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Optimization of an HRSG Inlet Duct Design for Improved Flow Uniformity for HTGR Applications

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Introduction

Background

- **Previous studies on Heat Recovery Steam Generators (HRSG) aimed at improving the efficiency of High-Temperature Gas-cooled Reactors (HTGR) have been continuously conducted.**
- **Flow optimization of the inlet duct is necessary to improve the efficiency of the HRSG.**

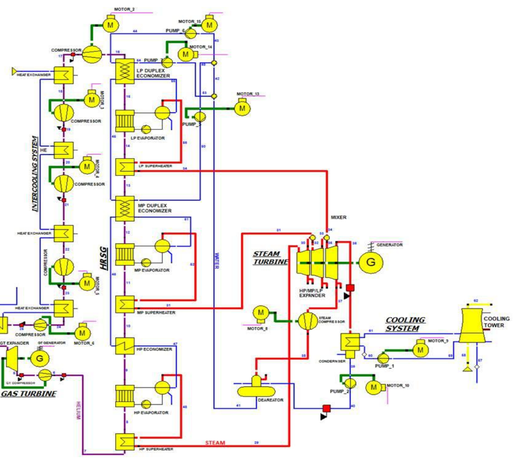


Fig. 1 HTGR system utilizing HRSG

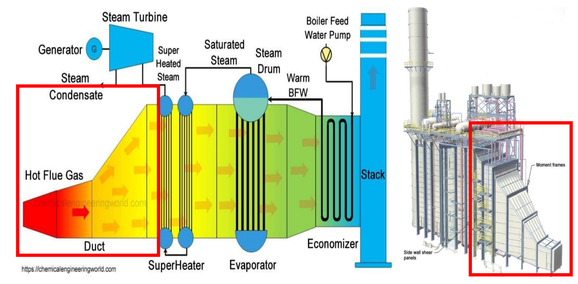


Fig. 2 Example of HRSG in HTGR

Purpose

Conventional optimization → **Requires a lot of time and energy** → **Optimization using metamodeling technique**

Optimization Method

Target of optimization

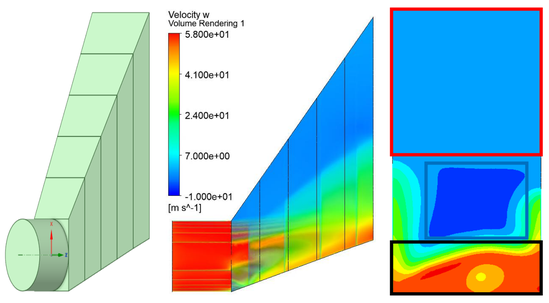
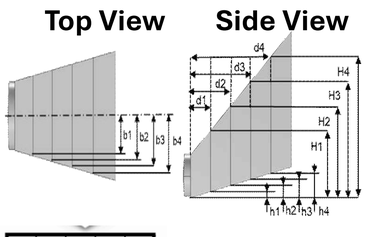


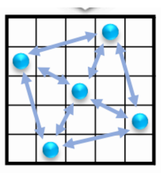
Fig. 3 Initial model's shape and CFD result

- **Red point : Shift lower concentrated flow upward into the wider space**
- **Blue point : Reduction of Reverse flow**
- **Black point : Reduction of concentrated flow**

Design variable and sample point



- **Parameters : Width, Length, Height**
- **Purpose : Generating 160 models**



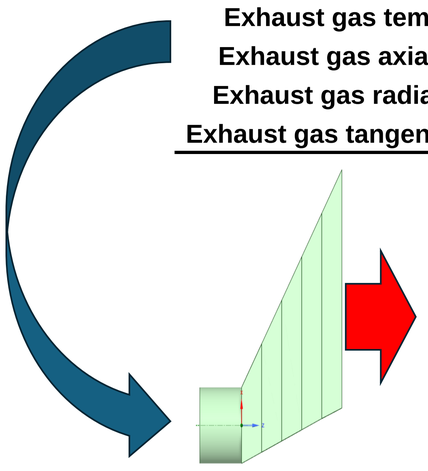
- **Determination of parameter values using the Optimal Latin Hypercube Design (OLHD) sampling method.**

Fig. 4 The algorithm of OLHD

Meta models simulation

Table 1 Inlet duct's boundary condition

Boundary Condition	Value	Unit
Exhaust gas flow	755.3	kg/s
Exhaust gas temperature	651	℃
Exhaust gas axial velocity	55.2	m/s
Exhaust gas radial velocity	2.4	m/s
Exhaust gas tangential velocity	-13.7	m/s



