FLOWWEX®
SIMULATION ENVIRONMENT

CASE STUDY

FLOW & HEAT TRANSFER IN A PACKED BED - TRANSIENT

This case study demonstrates the transient simulation of the heat transfer through a packed bed with no forced convection. This case study is applicable to packed pebble beds where only natural convection is present in the bed due to a heat source on the inside of the bed and a heat sink on the outside of the bed.

NUCLEAR & SMR

CHALLENGE:

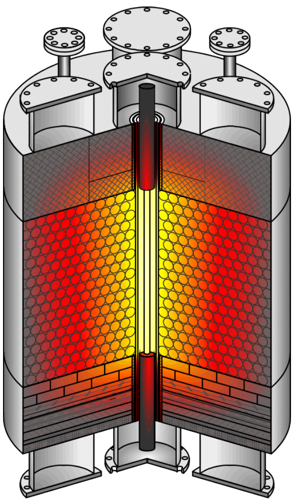
The thermal hydraulic conditions of a typical high temperature gas cooled pebble bed reactor core are simulated. Figure 1 shows a schematic of the pebble bed with a single central long heating element. The top and bottom of the bed is well-insulated while the outside of the furnace wall is open to atmospheric conditions. The heating is done with a graphite tube within a protection tube in the center of the bed.

BENEFITS:

This case study demonstrates the transient simulation of the heat transfer through a packed bed with no forced convection. This case study is applicable to packed pebble beds where only natural convection is present in the bed due to a heat source on the inside of the bed and a heat sink on the outside of the bed.

SOLUTION:

The transient simulation of a packed bed is demonstrated in this case study. The ability to model the correct transient removal of the heat through the bed will be important for predictions of when a nuclear pebble bed reactor will become recritical after the forced cooling flow was stopped or whether the bed will be able to remove the heat without any active heat removal systems present.



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INTRODUCTION

This case study demonstrates the transient simulation of the heat transfer through a packed bed with no forced convection. This case study is applicable to packed pebble beds where only natural convection is present in the bed due to a heat source on the inside of the bed and a heat sink on the outside of the bed.

SYSTEM DESCRIPTION

The thermal hydraulic conditions of a typical high temperature gas cooled pebble bed reactor core are simulated. Figure 1 shows a schematic of the pebble bed with a single central long heating element. The top and bottom of the bed is well-insulated while the outside of the furnace wall is open to atmospheric conditions. The heating is done with a graphite tube within a protection tube in the centre of the bed.

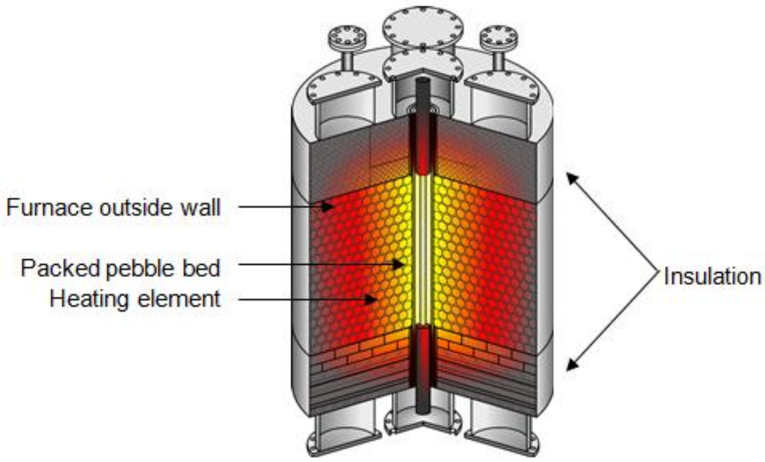

Figure 1: Schematic layout of SANA test facility taken from Nieβen & Stöcker (1997).

OBJECTIVE OF SIMULATION

The objective is to simulate the natural convection in the pebble bed during a transient event where the heat source is reduced from 30 kW to 10 kW. The pebble surface temperature distribution is also predicted.

FLOWNEX MODEL

The Flownex model of the system is similar to the steady-state case study (Flow and heat transfer in a packed bed – Steady-state).

