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Development of platform to compare different wall heat transfer packages for system analysis codes

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1. Introduction

System thermal hydraulic (STH) analysis code is used for analyzing and evaluating the safety of a designed nuclear system. The system thermal hydraulic analysis code typically solves mass, momentum and energy conservation equations for multiple phases with sets of selected empirical constitutive equations to close the problem. Several STH codes are utilized in academia, industry and regulators, such as MARS-KS, SPACE, RELAP5, COBRA-TF, TRACE, and so on. Each system thermal hydraulic code consists of different sets of governing equations and correlations. However, the packages and sets of correlations of each code are not compared quantitatively yet. Due to this reason, the authors are studying the difference in the analysis result of each code. In this study, the authors are going to study the difference between MARS-KS and SPACE with special attention given to the heat transfer packages.

In this study, the wall heat transfer packages are first compared.

2. Methods

2.1 Comparison of Wall Heat Transfer Packages, Coefficients and Correlations

In the system thermal hydraulic analysis code, wall heat transfer package determines the energy transfer from a heat structure to a fluid volume. Wall heat transfer package consists of a heat transfer mode transition map and heat transfer models for each region.

First, the authors compared the logic diagram of two codes. Fig. 1. and Fig. 2. are heat transfer logic diagrams of SPACE and MARS-KS. Most parts of each diagram are similar, however several differences are shown. Logics which decide the wall single heat transfer mode and wall condensation heat transfer mode are different. In addition, logics which determine wall nucleate / wall transition / wall film are different.

The correlations are compared next for the corresponding wall heat transfer mode. Most of correlations are the same, except for the wall film heat transfer mode. In MARS-KS, Bromley's correlation is adopted. However, Groeneveld's 2004 film boiling look-up table is adopted in SPACE. Table I shows the correlations matched with each wall heat transfer mode of SPACE and MARS-KS.

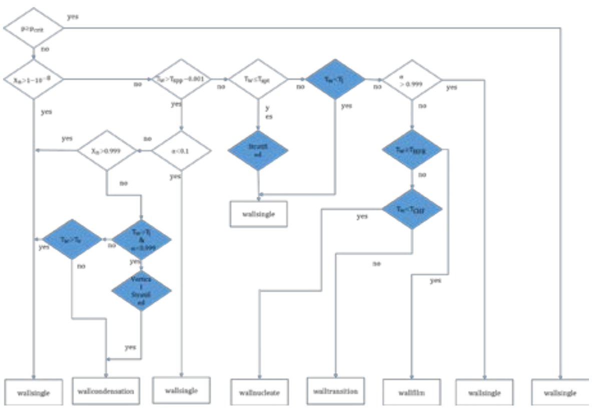

Fig. 1. Heat transfer logic diagram of SPACE

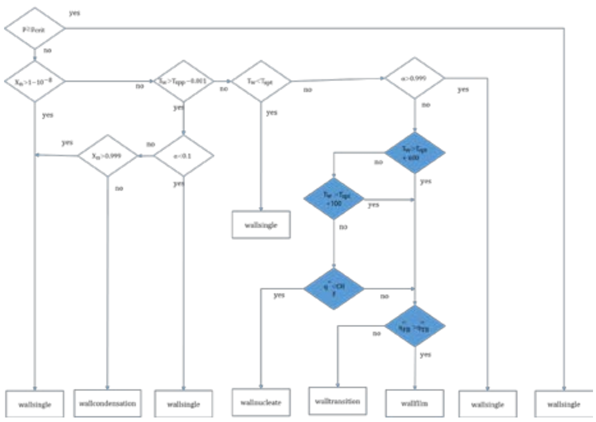

Fig. 2. Heat transfer logic diagram of MARS-KS

Table I: Correlations for heat transfer mode

	SPACE	MARS-KS
Wallsingle	Dittus-Boelter (1930) Sellars (1956) Spore (2000)	Dittus-Boelter (1930) Sellars (1956) Churchill-Chu (1975)
Wallnucleate	Chen (1963) Thom (1965)	Chen (1963)
Walltransition	User-option (Bjornard &	Chen (1977)