$$U_{RMS} = \sqrt{\frac{\Sigma\omega_i(u_i - U)^2}{\Sigma\omega_i}}$$

ω_i : Surface area of each mesh cell

u_i : Velocity in each mesh cell

U : Average velocity

Meta model

Metamodeling technique's result ✖ **CFD result**

Randomly select 2 out of 160 models and compare their error rates

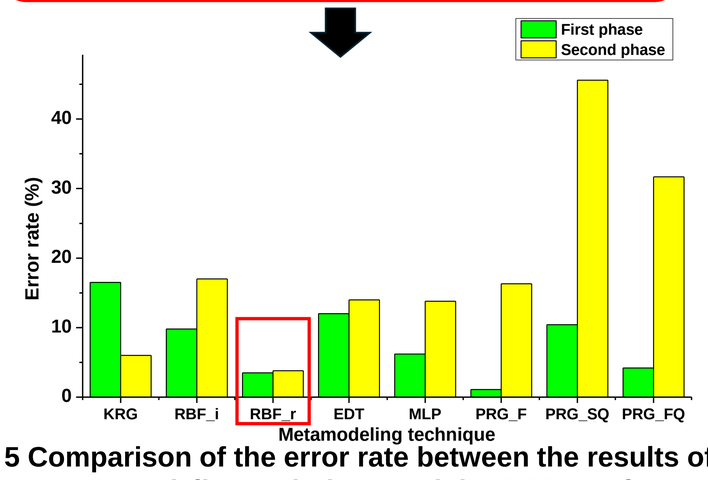


Fig. 5 Comparison of the error rate between the results of the metamodeling technique and the CFD results

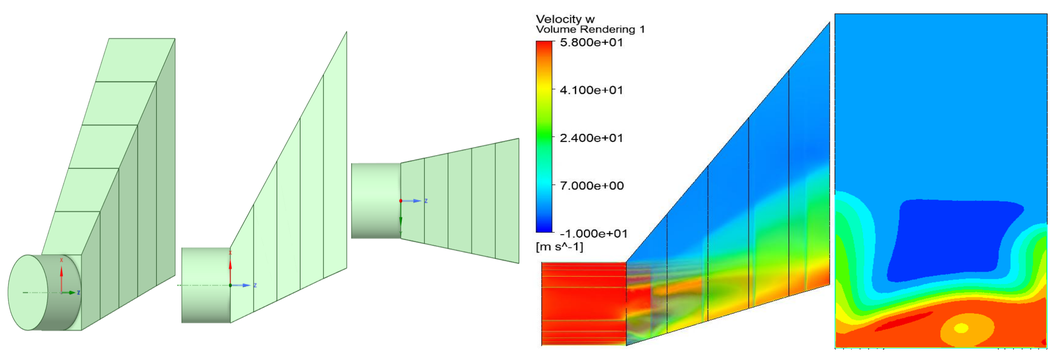
Result

Initial model vs Optimized model result

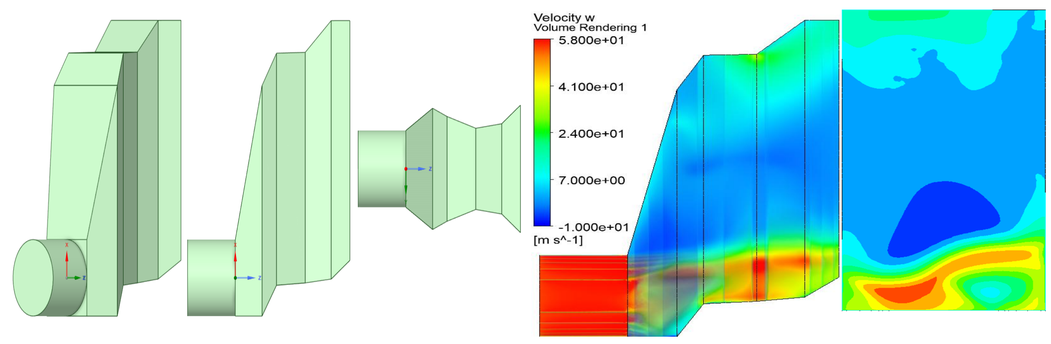
- **Verification of the RMS velocity values and the changed flow distribution in the optimized model.**
- **Comparison of CFD results between the initial model and the optimized model.**
- **The optimized shape showed a 22% reduction in RMS values compared to the initial shape.**

Table 2 Comparison of results between the initial model and the optimized model

Model type	Average Velocity	Root mean square velocity
Initial model	8.3301 m/s	19.035 m/s
Optimized model	8.3112 m/s	14.669 m/s



(a)



(b)

Fig. 6 (a) Initial model's shape and CFD result
(b) Optimized model's shape and CFD result

Conclusion

- **Although the desired complete uniformity was not fully achieved, flow uniformity has improved compared to the initial model**
- **This study has yielded promising results that are expected to serve as a valuable reference for future research on HRSG applications using HTGR**

Acknowledgement

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Reference

- **Marek Jaszczur, Michal Dudek, Tomasz Śliwa, and Zygmunt Kolenda, An analysis of high-temperature nuclear reactor coupled with gas turbine combined cycle, MATEC Web of Conferences 240, 05010 (2018)**