Simulation of Internal Flows of the Inlet Nozzle Assembly
of the CANDU-6 Moderator System
ABSTRACT

For predicting the inlet velocity profile at the CANDU-6 moderator nozzles, a commercial CFD code is tested and applied. The fluid flows going through the moderator piping network have three major phenomena such as pipe flows, curved pipe flows, and impinging jets. Some experimental data were collected for each flow type, and various turbulence models were tested and optimized. As a result of the investigation, detailed velocity profiles and turbulent parameters at the nozzle outlets are obtained, which can be applied to the simulation of the CANDU moderator circulation.
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1. 材料科学与工程基础（2）
1. 

CFX-5.7[1] 

Fig. 1
2. CFX-5.7

2.1 baseline

CFX-5.7, baseline k-\omega, SST, 6,900, 2,400, 6,900, (fully-developed), Reynolds, 40,000, 2,400, 40,000, (turbulent kinetic energy, k), baseline, (logarithmic region). 4

\[
u^* \left( \frac{U - U_{wall}}{U_r} \right) = \frac{1}{k} \ln y^* + B
\]

\[
y^* = \frac{y U_r}{v}, \quad U_r = \sqrt{\tau_w/\rho}, \quad k = 0.4, \quad B = 5.5
\]

2.2 90°

CFX-5.7, non-swirling, 57,400, 20°C, bulk velocity \(U_b\), 1.29 \(\pm 0.03\) m/s, 5, 15, 20°, LDV, Azzola, 3, 45, 90, 135, 177 degree, 6-8, Azzola, 3, 45, 90, 135, 177 degree,
Speziale, Sarkar and Gatski\cite{4} Reynolds stress (SSG Model)\cite{4} X/D = 200 (Axial) 180°

2.3 ¿¬°áµÈ

Cooper\cite{5} µÎ °³ÀÇ Á÷°ü Àß »ó·ù ÂÊÀ» ÀǹÌÇÑ´Ù.

µÎ °³·«µµÀÌ´Ù 70,000 Re °ú D = 101.6 mm °ú 2D °ú 101.6 mm °ú

(fully-developed) ¿¬°áµÈ. ¿øÇü ³ëÁñ·ÎºÎÅÍ ¼öÁ÷À¸·Î ¿æµ¹ÇÏ´Â À¯µ¿ÀÌ¸ð»çµÇ¾ú°í, ±× 9 ¿øÇü ³ëÁñ ª½¼öÀÎ 180° ±×¸² 9 ±×¸²

Cooper \cite{5} ½ÇÇè ÀÚ·á¿Í À§Ä¡´Â 11 ¼öÁ÷¹æÇâ ¿ÏÀü¹ß´Þ (fully-developed) µÇ¾ú´Ù. ±× 10 ¿øÇü ³ëÁñ ÀÔ±¸¿¡¼­ ¿ÏÀü¹ß´Þ Mean Velocity ¶ Normal

Stress(\(\bar{u}^2\)) ¶ øó À¸·Î Shear Stress Transport (SST) ¶ øó À¸·Î øó À¸·Î

Mean Velocity ¶ øó À¸·Î øó À¸·Î øó À¸·Î. Low-Re ¿¬°áµÈ µÎ °³·«µµÀÌ´Ù µî°ü Àß »ó·ù µÎ °³ÀÇ Á÷°ü Àß »ó·ù. X/D = 200 (Axial) 6,900 X 200(Axial)

±×¸² 10 ¿øÇü ³ëÁñ Á÷°ü 1.0 ¿øÇü ³ëÁñ Áï ³ôÀÌÀÌ´Ù ³ëÁñ [m]\cite{5}, y+ µÎ 1.0 ¿øÇü ³ëÁñ, R = 0.555 0.04735

<table>
<thead>
<tr>
<th>Turbulence Model</th>
<th>Near-Wall Treatment</th>
<th>Mesh (1/4 Domain)</th>
<th>y*</th>
<th>U\text{max} [m/s]</th>
</tr>
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<tr>
<td>k-(\varepsilon)</td>
<td>Wall Function</td>
<td>2,400 X 200(Axial)</td>
<td>13.5</td>
<td>0.04679</td>
</tr>
<tr>
<td>SSG</td>
<td></td>
<td></td>
<td>13.17</td>
<td>0.04642</td>
</tr>
<tr>
<td>k-(\omega)</td>
<td></td>
<td></td>
<td>0.546</td>
<td>0.04764</td>
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<tr>
<td>BSL k-(\omega)</td>
<td>Low-Re Method</td>
<td>6,900 X 200(Axial)</td>
<td>0.538</td>
<td>0.04739</td>
</tr>
<tr>
<td>SST</td>
<td></td>
<td></td>
<td>0.555</td>
<td>0.04735</td>
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2. --- • • • • • • • • • • • • • • • , CFX-5

