energy of whole steel industry is consumed by ironmaking process in the blast furnace, it is necessary to establish low reducing agent rate operation technique of the blast furnace. From the viewpoint of the improvement of reaction efficiency in the blast furnace, a trial of the use of the high reactivity coke into the blast furnace was carried out as one of the technologies to realize the low reducing agent operation by improving gas utilization through decreasing the temperature of the thermal reserved zone in a blast furnace.(1) At that time, not only the evaluation of the effect of coke reactivity on the reaction efficiency in the blast furnace but also it is important to establish the technology which predicts the coke strength after the gasification reaction in the blast furnace in order to evaluate the effect of coke quality on the blast furnace operation. However, the effect of coke reactivity index called CRI or the coke strength index after the gasification reaction called CSR on the blast furnace operation has not been clarified quantitatively yet. In this study, in order to evaluate the effects of coke quality indexes of CRI and CSR on the degradation behavior of coke in the blast furnace, a numerical analysis method based on the simultaneous analysis by a three dimensional mathematical model for the blast furnace and a solid flow model which can describe the stress field in the blast furnace was developed.

2 NUMERICAL ANALYSIS METHOD

Figure 1 shows the numerical analysis method to evaluate coke degradation behavior in the blast furnace. A coke reaction model(2) which can describe relations between the coke reactivity index called CRI and the coke strength index after the gasification reaction called CSR, a solid flow model that can describe the mechanical stress field in the blast furnace based on the rigid-plastic analysis(3) and a mathematical model(4) of the fines behavior derived from coke in the blast furnace were assembled in a three-dimensional mathematical model(5) describing the process.

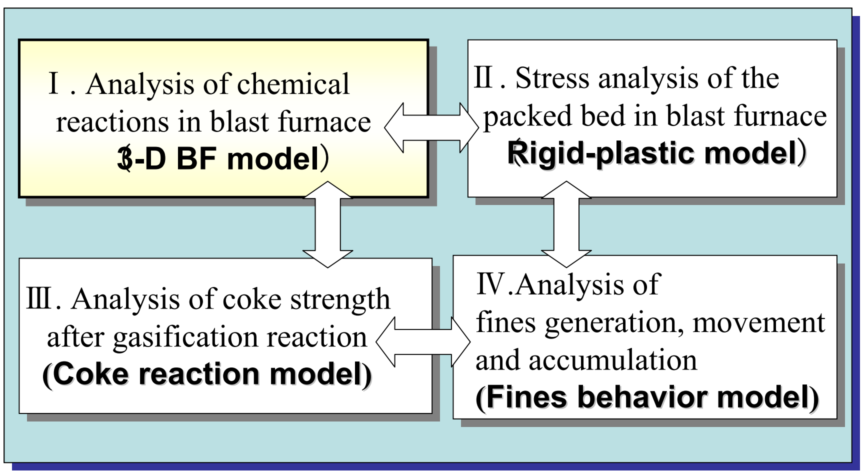

Figure 1. Numerical analysis method to evaluate coke degradation behavior in blast furnace.

2.1 Three-dimensional Mathematical Model for Blast Furnace (3-D BF Model)

Examples of inner state variables computed by the three-dimensional mathematical model for the blast furnace are shown in Figure 2. All of the inner state variables in the blast furnace can be simulated by the model.

