TRANSIENT CAPILLARY PUMPED LOOP MODELLING WITH ESATAN/FHTS AND SINDA/FLUINT

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CNES/MMS 5kW AMMONIA CAPILLARY PUMPED LOOP


5 CAPILLARY EVAPORATORS
4 CONDENSERS (IN PARALLEL)
1 VAPOUR LINE
1 LIQUID LINE
1 TWO-PHASE RESERVOIR

CAPILLARY EVAPORATOR PRINCIPLE

LIQUID INLET → POROUS MATERIAL → VAPOUR OUTLET

LIQUID → VAPOUR CHANNEL → POROUS MATERIAL → LIQUID

0.05 to 0.5 m

10 to 40 mm
**OBJECTIVES**

- START-UP MODEL OF 1st EVAPORATOR FROM FULLY FLOADED LOOP. DEVELOPED IN MID 90’s USING MECHANICAL PUMPS AND VALVES.

- MODEL CONVERTED IN ESATAN/FHTS IN 99, PRESENTED AT 13th EWTES.

- REMAINING ISSUES:
  - USE OF FHTS CAPILLARY ELEMENTS
  - COMPARISON WITH SINDA/FLUINT

- OBJECTIVE:
  - TO EVALUATE ESATAN/FHTS CAPILLARY ELEMENTS
  - TO GET A MODEL SIMPLER AND MORE PRACTICAL TO USE

- MAINS POINTS:
  - FLUID TIME CONSTANTS (little solid inertia)
  - EVAPORATORS CLEARING (EVAP. 2 TO 5)
  - VAPOUR FRONT DISPLACEMENT

**MODEL**

**VAPOUR LINE**
- Convective coupling with air
- Global pressure drop

**CONDENSER**
- Cooling loop @ 0°C

**LIQUID LINE**
- Convective coupling with air

**PRESSURISER**
- Heater with prop. regulation

MODEL GEOMETRY CORRECTED
MECHANICAL PUMPS MODELLING AS CLOSE AS POSSIBLE TO CAPILLARY PUMPS
**SINDA/FLUINT WITH MECHANICAL PUMPS**

**Pressure Oscillations Caused by Vapor Front Entering Each Fluid Node**

\[ \Rightarrow \text{HIGH MASS FLOW RATE} \]

\& \text{PRESSURE PEAKS}

**ESATAN/FHTS WITH MECHANICAL PUMPS**

**SAME BEHAVIOUR**

**SMOOTHER**
SINDA/FLUINT WITH CAPILLARY PUMPS

OSCIILLATIONS MORE SEVERE THAN WITH MECHANICAL PUMPS

SAME GLOBAL BEHAVIOUR

ESATAN/FHTS WITH CAPILLARY PUMPS

SAME CONCLUSION AS WITH SINDA/FLUINT
**TEMPERATURE (MECHANICAL PUMPS)**

Temperature: end of vapour line, beginning & end of liquid line results vs. test measurement

VAPOUR FRONT MOVES TOO FAST

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**TEMPERATURE ESATAN/FHTS mechanical vs. capillary**

THE VAPOUR FRONT MOVES EVEN FASTER WITH CAPILLARY PUMPS

(NO CONTROL ON MASS FLOW RATE FOR FIRST BUBBLES GENERATION IN THE CAPILLARY PUMP)
INFLUENCE OF NUMBER OF NODES

INITIAL STEADY-STATE:

Q < 0

THEN THE HEAT EXTRACTION IS REMOVED ON THE UPPER LINE

FINAL STEADY-STATE:

Q < 0

INFLUENCE OF NUMBER OF NODES ON MASS FLOW RATE WITHIN ISOLATOR?

CONVERGENCE IN TIME STEP

MASS FLOW RATE IN ISOLATOR

CPU: 0.02 s / 42 s, 0.004 s / 81 s, 0.0008 s / 146 s
INFLUENCE OF NUMBER OF NODES

1) CONVERGENCE REQUIRES A VERY HIGH NUMBER OF NODES
2) FRONT MOVES FASTER

CPU: 16 / 1mn21s, 28 / 2mn19s, 52 / 5mn12s, 100 / 10mn6s, 196 / 21mn4s, 388 / 60mn6s

ANALYSIS

- ABILITY TO SOLVE START-UP FROM FULLY FLOADED LOOP WITH PARALLEL LINES

- TYPICAL CPU TIME:
  - MECH. PUMPS: ESATAN/FHTS 120 mn, SINDA/FLUINT 10 mn
  - CAPIL. PUMPS: 180 mn, 50 mn

- LARGE INFLUENCE OF PRESSURE DROPS ON RESULTS
- NUMERICAL DIFFICULTIES TO SOLVE IF VAPOUR FRONT IS BLOCKED BY EVAPORATORS BEFORE IT REACHES THE CONDENSER
- VERY SMALL TIME STEPS

- HOWEVER, QUESTIONS ABOUT COHERENCE OF PHYSICS MODELLED WITH REALITY
  - LUMPED PARAMETER METHOD
  - HOMOGENEOUS MODEL

- => MORE ANALYTICAL AND EXPERIMENTAL WORK WOULD BE REQUIRED ON A SIMPLER LOOP (1 EVAPORATOR, 1 CONDENSER) TO GET CONFIRMATION
CONCLUSION

THE ESATAN/FHTS CAPILLARY ELEMENTS WORK PROPERLY WITHIN
THE LIMITATION OF THE PHYSICAL MODEL

CAPILLARY ELEMENTS SIMPLIFY THE WORK OF THE USER

THE MODELLING OF START-UP IS POSSIBLE

HOWEVER, MAYBE IT SHOULD BE LIMITED TO MODELS IN WHICH
FLUID TRANSIENT IS NEGLIGIBLE

• MORE QUESTIONS THAN ANSWERS AT THE END OF THE WORK

• DOUBT ON THE POSSIBILITY TO GET A SIMPLER AND MORE
PRACTICAL MODEL FOR FLUID START-UP

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