Coupled Analysis of Thermo-Fluid-Flexible Multibody Dynamics for a Two-Dimensional Engine Nozzle

Wonjong Eun[*], Jaewon Kim[#], Chanhoon Jung[*], Sang-joon Shin[*], Oh-joon Kwon[#], and Oliver A. Bauchau[†]

[*] Department of Mechanical and Aerospace Engineering
Seoul National University
1 Gwanak-ro, Gwanak-gu, Seoul, 157-744, Republic of Korea
[eun0914, ssjoon, chan3142]@snu.ac.kr

[#] Department of Aerospace Engineering
Korea Advanced Institute of Science and Technology
291 Daehak-ro, Yuseong-gu, Daejeon, 305-701, Republic of Korea
[guonetoo, ojkwon]@ kaist.ac.kr

[†] Department of Mechanical and Aerospace Engineering
Hong Kong University of Science and Technology
Clear Water Bay, Kowloon, Hong Kong
olivier.bauchau@outlook.com

Abstract
A jet engine nozzle is required to change its flow path area to adjust the thrust. To perform this behavior, engine nozzle consists of movable thin plates and joints. Then nozzle can change and maintain its configuration by actuators. Inside the nozzle, high temperature and pressure flow impinge on its surface. It may induce complicated stress and strain in the structural components. To predict the complex behavior of an engine nozzle under such high temperature and pressure, coupled analysis will be generally required between fluid and flexible multibody dynamics.
In this paper, various components of the nozzle were modeled as flexible multibody elements. Then temperature and pressure on the nozzle wall were predicted by the steady-state flow analysis, especially for the two-dimensional nozzle. For the coupled analysis, the patent two-dimensional nozzle configurations [1] were selected.

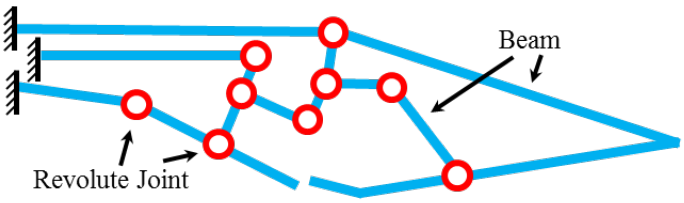

Figure 1: Two dimensional multibody configuration for the present patent nozzle

For the present configuration, flow analysis was performed based on CFD. Unstructured meshes were applied. Stagnation boundary condition was adopted for the nozzle inlet, and nozzle surface was assumed as adiabatic wall.

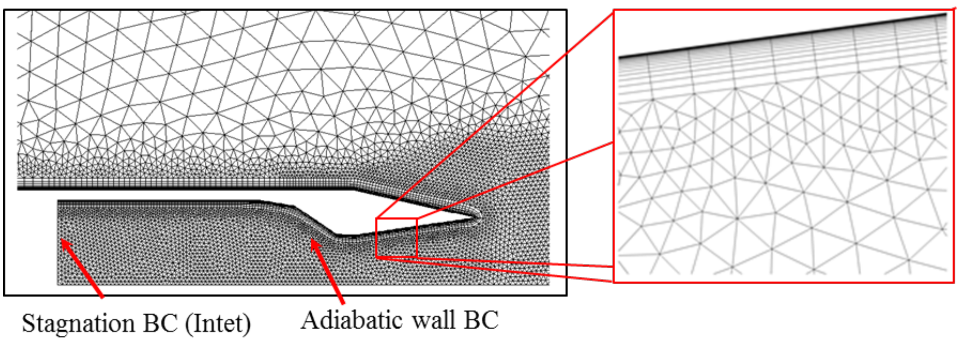

Figure 2: Unstructured meshes and boundary condition for the present simple nozzle

In this paper, the one-way and both-way coupled analysis was performed. Figure 3 shows flowchart for both analyses.