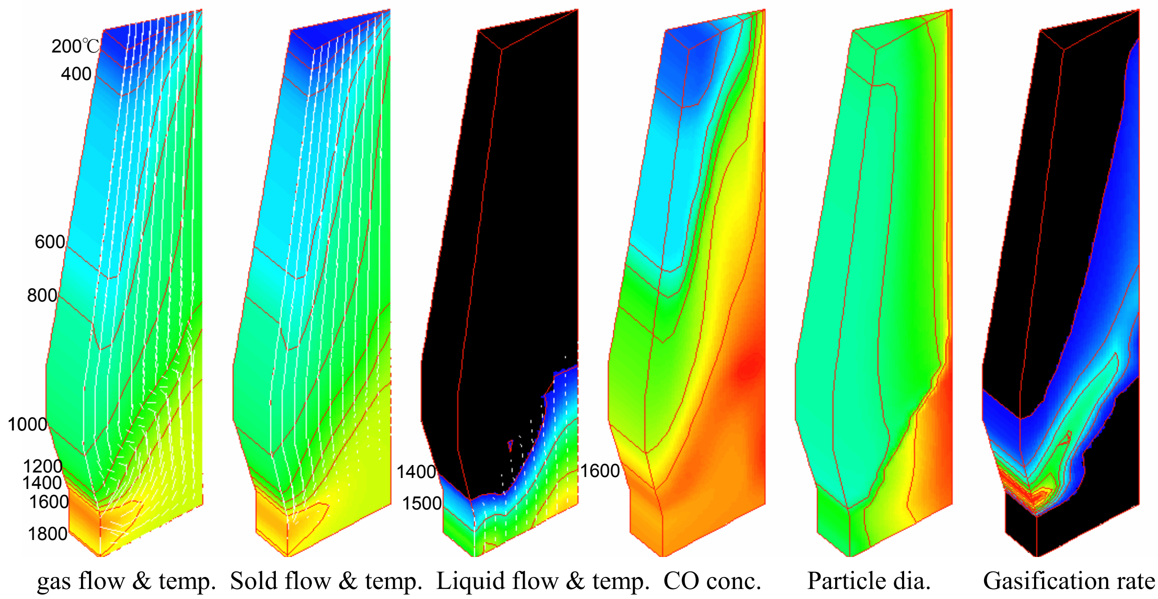

Figure 2 . Computed results by the three-dimensional mathematical model.

2.2 Coke Reaction Model

Figure 3 shows modeling of the coke reaction model. The model can simulate both of the CRI test system and the CSR test system. Figure 4 shows examples of relations between CRI test and CSR test calculated by the model with the observed data.

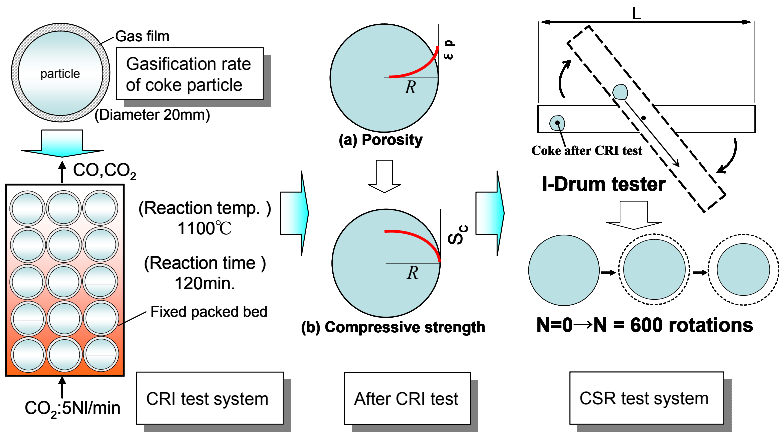

Figure 3. Modeling of the coke reaction model.

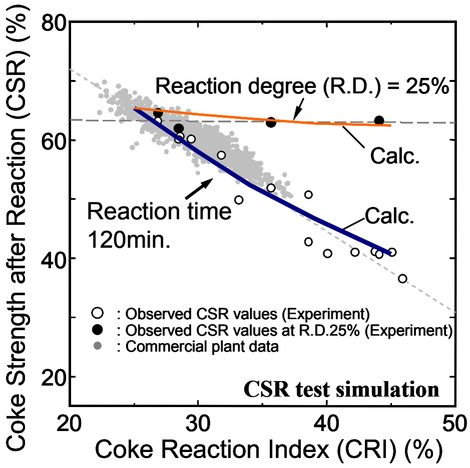

Figure 4. Relations between CRI and CSR.

2.3 Rigid-plastic Model

Figure 5 shows inner state variables calculated by the three-dimensional mathematical model with the rigid-plastic model. Not only flow fields, heat transfer and chemical reactions but also stress field and impact energy rate on coke particle can be solved in the blast furnace.

