ИЗВЪРШВАНЕ АНАЛИЗИ НА ЧУВСТВИТЕЛНОСТ С ИНТЕГРАЛЕН КОД MEDICIS(ASTEC-V2) ЗА ИЗСЛЕДВАНЕ ОБРАЗУВАНЕТО НА КОРА ПРИ VB-U5 И VB-U6 ВУЛКАНО ТЕСТОВЕ

Росица Генчева, Антоанета Стефанова и Павлин Грудев

MEDICIS(ASTEC-V2) SENSITIVITY CALCULATIONS FOR INVESTIGATION OF THE CRUST FORMATION IN VB-U5 AND VB-U6 VULCANO TESTS

Rositsa Gencheva, Antoaneta Stefanova and Pavlin Groudev

1. Abstract

This paper presents the results from sensitivity calculations made with MEDICIS(ASTECv2) for investigation of the crust formation during the Molten Corium-Concrete Interaction(MCCI) in VB-U5 and VB-U6 VULCANO tests. All calculations are made with MEDICIS computer code. The main goal of these analyses is to assess how the assumptions for crust formation or not formation influence over the concrete ablation. Three calculations have been done for each one of the experiments with different crust thickness and lock of crust formation at the bottom, side and upper surface.

2. Introduction

Hypothetically in case of severe accident reactor core could be overheated and a molten pool called corium could be generated at the bottom of the reactor vessel. This molten pool will consist mainly of uranium oxides, zirconium oxides, still oxides and fission products. If the reactor vessel bottom failure appears this corium will enters in the containment basement and will start to interact with reactor pit concrete. That's why it is very important to study the process of concrete ablation because the concrete appears last barrier, which preserves FP release through the environment.

To investigate MCCI phenomena a number of experiments have been provided in many test facilities in the world. The results of these experiments

are used to improve the modelling capabilities of the available MCCI codes.

The experiments conducted at VULCANO test facility, sited at Cadarache French National Laboratory (CEA), were devoted to the study of 2D long-term dry MCCI with either purely oxidic prototypic corium or with stratified oxide and metal layers [2]. These experiments were provided in the frame of French national program on Molten Corium-Concrete Interactions research. The programme has been initiated in 2001 by CEA, EDF and IRSN in order to reduce the remaining uncertainties on the interaction between corium and basement concrete and mainly to investigate the ablation rate ratio between axial and radial directions in the homogenous and stratified configurations.

The reference tests in this paper are VBU5(with silica-rich concrete) and VBU6(with limestone-rich concrete) VULCANO tests. It has been decided to open the results of these two oxidic tests for investigation in the frame European Severe Accident Research Network of Excellence (SARNET). It is not detected in the real tests results crust formation or not formation [1], so it is the matter of this investigation.

In MEDICIS [3]code calculations crust formation is predicted by $(T_{solidification})$. The solidification temperature in MEDICIS/ASTECv2 was derived from the equation:

$$T_{solidification} = GAMMA * T_{solidus} + (1 - GAMMA) T_{hquidus}.$$

So the crust formation depends on user choice of GAMMA. Also in MEDICIS the thickness of the crust is the same at each point of the layer-concrete boundary. Three calculations have been done for each one of the experiments VBU5 and VBU6 with GAMMA=0.3, GAMMA=0.5 and GAMMA=0.7 to investigate how the crust formation or not formation influence over the final cavity shape and the ablation volume.

3. Description of the VULCANO test section

The test section is made of a concrete block (700x 400 x 450 mm) in which there is a semi-cylindrical cavity (300 mm diameter, 250 mm depth), enabling a maximum ablation of 15 cm both radially and axially. Concrete has been poured inside a rectangular inductor, as shown in Figure 1 to Figure 2

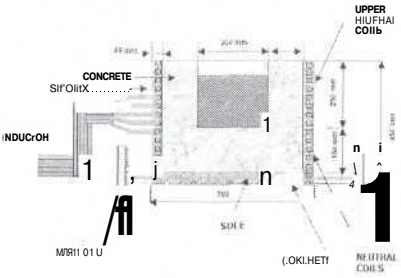


Figure 1: Test section (Side View)

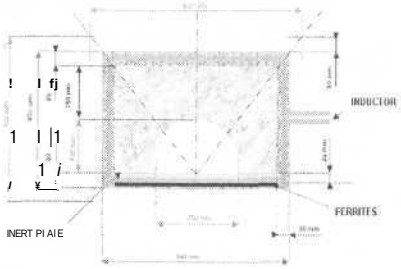


Figure 2: Test section (Cross View)