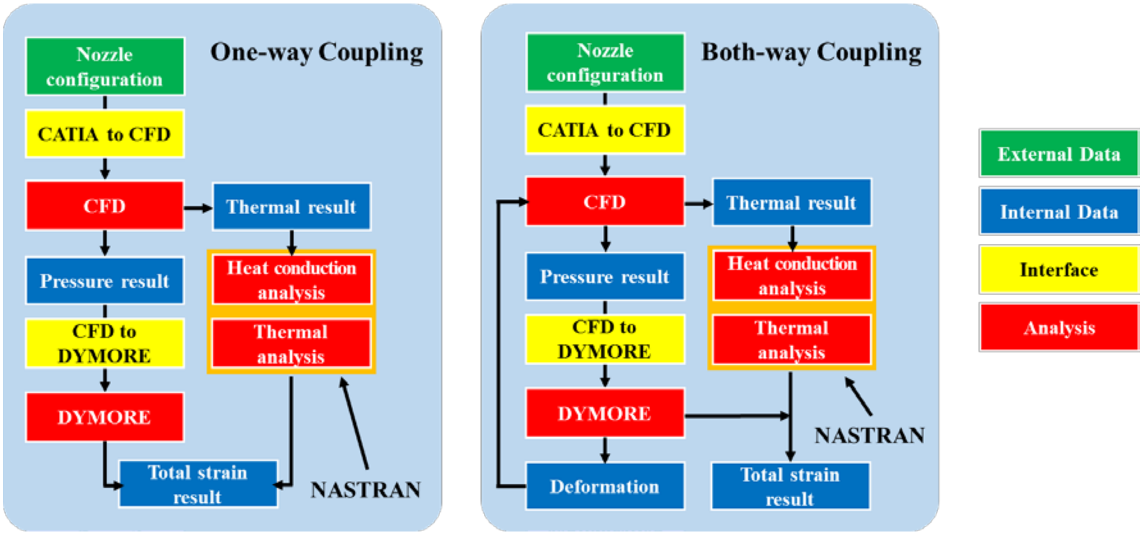

Figure 3: Flowchart of the both coupled analyses

At first, one-way coupled analysis was performed. For the present nozzle configuration, rotation in the joints was restrained in order to maintain the nozzle shape. Heat conduction and thermal analysis was conducted by MSC.NASTRAN. Total strain results were obtained as a summation of the mechanical strain and thermal strain. For a both-way coupled analysis, structural deflection induced at the nozzle wall was delivered to flow analysis. Such both-way information exchange process was performed repeatedly. Figure 4 shows the total strain results of both-way coupled analysis.

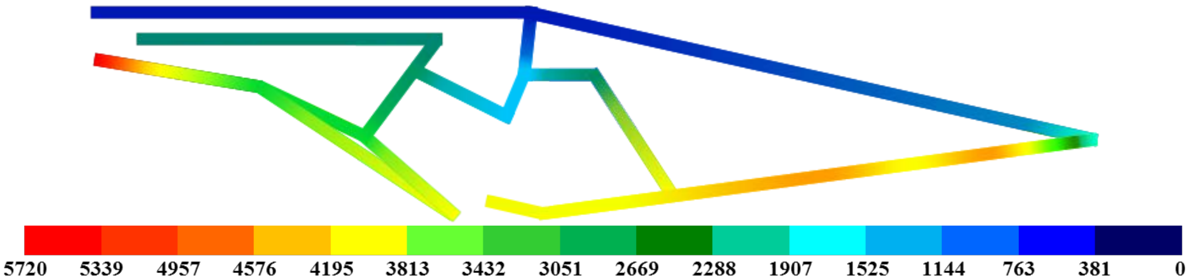

Figure 4: Total strain result of both-way coupled analysis [μ-strain]

In the next step, torsional springs will be added instead of revolute joints to maintain the nozzle shape. The result will be compared with those predicted by using RecurDYN. And coupled analysis procedure will be extended for a three-dimensional nozzle configuration.

References

[1] Johnson, D., and Mar, H., US Patent 3612400, 1973.

[2] Bauchau, O.A.: DYMORE Users` Manual. School of Aerospace Engineering Georgia Institute of Technology, Atlanta, GA, May 2006.

[3] Kim, J.W.; Kwon, O.J.: Numerical study of variable geometry nozzle flow using a mesh deformation technique on hybrid unstructured meshed. 2013 Korean Society of Computational Fluids Engineering Spring Conference, pp.389-395, 2013.

[4] Bauchau, O.A.; Rodriguez J.: Formulation of Modal Based Elements in Nonlinear, Flexible Multibody Dynamics. Journal of Multiscale Computational Engineering, Vol. 1, No. 2, pp. 161-180.

[5] Eun, W.J.; Kim, J.W.;Kwak, J.Y.; Shin, S.J.; Kwon, O.J.; Bauchau. O.A.: Thermo-Fluid-Multibody Dynamics Coupled Analysis of an Engine Nozzle. KSAS 2013 Fall Conference, November 14th, 2013.