Coupling the Severe Accident Code SCDAP with the System Thermal Hydraulic code MARS

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1. Introduction

MARS is a best-estimate system thermal hydraulics code with multi-dimensional modeling capability.[1] One of the aims in MARS code development is to make it a multi-functional code system with the analysis capability to cover the entire accident spectrum. For this purpose, MARS code has been coupled with a number of other specialized codes such as CONTEMPT for containment analysis, and MASTER for 3-dimensional kinetics. And in this study, the SCDAP[2] code has been coupled with MARS to endow the MARS code system with severe accident analysis capability. With the SCDAP, MARS code system now has acquired the capability to simulate such severe accident related phenomena as cladding oxidation, melting and slumping of fuel and reactor structures.

2. Coupling Methods and Techniques

A number of different methods have been used in coupling MARS with other codes. These include embedding the code at source level as used in the coupling of RELAP and COBRA-TF to produce MARS, linkage via DLL (Dynamic Link Library) used for GUI (Graphic User Interface) using ViSA, simple data transfer at a given time step, or through parallelization using such programs as PVM. In this study, the SCDAP code obtained from SCDAP/RELAP/MOD3.3, which models solid heat structures of the reactor system, has been embedded in the MARS code, which models the fluid part, by following the methods used in SCDAP/RELAP.

The 1D part of MARS code is based on RELAP and retains the overall code structure of RELAP. The overall code structure of MARS-SCDAP is shown in Figure 1 and it is identical to that of SCDAP/RELAP. The MARS code executes in PC-Windows environment whereas the SCDAP/RELAP works under UNIX environment of the Workstations. Therefore it was necessary tomodify and re-compile the SCDAP/RELAP to work on PC-Windows environment. The MARS code uses the structured data forms available in Fortran 90, whereas the SCDAP/RELAP retains use of FTB package with a large one-dimensional data array form of RELAP. In addition, SCDAP/RELAP uses the bit-operation functions to manipulate bits to set, reset and test various options. Such functions had been replaced by the logical variables in MARS code. Thus, it was crucial to convert the data structure and various bit-operation functions of SCDAP/ RELAP to the form used by the MARS.

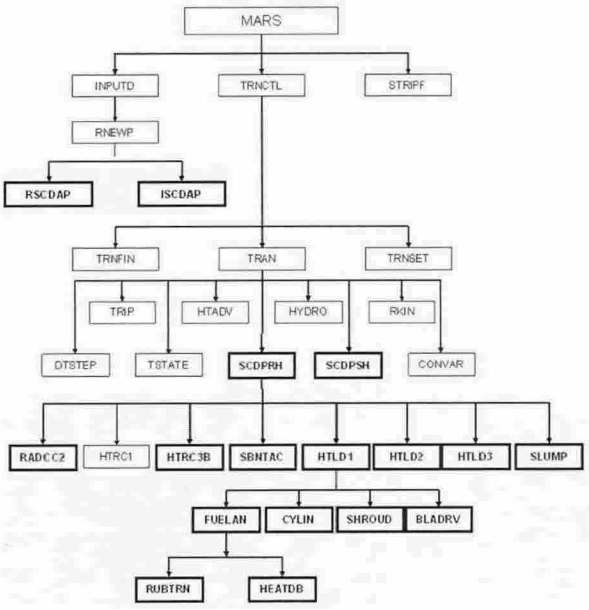

Figure 1. Overall Structure of MARS-SCDAP

Figure 2 shows the data transfer between the MARS and SCDAP codes. As can be seen in the figure, there is a tight coupling at the source level between the two component codes.

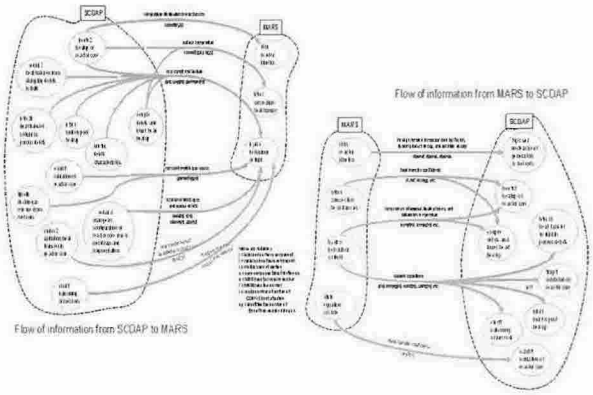

Figure 2. Flow of Information between MARS and SCDAP

3. Modeling Capabilities of MARS-SCDAP

With MARS-SCDAP, MARS simulates the overall RCS thermal hydraulics, control system interactions and the reactor kinetics. Whereas, the SCDAP part simulates the followings for the severe accident analysis :

- Heatup/damage progression in core structure and lower RPV head.
- Meltdown of fuel rods and structures.
- Fragmentation of embrittled fuel rods.
- Convective and radiative heat transfer in porous debris.
- Formation of molten pool of core materials.
- Slumping of the molten material to the lower head.

The relocation and slumping of the core are handled by the COUPLE sub-code embedded within the SCDAP code and it is based on two dimensional finite-element heat conduction model. Compared to other severe accident codes, SCDAP provides much more detailed behavior of the molten fuel and structure by the virtue of having mechanistic models. However, SCDAP does not simulate the fission product transport and deposition behavior.

4. Simple Validation

For simple validation aimed primarily at validating whether the coupling is sound, calculations using the three sample inputs provided in the SCDAP/RELAP package were carried out and the results of MARS-SCDAP and SCDAP/RELAP were compared. One of the calculations is the boiloff simulation which is intended to test the interface between the MARS heat transfer package and the severe accident models. Figures 3 shows some representive results and these show that the MARS-SCDAP gives good results compared with the SCDAP/RELAP.

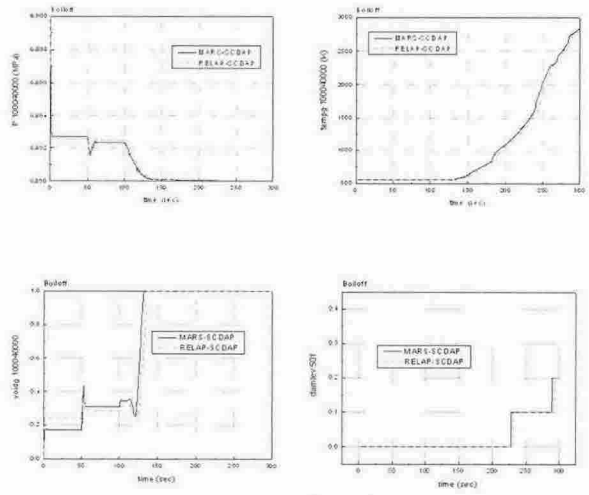

Figure 3. Representive Results from Sample Simulations

5. Conclusion

The severe accident simulation is receiving increased interests in nuclear community and there is a need for accurate modeling of phenomena and sequences involved. To partly satisfy this need, the best estimate T/H code MARS and the mechanistic severe accident modeling program SCDAP has been successfully coupled. Both the MARS and the SCDAP codes are complex codes with accurate modeling capabilities. Thus the verification of the MARS-SCDAP will not be an easy task but considering that MARS-SCDAP is a general code which is not limited to specific configuration, further verification and development effort will be of value in severe accident analysis efforts.

REFERENCES

[1] "MARS 3.0 Code Manual", Korea Atomic Energy Research Institute, KAERI/TR-2811/2004.

[2] L. Siefken et al., "SCDAP/RELAP5/MOD3.3 Code Manuals Volume I ~ V", Idaho National Engineering and Environmental Laboratory, NUREG/CR-6150, 2000.