DESCRIPTION OF SIMULATION

In this case the bed consisted of spherical graphite pebbles (60 mm diameter). The atmospheric conditions are at a pressure of 101 kPa and a temperature of 25.3 °C. During the transient event the heating power is reduced from 30 kW to 10 kW at a rate of 0.4

The duration of the experiment was 90 hours. The pebbles were first cooled with Nitrogen and then the simulation was repeated with Helium as the cooling fluid.

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kW/h and thereafter held constant on 10 kW nominal heating power. The duration of the experiment was 90 hours. The pebbles were first cooled with Nitrogen and then the simulation was repeated with Helium as the cooling fluid.

RESULTS

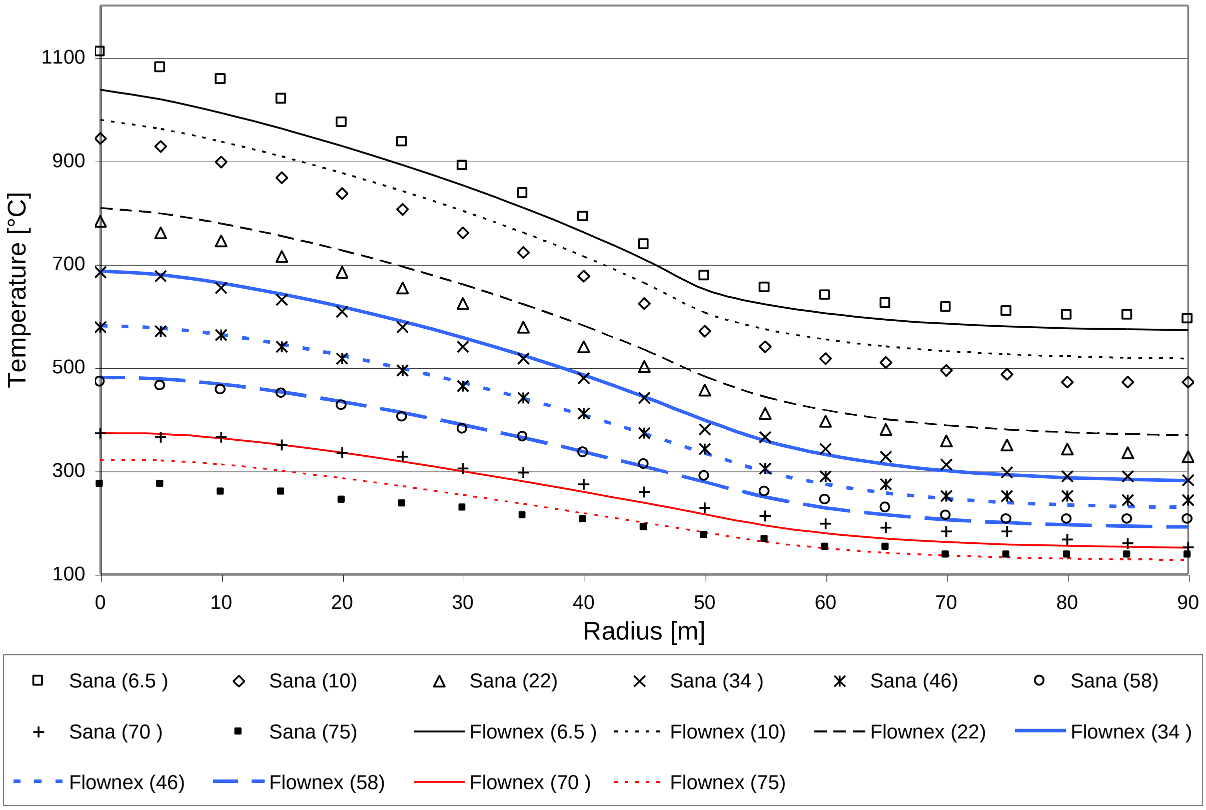

Figure 2: Flownex and SANA comparison for 30 kW to 10 kW transient with Nitrogen.

