A Grooved Core Barrel Concept for Reducing the Direct ECC Bypass

Tae-Soon Kwon, Yong-Seong Shin, Seon-Hong Hwang, Chul-Hwa Song, Myoung-Ho Park
KAERI, 150 Duckjin-Dong, Yuseong-Ku, Daejeon, tskwon@kaeri.re.kr, http://theta.kaeri.re.kr
AJou Motor College, Boryong ChungNam,parker@dcc.re.kr

1. Introduction

The enhancing effect of ECC penetration by adopting a grooved core barrel wall, which has vertically arranged small rectangular-shaped grooves on the core barrel wall of the reactor vessel (RV) downcomer, has been investigated. Small scale vortexes are induced due to the high-speed cross flow around the grooves on the core barrel surface. Since the vortex is stagnant, thus the pulling force of ECC drop or film to flow out through a broken cold leg is minimized due to the existence of the grooves. The grooves vertically arranged against the cross flow play a role of the flow converting mechanism to generate a secondary vortex from the high-speed cross flow in the downcomer. The secondary vortex also plays a role of capturing the liquid drops, which normally tend to be bypassed to a broken cold leg while being carried along in a high-speed cross flow of steam going throughout the break. The grooved channels allow the stagnant vortexes of the ECC to flow downwardly to the lower downcomer due to gravity. That makes the direct ECC bypass fraction reduced, and allowing a large amount of ECC to reach the reactor core.

2. Experimental Methods and Results

2.1 Test conditions

The square-shaped grooves have 10mm in pitch, and 10mm in depth and width. The grooves are vertically arranged on the core barrel wall. The thin SUS plate has 1 mm in thickness. If the ECC film is concentrated at the suction zone of the broken cold leg, the liquid flows out all. Thus, the direct ECC bypass fraction is highly increased. In this study, the grooved core barrel is installed at the half elevation between the DVI nozzle and the cold leg center to prevent a high ECC suction out through a broken cold leg. The grooved cylinder is installed at the outside of the core barrel only. The grooves, as shown in Fig.1, consist of a series of open and closed channels. The open channel generates the stagnant vortex, while the closed channel makes an ECC downward flow channel which is isolated from the high-speed cross flow. The scaled groove height of 10mm is corresponding to 50 mm in a prototypic RV.
The tests are performed in the air-water separate effect test facility (DIVA). The injection velocity of ECC water is fixed at 0.89m/sec to compare the results of the horizontal injection mode in the standard design of APR1400. The air velocity of the cold leg varies from 5 m/sec to 20 m/sec with a step of 5m/sec. The performance with grooved core barrel wall is compared in terms of the ECC direct bypass fraction. The test condition is summarized at Table 1.

Table 1. Test conditions

Components	Flow Condition	Velocity
Fluid	Air, Water	-
ECC	DVI-2&4 DVI-4 Only	0.89 m/sec
Cold Leg	CL-1, CL-2, CL-3	5~20 m/sec

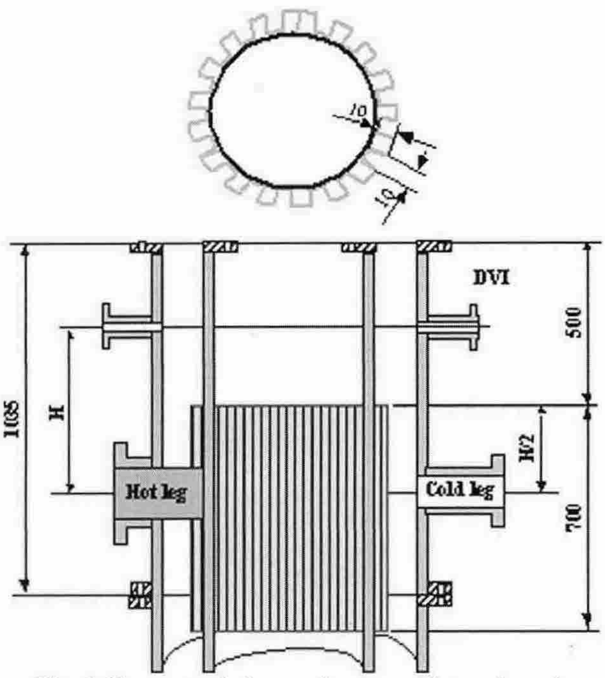

Fig. 1 Conceptual shape of a grooved core barrel

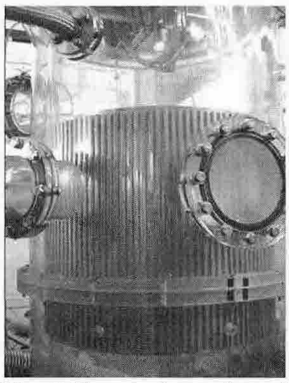

Fig. 2 Grooved core barrel

2.2 Flow Visualization

Fig. 3 shows a typical shape of ECC injection. The ECC water flows into the grooved core barrel annulus in the form of liquid film because the ECC water is injected on the smooth core barrel above the grooved core barrel to prevent concentration. Fig. 4 shows the flow pattern at the broken cold leg. No slug of ECC water or film appears around the suction zone of the broken cold leg, but the small drops come from the top of the open grooves of the grooved core barrel. Fig. 5 shows the ECC penetration at the bottom of the grooved core barrel annulus. The ECC water is penetrated well. From the visualization, it seems that the grooved core barrel wall is very effective to prevent the direct ECC bypass due to the high-speed cross flow in the RV downcomer.