3. --- • • • • • • • • • • • • • • • , CFX-5
4. Azzola\textsuperscript{[3]} used CFX-5.
6. Azzola [3] presented the following results for the SSG and SST models:

- **SSG Model**:
  -ophone angles: 0°, 3°, 45°, 90°, 135°, 177°
  -plots for X/D = 1, 2

- **SST Model**:
  -same angles as SSG
  -plots for X/D = 1, 2

- **k-ε Model**:
  -same angles as SSG
  -plots for X/D = 1, 2

- **BSL k-ε Model**:
  -same angles as SSG
  -plots for X/D = 1, 2

(○: experimental, △: CFX-5 simulation)
Azzola\cite{3}  

\textbf{SSG Model}  

\textbf{SST Model}  

\textbf{k-\epsilon Model}  

\textbf{BSL k-\epsilon Model}  

\begin{align*}  
\text{7.} \quad & \quad \text{(Circumferential)}  
\end{align*}

\begin{align*}  
\text{\textbullet}  \quad & \quad \text{\textbullet}  
\end{align*}

\begin{align*}  
\text{\textbullet}  \quad & \quad \text{\textbullet}  
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\begin{align*}  
\text{\textbullet}  \quad & \quad \text{\textbullet}  
\end{align*}

\begin{align*}  
\text{\textbullet}  \quad & \quad \text{\textbullet}  
\end{align*}
Azzola [3] 

(Circumferential)

(symbol : , symbol : CFX-5)
9. Cooper\textsuperscript{[5]}

10. (y-x)
11. CFX-5 Streamlines (y-x-z plane)
(a) SST

(b) SSG

(c) k-ε

12. CFX-5
(d) BSL Reynolds Stress

(e) LRR

(f) QI

12. CFX-5...
(a) SSG

(b) BSL Reynolds Stress

12. CFX-5 Normal Stress ($u^2$)
13. CFX-5 Normal Stress ($u^2$)
3. 3.2.2 90°

3.1 3.1 6.0 inches (= 0.1524m) (elbow) 2m 2m (D₂O) 117.5 L/s Re 1.25×10⁶ node (Interface) 1084.7 kg/m³ μ 8.5×10⁻⁷ kg/(m·s)

3.2 3.2

3.2.1 3.2.1 10⁶ 45.7 k-e 1.5 atm 45°C 104° 1084.7 °C 1-ε 0.4 B = 5.5

\[ \frac{L}{d} \approx 4.4 \text{Re}^{1/6} \]

(2)

3.2.2 90°

Azzola [3] 2×D 2×D 208,229 node Fig. 14
SSG Reynolds stress $y'$ 15

$y' = 10-15$ 

$y'$ 16

(14)

$y'$ 17

(streamline)

(secondary flow)

$y' = 1.0$

19

20

Reverse Flow

3.2.3

Zwart et al.\cite{7} 

$y' = 10$ 10-15 node

615,379 node

119,073 node

Prism mesh

$y' = 1.0$

19

20

Dead Zone
14. Mesh

15. SSG
16. Streamlines

17. Streamlines
4. °·

... the equations and their solutions, which are important in various fields such as engineering and physics. These equations can be applied to real-world scenarios, such as the Dead Zone in ecosystems or the SST (surface skin temperature) in climate studies, to understand temperature gradients and their impacts. Specifically, for the SST, $y'$ represents the temperature gradient and is crucial for understanding the thermal dynamics of the ocean. 

...
KAERI/TR-3141/2006

(ARTR µîÀÇ °æ¿ì ÁÖÀúÀÚ)

(15-20ÁÙ³»¿Ü)

CANDU-6
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**Title / Subtitle**

Simulation of Internal Flows of the Inlet Nozzle Assembly of the CANDU-6 Moderator System

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**Abstract (15-20 Lines)**

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**Subject Keywords**

CANDU-6, Safety Analysis, Moderator, Nozzle

CFD, Impinging Jet