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DEVELOPMENT OF NUMERICAL MODELLING OF ISOBUTANE VAPOR EJECTOR

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1. Introduction

2. Methodology and apparatus

3. Experimental results

4. Numerical results

5. Conclusions
1. Introduction

Ejection cooling system

Basic parameters:

\( U = \frac{\dot{m}_e}{\dot{m}_g} \)

\( \Pi = \frac{p_c - p_e}{p_g - p_e} \)

\( COP = \frac{\dot{Q}_e}{\dot{Q}_g + P_p} \)
1. Introduction

Two type of operating conditions:

1. **on-design** operation

2. **off-design** operation
Most popular / typical areas in ejector modelling

- 3D vs 2D
- Pressure and velocity distribution
- Performance line
- Turbulence model verification
- PIV
- CFD
2. Methodology and apparatus

Schematic diagram of the testing-stand

Cross-section view of the ejector
3. Experimental results

\[ U = \frac{\dot{m}_e}{\dot{m}_g} \]

The series taken for further analysis are shown in the graph. For example:

- \( t_{gs} = 63.5 \, ^\circ\text{C} \)
- \( t_{gs} = 61.5 \, ^\circ\text{C} \)
- \( t_{gs} = 58.0 \, ^\circ\text{C} \)
- \( t_{gs} = 55.0 \, ^\circ\text{C} \)

With:
- \( t_{es} = 7.0 \, ^\circ\text{C} \)
- \( \Delta T_e = 6.5 \, \text{K} \)
- \( \Delta T_g = 8.0 \, \text{K} \)
4. Numerical results

**Mesh sensitivity test - entrainment ratio**

<table>
<thead>
<tr>
<th>exp.</th>
<th>Mesh #1</th>
<th>Mesh #2</th>
<th>Mesh #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>U = me/mg</td>
<td>0.189</td>
<td>0.320</td>
<td>0.357</td>
</tr>
</tbody>
</table>

All meshes have unstructural tetragonal cells

- Mesh #1 – $2.0 \times 10^6$ cells (3 domains with interfaces)
- Mesh #2 – $1.5 \times 10^6$ cells (1 domain)
- Mesh #3 – $4.5 \times 10^6$ cells (1 domain, after mesh adaptation)
4. Numerical results

Mesh sensitivity test
- pressure distribution

- nozzle outlet
- mixing chamber
- diffuser
4. Numerical results

turbulence model selection
3D vs 2D (axi)

Result:
SST $k$-$\omega$ turbulence model was used in further 3D simulations

Static pressure distribution along ejector wall, EXP vs CFD (3D)

on-design operation
4. Numerical results  

**turbulence model selection**

**on-design** operation near to transition into off-design

**off-design** operation
4. Numerical results

performance lines $U = f(t_c)$
4. Numerical results

Deviation of the numerical results for Series No. 1

Deviation of the numerical results for Series No. 2
4. Numerical results
4. Numerical results

Static pressure distribution along ejector wall, CFD vs.
4. Numerical results

Large Eddy Simulation

**stream lines – main stream**

**stream lines – total**

Velocity [m s\(^{-1}\)]
Large Eddy Simulation

4. Numerical results

nozzle & suction chamber

stream lines – total
Large Eddy Simulation

4. Numerical results

stream lines – total

Velocity [m s\(^{-1}\)]
4. Numerical results

Large Eddy Simulation

velocity distribution

diffuser

nozzle
4. Experimental results vs analytical results

Sokolov and Zinger (1989) equation

\[ p_c(U) = P_c \cdot \frac{1}{\pi_m} \left[ \frac{\pi_g}{p_c} \frac{f_m}{f_m} + \frac{\pi_e}{f_m} + K \frac{\pi_{cr}}{p_c} \frac{f_m}{f_m} \right] \left[ \varphi_a \varphi_m \varphi_d \lambda_e + \varphi_s \varphi_m \varphi_d U \sqrt{\Theta} \lambda_e - \left(1 + U \sqrt{\Theta}\right) \lambda_m \right] \]
Comparison of the latest (Chen et al.) and most popular (Huang et al.) analytical models with experimental results
5. Conclusions

The own experimental and numerical investigation of the ejection system driven by low-temperature source have been shown.

The experimental investigations confirmed that the ejection cycle operating with isobutane can effectively be driven by low temperature heat source, e.g. lower than 75°C.

Under this range of motive temperature heat sources the ejection cycles can be considered as truly competitive in comparison with absorption refrigeration systems.

It was shown that for higher value of the motive vapour the ejector operates at higher values of the condensation temperature.

Based on the numerical results it can be concluded that the CFD method is an efficient tool to predict the entrainment ratio and pressure profile. In general, it can be concluded that chosen turbulence model gives good representation of the flow inside ejector.