

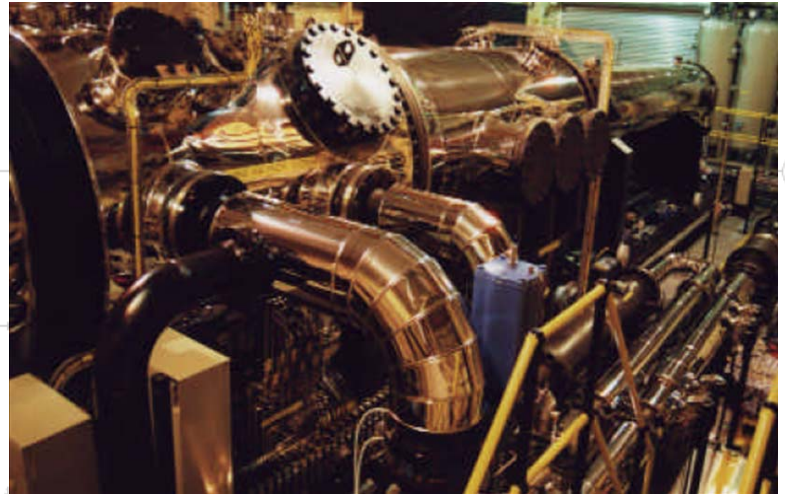
Pebble Bed Micro Model (PBMM) start-up – North West University (RSA)

Industry application:

Energy Generation

Introduction

The PBMM (the world's first closed cycle multi-shaft gas turbine test rig) was developed to demonstrate the operation of a three-shaft, pre- and inter-cooled recuperative Brayton cycle in order to gain a better understanding of its dynamic behavior. The entire cycle was designed, simulated and commissioned with Flownex within 9 months at a cost saving of \$48 million.



The system was also used to validate the control strategies of the PBMR namely, startup, load following and load rejection.

In this case study we will demonstrate Flownex's ability to simulate the startup of the PBMM.

See the article "Comparison of the thermal-fluid analysis code Flownex with experimental data from the Pebble Bed Micro Model" by Van Niekerk *et al.*¹ for a complete description of the PBMM cycle.

Challenges

The design team was faced with the following challenges:

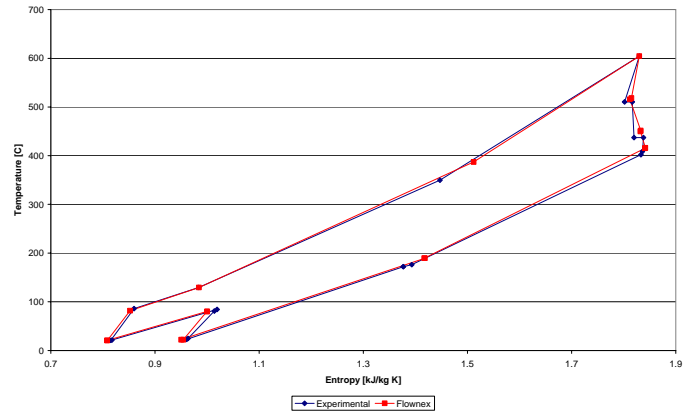
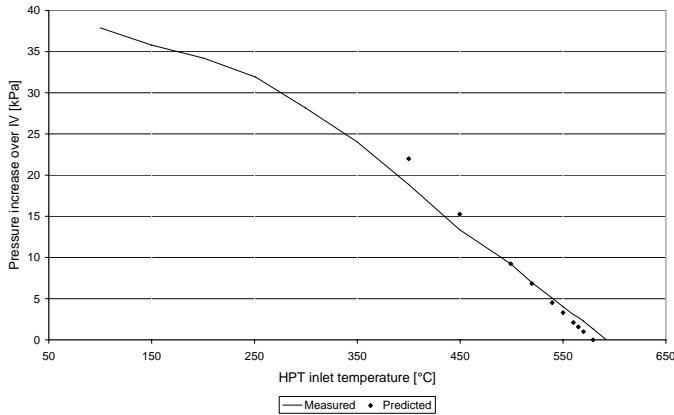
- Construct a three shaft recuperated Brayton cycle that should be able to operate at design conditions, and also be able to perform dynamics such as start-up, load following and load rejection.
- A three shaft recuperated Brayton cycle has never been built before and was only proven as a theoretical exercise in the past.
- Therefore no validated and verified design or experience on similar Brayton cycles was available to guide the design.
- No off the shelf components were available for this Brayton cycle.
- The Pebble Bed Micro Model (PBMM) were to be designed, built, commissioned and proven to work within 9 months.

