Recent development of high performance computing (HPC) technology makes the full scale 3-dimensional computational fluid dynamics (CFD) analysis possible. This study develops fluid structure interaction (FSI) CFD code including open source library, Elmer, and simulates an offshore turbine dynamics in the state of ultimate wind considering the effect of wind speed fluctuation.

**Theory**

- **Computational Fluid Dynamics**

  The CFD library used in this study [1] stabilize the solution while using equal degree of shape function orders to the pressure and velocity, by introducing streamline upwind/Patrov-Galerkin (SU/PG) method which adds a square term of governing equation’s residual to Galerkin weighted function. The moving mesh was emulated by arbitrary Lagrangian-Eulerian (ALE) method. The governing equation discretized by Galerkin Least Square method by using the open source library. FSI software developed in this study [2] consists of three parts which are fluidic, structural and interaction part as shown at Figure 1. If n is the number of parallel analysis node. The n number of fluidic modules give same number of parted pressure results.

  Interaction part transfers these results to the structural part in a concept of modal analysis. Structural part calculates modal displacement at each time step and the interaction part turns it back to the fluidic parts. In case of analysing 3.4 million tetrahedron elements using 64 nodes at once, it takes about 5~20sec at each time step. The mesh of a blade was configured as Figure 2.

- **Structure Model**

  The object of this study was to analyze response differences between the case of considering FSI effect and the other case of not considering the effect for a support structure of a wind turbine under the 50-year return period ultimate wind speed. The geometries of the structure should be exactly defined to perform the CFD analysis. NREL 5MW reference turbine [3-4] is selected by target upper structure. The hybrid support structure was developed to construct at the 20m depth south-western coast shown as Figure 2. The hollow sectioned concrete base has 0.5m wall thickness and 10m height, the jacket structure of concrete filled hollow steel tube has 21m height. The length of the blade is 63.333m and the chord is 4.557m. The model of ambient fluid region of one blade shown as Figure 2 is constituted using 358,652 nodes and 1,985,609 tetrahedron elements.

**Numerical Simulation**

In case of using blade momentum theory to calculating the wind turbines responses, the process of calculating aerostatic coefficients of the airfoil section is needed. Furthermore, many of commercial codes could not consider the FSI effect. However, 3D CFD analysis of this study calculated the responses directly without any aero-static and dynamic coefficients. The time history displacement of the structure is shown as Figure 4. The two results shows relatively similar tendency but the differences are getting larger in process of time. From the results, in case of considering FSI effect, the ultimate loads transferred to the support structure have a tendency of decrease 3~7%.

The results of full 3D CFD analysis of a 5MW wind turbine on the ultimate wind speed. FSI effect should be considered to estimate exact responses of a turbine although the difference of responses is relatively small.

**Discussion**

This study is on-going study to analyse structural responses of wind turbine support from the wind load variation. The analysis software has been developed for the other purpose by the same authors – to analyse a cable-stayed bridge’s buffeting responses. In this study the analysis model is shifted from bridge to wind turbine using same concept of numerical process. However, the magnitude of the turbine model used in this study is very large to analyse properly although using super computer – KISTI Tachyon II. Owing to circumstances beyond control, the authors couldn’t get the simulation results, but the numerical process used in this study has and identity. It needs more knowledge exchanges to solve this problem.

**Conclusion**

1. Supercomputer executable 3D FSI parallel CFD code has been developed using open source library Elmer.
2. Detailed structure interaction wind flow and surface loads on the structure are estimated.
3. The responses contains FSI effects shows relatively small value. If consider the FSI effect to calculate ultimate load on the support structure, the structure can be designed more economically.
4. Proposed CFD method can be one of the good alternative for the wind tunnel tests or field measurements.

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**References**


**Figure 1: Flowchart of developed parallelized FSI CFD program**

**Figure 2: Structure model & generated mesh**

**Figure 3: Target and generated wind velocity spectrum (L: along wind, R: vertical wind)**

**Figure 4: Displacements of tower of structure of wind turbine (expected value. Not yet done.)**