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SCILAB-BASED RELIABILITY ANALYSIS OF 5-STOREY OFFSHORE JACKET STRUCTURE USING MONTE CARLO FINITE ELEMENT METHOD

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ABSTRACT

Monte Carlo Finite Element Method (MCFEM) is a robust reliability analysis method for complex structures which do not have an explicit performance function. This method is a combination of Finite Element Method and Direct Monte Carlo Simulation in an open source software environment (Scilab). MCFEM performance has been well proven for the reliability analysis of 2d truss, 3d truss, 2d frame and a simple real offshore jacket structure (APN-A Offshore jacket). This paper will demonstrate Scilab based MCFEM to analyze 5-storey offshore jacket structure which has 120 number of tubular members in 155,6 feet water depth. The failure mode is based on global analysis by using computed normal stress compared with their buckling strength. Randomization will be done at element level for some significant variables. Reliability of the jacket will be represented by the smallest reliability of its member. This analysis and all of the previous reliability analysis based on open source software, are important steps toward the establishment of Reliability Based Structural Analysis capability which belongs to Ocean Engineering Department, ITS, Indonesia.

Keywords : *scilab, finite element, monte carlo simulation, open source software development*

1.0 INTRODUCTION

Reliability analysis of offshore jacket is an important analysis to ensure its safety operation during its life time. Monte Carlo Finite Element Method (MCFEM) is one of reliability analysis technique which relies on computational capacity. Although this may look like conventional, this method should be the most accurate reliability method since the use of high number Simulation of Monte Carlo. MCFEM has proven to be applicable in various structural reliability problem such as in the 2D truss structure (1) and APN A offshore jacket platform (2).

Nowadays, world is changing to the trend in using open source software in education process due to the high cost of commercial software. In offshore engineering area, the use of commercial package software such as *SACS* or *Ansys* in educational process lead to more disadvantages rather than its advantages. Beside the high cost of annual license, this package software pushed the students to be a mere operator not an engineer who is knowledgeable of basic engineering concepts. Knowing this disadvantages, Department of Ocean Engineering (DoE), ITS Surabaya started to follow the world trend by developing its own engineering software based on open source

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software. Figure 1 show the road map and the development progress of Open Source Based Structural Analysis of DoE, ITS. Some research in DoE were using this software for global static analysis in 2D truss, 3D truss and also 3D frame. Dynamic analysis have developed as well, but it has not proven yet.

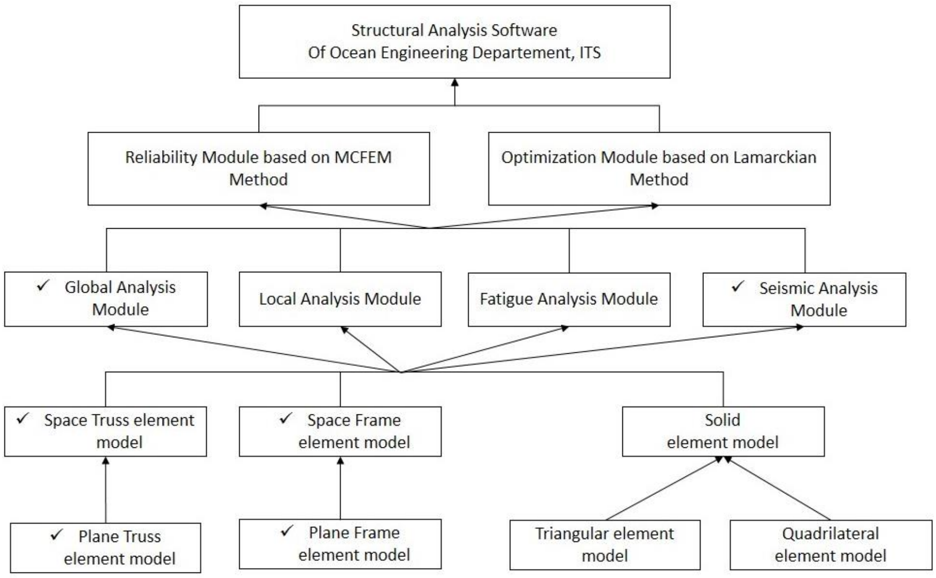

Figure 1 : Road map of developing structural analysis software for DoE, ITS, Indonesia

Scilab is one of the most powerful open source numerical software. Comparing with another free mathematical software such as : Freemat, Mathium, Octave, and R, we conclude that Scilab has the best performance in computational evaluation and it may be the best solution for a scientist in the area of mathematical programming (3). In simulation based reliability calculation field, some previous works of Scilab based are convincing (1,2,4). Further, direct simulation of MCFEM can be held by using Scilab to obtain the best accurate result. It will overcome the MCFEM problem without adopting some function resulting in intolerable error (5).

This paper will discuss the reliability analysis of 5 storey offshore jacket by using MCFEM method in Scilab environment. This analysis is very attractive since it involves a large number of elements.