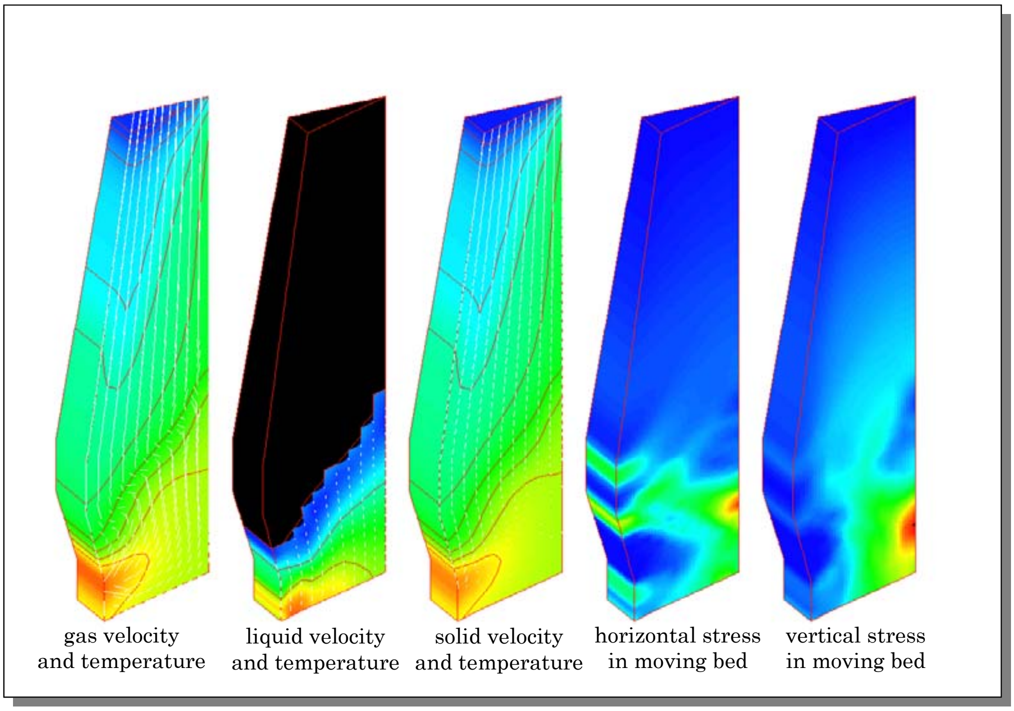

Figure 5. Computed results by the three-dimensional mathematical model with rigid-plastic model.

2.4 Fines Behavior Model

Figure 6 shows the fines derived from coke behavior model. The model can solve moving, accumulation and consumption behaviors of the fines with use of its generation rate calculated by the three-dimensional mathematical model with the rigid-plastic model.