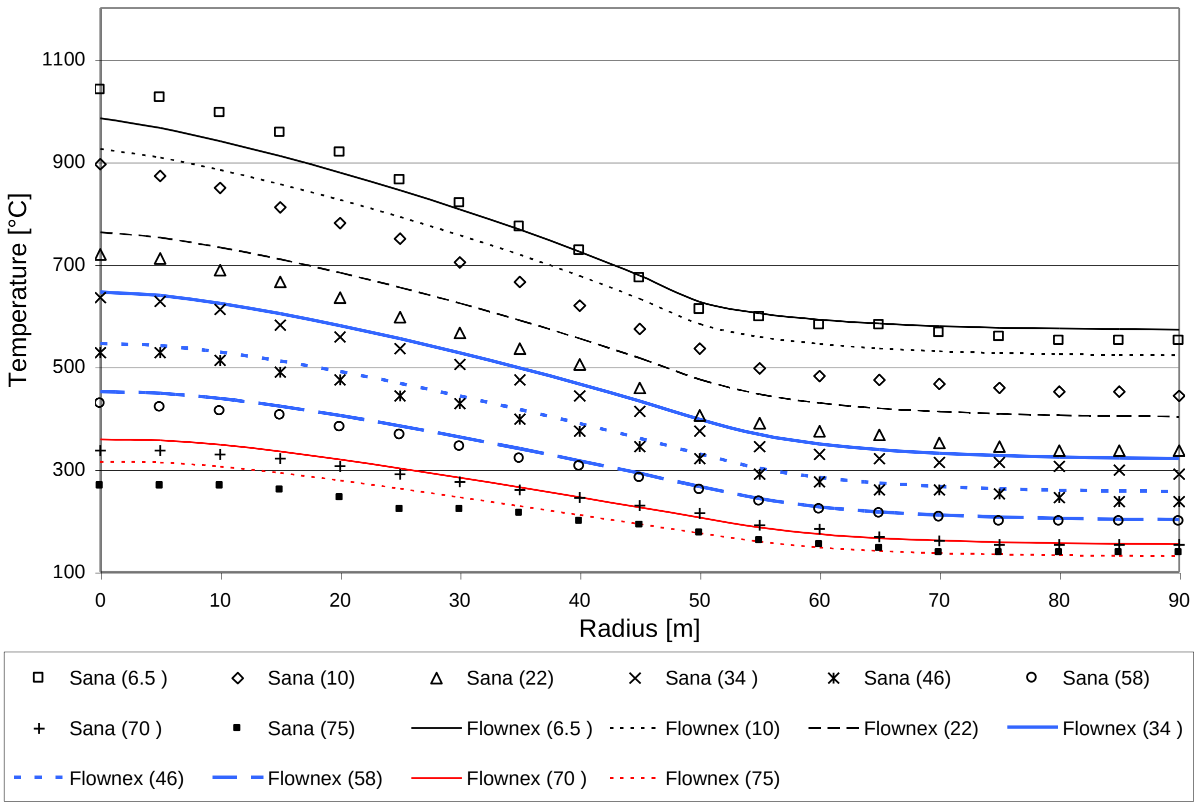

Figure 3: Flownex and SANA comparison for 30 kW to 10 kW transient with Helium.

The Flownex simulation results are compared to experimental data from the SANA test facility (Stöcker, 1998) at different heights through the bed at certain radial positions. In Figure 2 the results for the transient with Nitrogen and in Figure 3 for helium as cooling fluid are shown at different heights. From the Flownex results the user can determine what the maximum temperature in the bed will be and the amount of heat that can be removed from the bed during the transient.

The Flownex simulation results are compared to experimental data from the SANA test facility (Stöcker, 1998) at different heights through the bed at certain radial positions

CONCLUSION

The transient simulation of a packed bed is demonstrated in this case study. The ability to model the correct transient removal of the heat through the bed will be important for predictions of when a nuclear pebble bed reactor will become recritical after the forced cooling flow was stopped or whether the bed will be able to remove the heat without any active heat removal systems present.

REFERENCES

[1] STöCKER, B., 1998. "Investigations for the self-acting decay heat transport in high temperature reactors under special consideration of the natural convection" JüL-3504 dissertation, Forschungszentrum Jülich.