The inductor, used to simulate corium decay heat, is made of 14 rectangular (25x10 mm section) copper coils, with 5 mm interspaces. From top to bottom (see Figure 2), they are as follows: Neutral coils, Active coils and Neutral coils. All the coils are water cooled. Electrical characteristics (voltage, intensity, frequency) of the active coils and of the generator are also monitored during test. 131 type-K thermocouples have been installed in the concrete block in order to monitor the temperature evolution and ablation front progression. The prototypic oxidic corium is melted and heated to the necessarily temperature in plasma-arc furnace and after that poured in the test section.

4. VB-U6 test definition

For VB-U6 test it is used prototypic oxidic corium and limestone rich concrete. The corium composition is presented in Table 1.

Table 1: VB-U6 corium composition (as poured)

Oxide	UO_2	ZrO_2	SiO_2	CaO	Fe_2O_3
Mass fraction (wt.%)	57%	33.1%	5%	2.6%	2.3%

The composition of silica rich concrete is presented in Table2.

Table 2: Limestone-rich concrete composition in oxides

Oxides	CaO	CO_2	SiO_2	H_2O	Al_2O_3
Mass fraction (wt.%).	41.2%	24.6%	25.1%	6.7%	2.3%

The initial corium mass is estimated as 31 kg. These 31 kg of initial corium mass represent 4,9 L corresponding (in the absence of void) to a height of 14 cm.

TheVB-U6 test considered time is 2 hours (7200s)

The average injected net power is 9 kW.

The external temperature remained below 50°C (323 K) during the test. The concrete initial temperature was of 300 K.

An initial corium temperature of 2625 K has been estimated.

Concrete ablation volume at the end of the test is estimated to 4 L.

Ablation temperature for the limestone concrete is evaluated at 1700K and concrete density 2016 kg.rrr^3.

5. VB-U5 test definition

For VB-U5 test it is used prototypic oxidic corium and silica rich concrete. The corium composition is presented in Table 3.

Table 3: VB-U5 corium composition (as poured)

Oxide	UO_2	ZrO_2	SiO_2	CaO	Fe_2O_3
Mass fraction (wt.%).	54%	37.4%	3.7%	2.4%	2.5%

Table 4: Silica rich concrete compositions in oxides

Oxides	SiO_2	CaO	CO_2	AI2O3	H_2O
Mass fraction (wt.%)	66%	17%	9%	5%	3%

About 27,9 kg of corium were initially poured in the test section cavity.

These 27,9 kg of initial corium mass represent 4,4 L corresponding (in the absence of void) to a height of 13 cm.

The VB-U5test considered time is 1h20 (4800 s).

The average injected net power is 11.5 ± 1 kW.

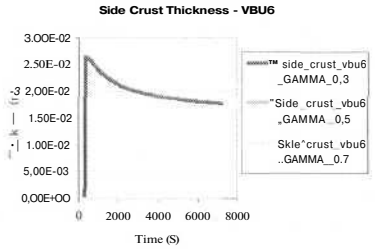
The external temperature remained below 50°C (323 K) during the test. The concrete initial temperature was of 300 K.

An initial corium temperature of 2336 K has been estimated.

From the ablation cartography, the concrete ablated volume at the end of the test is of 5.8L.

Ablation temperature for the silica rich concrete is evaluated at 1570K and concrete density 2140 kg.nr^3.

6. Sensitivity calculation results for VB-U6



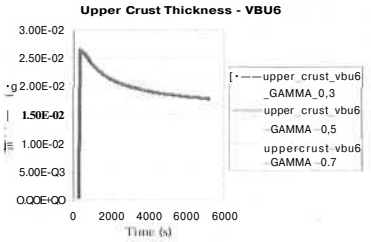
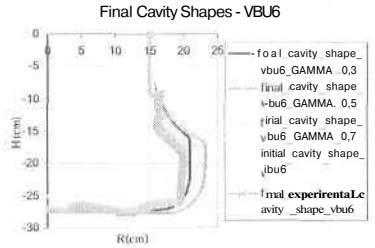


Figure 3: Lateral crust thickness - VBU6 Figure 4: Upper crust thickness - VBU6

It could be seen in the Figures 3 and 4 above that crusts of about 2,7cm appear at approximately 350 sec. just in case of GAMMA=0.3. Due to intensive gas formation in the first 350 sec crusts didn't appear.