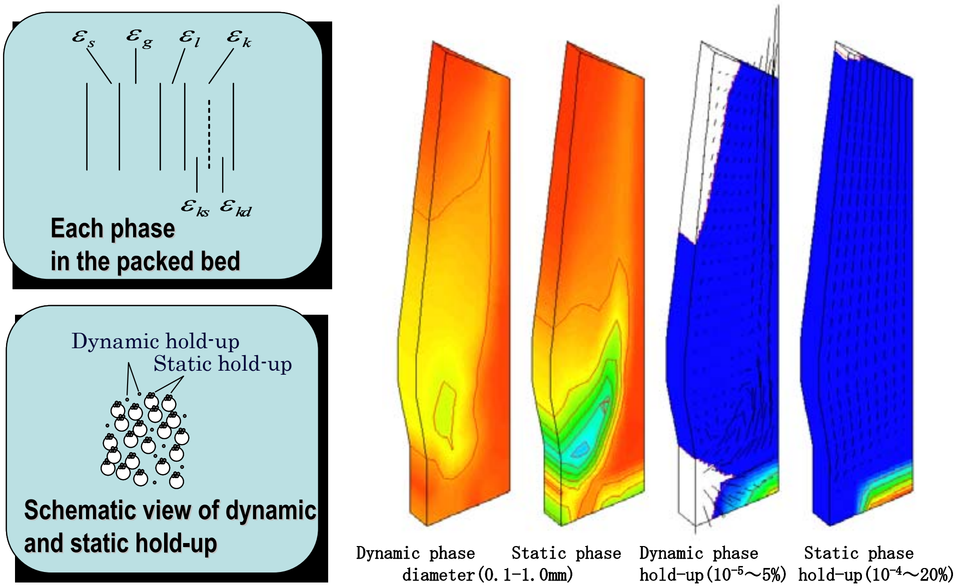

Figure 6. Computed results by the fines behavior model.

3 RESULTS AND DISCUSSION

Figure 7 shows calculated results by the three-dimensional mathematical model for the blast furnace with the coke reaction model, rigid-plastic model and fines behavior model. Where, the given properties of coke are the strength of matrix of 1608Mpa, the porpsity of 0.48 before the gasification reaction, CRI 30%, and CSR 57%. In addition, the size of the generated coke powder assumed 1mm. The generation rate of the coke powder is very small in the shaft. On the other hand, it is very high in the middle region of the surface on deadman where the difference of solid velocity is large and the stress is high. Although the generated powder is consumed by the gasification, smelting reduction, and carburization reactions, the residual powder accumulates locally in the core part of deadman and forms a domain obstructing the gas flow.

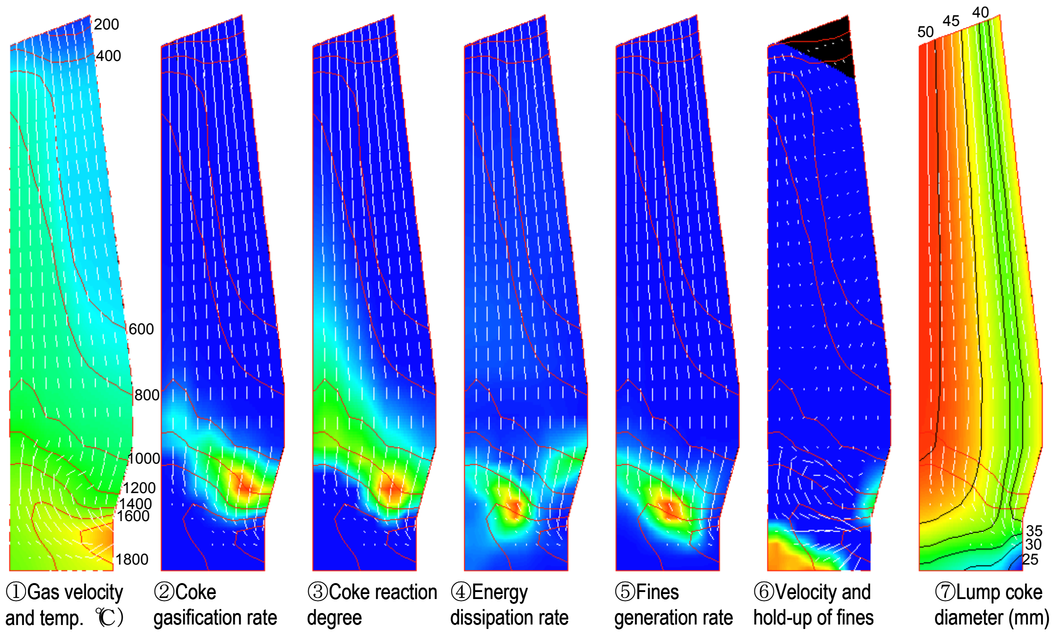

Figure 7. Numerical analysis technology to evaluate coke degradation behavior in blast furnace.

4 CONCLUSIONS

In order to evaluate the coke degradation behavior in the blast furnace quantitatively, a numerical analysis method was developed.

1) The powder derived from coke is mainly generated on the surface of dead man. On the other hand, the powder generated in the shaft part is a little.
2) The dynamic and static hold-up of powder are accumulated in the dead man. A low permeability region is formed in the dead man owing to the accumulation of powder.

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