	Griffith (1977) Jones & Bankoff (1977) Chen (1977) Elias (1998))	
Wallfilm	2004 film boiling look-up table (Groeneveld et al. (2003))	Bromley (1950)
wallcondensation	Nusselt (1916) Chato (1962) Shah (1979)	Nusselt (1916) Shah (1979)
Reflood	Bajerek & Young	Modified Weismann (1959)

2.2 Quantitative Analysis of Heat Transfer Packages, Coefficients and Correlations

To compare and analyze the difference between system thermal hydraulic codes, an in-house code to obtain the wall heat transfer mode, correlation and calculated heat transfer coefficient was developed. The heat transfer package, heat transfer mode transition map and correlations are all referred from manuals [1,2]. To decide heat transfer mode and calculate heat transfer coefficient, velocity of gas phase (vg) and liquid phase (vl), wall temperature (Tw), liquid phase temperature (Tl), static quality (x), equilibrium quality (x_e) and pressure (P) are required. Geometric information of volumes and heat structures is required. Other properties, such as enthalpy, density, and so on, are obtained all from NIST REFPROP program. First, the in-house code determines the heat transfer mode. Next, according to the correlation selection criteria, heat transfer coefficient correlation is decided and heat transfer coefficient is calculated.

2.3 Sample Results

To investigate the difference of the two wall heat transfer packages, the authors chose a sample region of thermal hydraulic variables and gave perturbation to them to observe effects. Table II shows the range of sample variables.

Table II: Sample input variables and range

vg	vl	Tw
1.56m/s	1.17m/s	412K
1-5m/s	0.1-1.9m/s	300-560K
X	P	Tl
4.7E-6	1.93E+5Pa	375.1K
10E-8 to 10E-2	1.5E+5 to 5.0E+5Pa	300-390K

Most of correlations are similar between MARS-KS and SPACE in this sample variable field, therefore most of heat transfer coefficients are the same. However, when the wall temperature is increased while other variables are fixed, different transition point is observed. Transition from wall nucleate heat transfer mode to wall film heat transfer occurs earlier with MARS-KS than that of SPACE. Table III and IV show the heat transfer mode, correlations and coefficients while wall temperature changes.

Table III: Transition of heat transfer package along wall temperature increase of MARS-KS

Tw(K)	Mode	Correlation	Coefficient (W/m^{2}K)
300	Wall single	Dittus-Boelter	7814.5
380	Wall single	Dittus-Boelter	7814.5
400	Wall nucleate	Chen	28065
480	Wall nucleate	Chen	79288
500	Wall film	Bromley	7856
540	Wall film	Bromley	7853
560	Wall film	Bromley	7852

Table IV: Transition of heat transfer package along wall temperature increase of SPACE

Tw(K)	Mode	Correlation	Coefficient (W/m^{2}K)
300	Wall single	Dittus-Boelter	7814.5
380	Wall single	Dittus-Boelter	7814.5
400	Wall nucleate	Chen	28065
480	Wall nucleate	Chen	79288
500	Wall nucleate	Chen	110210
540	Wall film	2004 Groeneveld LUT	177.8
560	Wall film	2004 Groeneveld LUT	176.0

3. Summary and Further Works

Wall heat transfer mode transition maps of SPACE and MARS-KS have a little difference for the transition from wall nucleate heat transfer mode to wall film heat transfer mode. Both codes have the same heat transfer packages and correlations in most region except for wall film heat transfer mode. Most of heat transfer coefficients calculated for the range of selected variables of SPACE are the same with those of MARS-KS. For the intervals between 500K and 540K of wall temperature, MARS-KS selects the wall film heat transfer mode and Bromley correlation but SPACE select the wall nucleate heat transfer mode and Chen correlation. This is because the transition from nucleate boiling to film boiling of MARS-KS is earlier than SPACE. More detailed analysis of the heat transfer package and flow regime package [3] will be followed in the near future. Visualization of the difference of flow regime which developed in [3] will be added with analysis. The platform will expand to include wall friction factor, interfacial heat transfer coefficient and interfacial friction factor in the near future. Modified analysis result and expanded comparison map will be presented in conference.

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