In the other cases GAMMA=0.5 and GAMMA=0.7 crusts didn't appear.



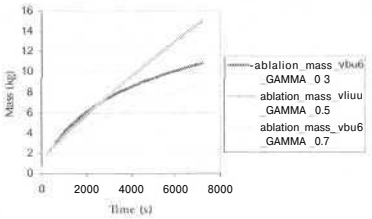


Figure 5. Final cavity shapes - VBU6 Figure 6. Global ablation mass - VBU6

It could be seen from the Figures 5 and 6 that final cavity shape in case of GAMMA=0.7 is closer to the final experimental cavity shape. Also the final ablation volume in case of GAMMA=0.7 is approximately 4.4 L, which is closer to the final experimental value of 4 L(see Figure 6).

7. Sensitivity calculation results for VB-U5

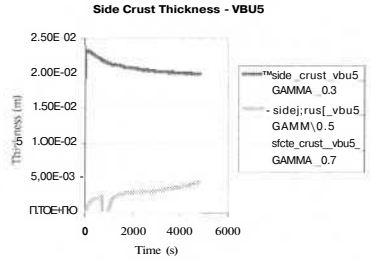


Figure 7. Lateral crust thickness - VBU5

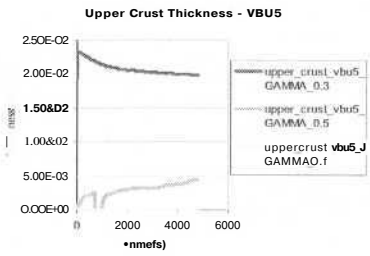


Figure 8. Upper crust thickness - VBU5

It could be seen from Figures 7 and 8 that crusts of approximately 2.4 cm appear in case of GAMMA=0.3. These crusts start to decrease to 2cm till the end of calculation.

In case of GAMMA=0.5 crusts starts to increase to 0.3mm from the beginning to approximately 800sec. From 800s to 1000s crusts are dissolved in the corium-concrete melt. After 1000s crusts start to increase till the end of calculation and reach values of 5mm.

In the case of GAMMA=0.7 crusts didn't appear.

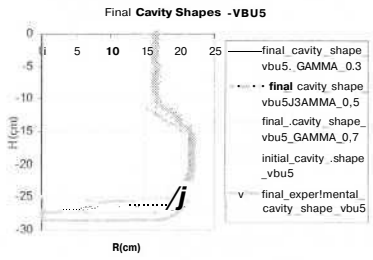


Figure 9: Final cavity shapes - VBU5

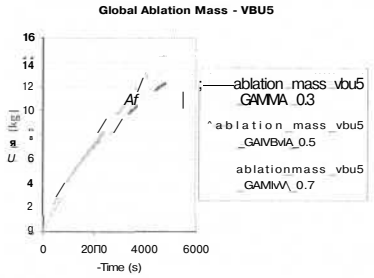


Figure 10: Global ablation mass - VBU5

It could be seen from the Figures 9 and 10 that final cavity shapes in case of GAMMA=0.3 and GAMMA=0.5 are closer to the final experimental cavity shape. Also the final ablation volume in case of GAMMA=0.3 is approximately 5.7 L, which is closer to the final experimental value of 5.8 L(see Figure 10).

4. Conclusion

In case of limestone-rich concrete (VB-U6) the best results are achieved in case of GAMMA=0.7, which leads in the MEDICIS model to lock of crust formation. It correspond better with the real VB-U6 experiment, where due to limestone concrete decarbonisation an intensive gas formation could be observed. This calculation case indicates also better agreement of calculated final ablation volume (4.4L) and the experimental final ablation volume (4L).

In case of silica-rich concrete (VB-U5) the best results are achieved in the calculation case where GAMMA=0.3. There is no significant gas formation and crusts of approximately 2.7cm appear at the beginning of calculation and start to decrease to 2cm till the end. Calculation case with GAMMA=0.3 indicates also better agreement of calculated final ablation volume (5.7L) and the experimental final ablation volume (5.8L).

5. Literature

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6. **Автори**

Росица Веселинова Генчева, асист.
Антоанета Емилова Стефанова, главен асист.
Павлин Петков Грудев, доц.
Институт за ядрени изследвания и ядрена енергетика, Българска Академия на Науките
Тел: (+359 2) 979 5583
roseh@inrne.bas.bg;
antoanet@inrne.bas.bg;
pavlinpg@inrne.bas.bg.