¹ VAN NIEKERK, W., GREYVENSTEIN, G.P., VAN RAVENSWAAY, J.P., LABUSCHAGNE, J.T. and SWIFT, W.J., 2006 "Comparison of the Thermal-Fluid Analysis Code Flownex with Experimental Data From the Pebble Bed Micro Model", Proceedings HTR2006: 3rd International Topical Meeting on High Temperature Reactor Technology, October 1-4, 2006, Johannesburg, South Africa.

temperature the system will bootstrap at was also determined with the help of Flownex simulations.

The exit temperature of the heater is probably the most important determinant of the bootstrap point as the energy that the turbines can deliver depends on the inlet gas temperature.

Flownex predicted the bootstrap temperature as shown below. In the figures a comparison between the calculated and measured variables can be seen.

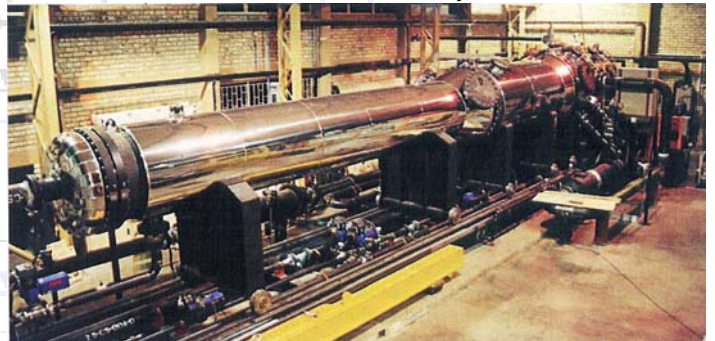


The heat loss to ambient conditions, the transient behaviour of the turbo machines, the thermal inertia of the heat exchangers and the system as a whole, the pressure drop and heat transfer through the piping and valves were integrated in Flownex to be able to design an operational plant from the selected turbo machines without any prior practical knowledge of a similar three shaft recuperated plant. Not only was the plant designed for a design point operating condition, the start-up of the plant from cold initial conditions, through the bootstrap point to the designed operating point was predicted with Flownex very accurately.

Results

The initial cost estimates were in the order of \$50 million and with a lead time of 3 years.

The Pebble Bed Micro Model was designed, manufactured, constructed, commissioned and proved to be successful within 9 months as required and at a cost of only \$2M. Flownex was instrumental throughout the design of the cycle and provided the design team with quick, accurate and integrated performance information. This performance information enabled the design team to make critical time saving decisions in terms of component selection and component interaction and still ensure cycle controllability at design and off design conditions.



Flownex proved to be accurate in the calculation of the bootstrap point.

The powerful Transient feature within Flownex allowed accurate simulation of the startup events within the PBMM, and proved to be a tool capable of determining complex variables in seconds. The dynamics of the compressors, turbines and thermal storage in heat exchangers are all accounted for in Flownex.

Quotes

“Flownex accurately predicted various plant parameters, providing a major boost of confidence in technical feasibility of the PBMR concept”

- **David Nicholls**, CEO of PBMR (February 2003)

“... due to the successful demonstration of the PBMM and the resulting boost in confidence in the bigger PBMR project ...the local economy stands to benefit on an unprecedented scale. If successful the PBMR could create more than 200 000 new jobs, add R8 billion to the country’s annual gross domestic product and R10 Billion in exports.”

- **Prof. Gideon P. Greyvenstein**, Dean of the faculty Engineering, Northwest University (March 2003)

“Flownex provides a suitable compromise between accuracy, complexity and speed while allowing integrated simulation of the entire plant within acceptable computer times”

- **Prof. Pieter G. Rousseau**, Professor of Mechanical Engineering and Director of Energy Systems Research at Northwest University, South Africa (March 2004)