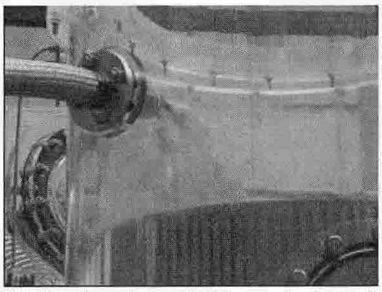

Fig. 3 ECC injection from DVI nozzle into the grooved core barrel cylinder at the upper downcomer

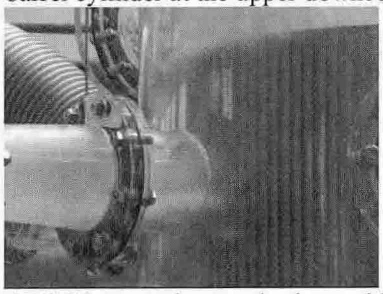

Fig. 4 ECC bypass shape at broken cold leg

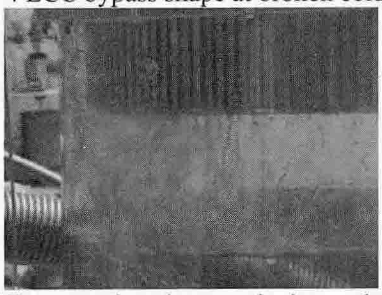

Fig. 5 ECC penetration shape at the lower downcomer below the broken cold leg.

2.3 Direct ECC Bypass

Fig. 6 represents the performance of the grooved core barrel in terms of the direct ECC bypass fraction. The bypass fraction for the grooved core barrel is much lower than that of a standard DVI injection concept. The direct bypass fraction of grooved core barrel annulus is about 27% while the standard DVI injection has 43% for DVI-2 and DVI-4 injection mode. For the DVI-4 which is located at near the broken cold leg, the direct ECC bypass fraction of the grooved core barrel wall is about 36% while the standard DVI-4 has 82%. The direct ECC bypass fraction of DVI-4, as shown in Fig. 6, is about half ratio compared to the standard downcomer design for DVI-4. The grooved core barrel is believed to be an effective concept to reduce the direct ECC bypass since it can prevent the liquid entrainment or suction out at the downcomer near the broken cold leg.

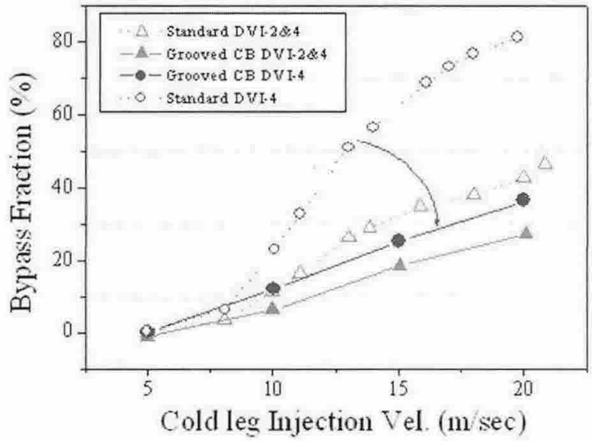

Fig. 6 Direct ECC bypass fraction for grooved core barrel cylinder

3. Conclusion

It has been demonstrated that a grooved core barrel concept is very effective in terms of reducing the direct ECC bypass compared to the standard downcomer design with the DVI. From the visualization tests, it is observed that the stagnant vortex formed onto the vertically grooved core barrel contributes very much to reduce the direct ECC bypass.

ACKNOWLEDGMENT

This research has been performed under the R&D program supported by the Ministry of Commerce, Industry & Energy (MOCIE) of the Korean Government.

REFERENCES

[1] T. S. Kwon, C. R. Choi, and C.-H. Song, 2003a, Three-dimensional analysis of flow characteristics on the reactor vessel downcomer during the late reflood phase of a postulated LBLOCA, *Nucl. Eng. & Des.* Vol. 226, pp.255-265.

[2] T. S. Kwon, C.-H. Song, B. J. Yun, and H. K. Cho, 2003b, Effect of the Yaw Injection Angle on the ECC Bypass in Comparison with the Horizontal DVI, *Nucl. Eng. & Des.*, Vol. 225, pp.295-304.

[3] T.S. Kwon, C.R. Choi, C.-H. Song, 2003, Numerical simulation of ECC bypass behavior on a grooved annulus wall, 2003-KNS Spring meeting.