2.0 OFFSHORE JACKET MODELLING PROCESS

Figure 2 show the jacket geometrical model. Total height of the jacket is 155.6 feet and there are 44 nodes as well as 120 members. This is a big and complex structural object to be analyzed. The modelling and computation process in Scilab was done by several steps as follows :

1. Draw the geometrical jacket structure in drafting software (CAD). In this step, we will get the x, y, and z coordinates of each node. This strategy will be very helpful to avoid geometrical error
2. Input the coordinates data to the space frame stiffness matrices module in Scilab
3. Arrange the global stiffness matrices by using node and member data
4. Calculate the wave forces using Morison Equation (6) and establishing topside load data. The total topside load is 1200 kips. The calculated wave forces are subjected in each submerged nodes

5. Input the calculated force in right side force matrices of static analysis

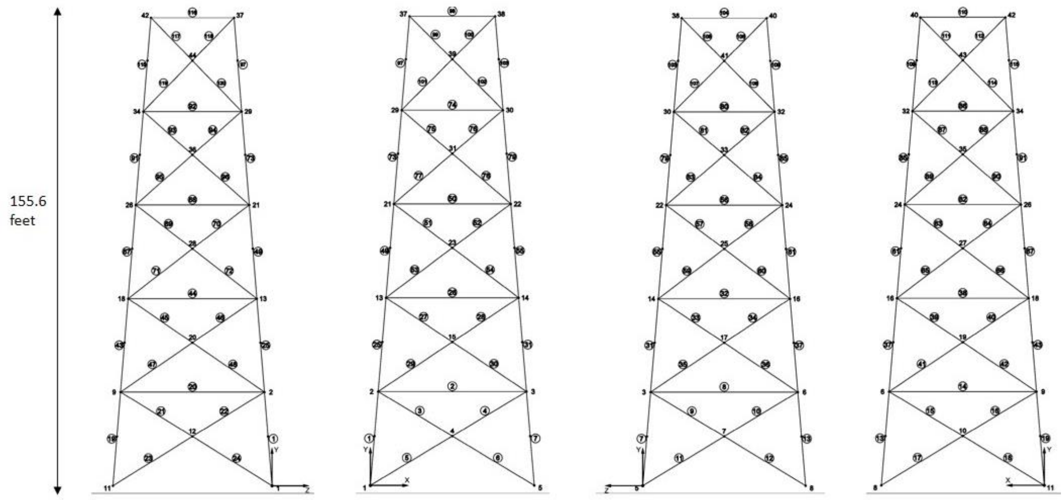

Figure 2 : Four side 2D view of 5 storey offshore jacket

3.0 RELIABILITY CALCULATION

After establishing the structural model to be run in Scilab, MCFEM algorithm for frame structure was applied to calculate the reliability (7). The failure mode for the simulation is based on maximum stress of each member and allowable stress are based on critical buckling criteria:

$$\frac{\sigma_{aksial\ member}}{\pi^2 E \left(\frac{r}{K\ L}\right)^2} \leq 1 \quad (1)$$

Table 1 shows the random variable and deterministic material properties of offshore jacket.

Table 1 : Offshore jacket data

Random variables	Mean	CoV	Distribution Type
Modulus of elasticity (E)	29,000 (ksi)	0.06	Normal
Shear Modulus of Elasticity (G)	11,600 (ksi)	0.06	Normal
Topside load	1,200 (kips)	0.2	Lognormal
Deterministic data			
OD jacket leg	14 inch		
OD horizontal and diagonal braces	12 Inch		
t jacket leg	0.5 inch		
t braces	0.3 inch		
Wave height	10.5 feet		

One of the most important of Monte Carlo Simulation is the generation of random number. Scilab 5.4 generate random number using Urand, A Universal Random Number Generator by Michael A. Malcolm et. Al (8). It is a linier congruential generator of the form :

$$x = (ax + c) mod\ M \quad (2)$$

Where the constant are a=843314861, c = 453816693, M = 2^{31}. This data ensure that the random number generated by Scilab will never be same along the simulation process.

3.0 RESULT AND DISCUSSION

The MCFEM coding in Scilab was established by several deterministic data and random variables showed in Table 1. For this case, wave load are assumed to be deterministic data by using airy wave theory due to the insignificant magnitude compared to the topside load. The great variation of topside load is assumed to be Lognormal distribution with the high number of coefficient of variation i.e. 0.2. Since the absence of Lognormal distribution in Scilab module, the mean and cov data should be transformed into parameter of λx and ζx, using Equation 3 and 4.

$$\lambda x = \ln \mu - \frac{1}{2}\zeta^2 \tag{3}$$

$$\zeta^2 = \ln(1 + \delta^2) \tag{4}$$

Where λx and ζx are two parameters of the lognormal distribution, μ is mean of data and δ are coefficient of variation (cov). After getting the parameters, Lognormal distribution is expressed as exponential of normal distribution with mean is λx and standard deviation is ζx.

The established MCFEM model was run in the PC by the following specifications :

- Intel ® Core™ i7-4770 @ 3.40 GHz
- Speed : 3400 MHz
- Total memory : 8192 (DDR3-1600)

The simulation was held gradually to get the reliability trend. In each iteration, computer will evaluate all members based on failure mode. Computer will judge an iteration as failed due to the existence of failed member even 1 member only.

Table 2. MCFEM simulation

Number of Iteration	Probability of failure	Reliability	CPU time (second)
1,000	0.053	0.947	180
10,000	0.0583	0.9417	1,628
25,000	0.05828	0.94172	5,505
30,000	0.0585	0.9415	4,763
50,000	0.05822	0.94178	8,224
100,000	0.05762	0.94238	17,101

Table 2 shows the result of simulation. Although the computed reliabilities are varying in accuracy, but the simulation converge to 0.94.

4.0 CONCLUSION

The reliability analysis of 5 storey offshore jacket structure have been conducted using direct MCFEM in gradually increased number of iteration. The result of 0.94238 in 10^5 iteration was very satisfactory with reasonable computational time. This achievement prove the performance of Scilab software to conduct the calculation of large finite element matrices and simulates it in high number of iteration. This successful application of open source based structural analysis software, will drive a more development software for independency and high quality of education in DoE.

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