Assessment of Methods to implement Multi-point Constraints in FEA and Guidelines for Selecting a Method based on Complexity

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ABSTRACT (INTRODUCTION & OBJECTIVE)

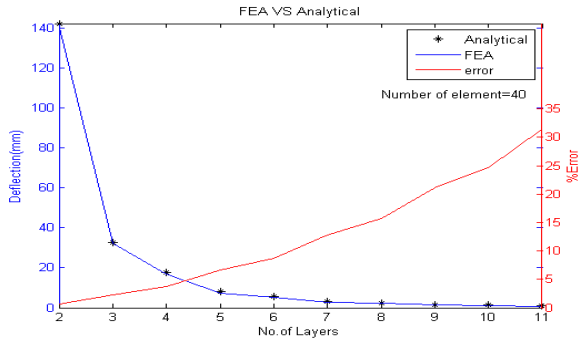
In finite element analysis, whenever a boundary condition involves more than one degree of freedom, such conditions are referred to as multipoint constraints (MPC). In most of the contact problems, MPC equations are needed whereas bonded contact can be analysed without using MPC equations. It can be analysed only with two-dimensional elements. The problem with this modelling is that for obtaining the accurate results, a greater number of elements may be needed. It will increase the degree of freedom and hence the computational time. To handle MPC, there are multiple methods such as penalty method[1], Lagrange method[2], Master-Slave method, and Augmented Lagrange method. Thorough understanding and correct choice of the method will help in better accuracy and computational efficiency. In this work, the focus is to use the multipoint constraint equations effectively and to know how the method of application of MPC equations are affecting the final results[3]. For this purpose, case studies are carried out. A case of the turbine blade and hub and the analysis of composite beam are considered. The turbine blade and hub are modelled with MPC (that is using 2D and Beam elements) and without using MPC (only 2D elements) equations and the value of deflection and time taken for calculation have been compared. The analysis of the composite beam is performed by using MPC equations in such a way that each layer of the beam is taken as an independent beam element and connected by using MPC equations[4]. By this modelling, the value of deflection, time taken for calculation are found and those values are compared with the analytical solution. The Master-Slave method can only be used in the case of bonded and no separation contact. An attempt is also made to suggest a method for the complex model with contact, based on their complexity. The number of elements required, type of material, type of contact, type of support and type of loading are taken as parameters to define complexity[5]. A graphical representation is developed to differentiate the model based on their complexity and it has been tried to suggest which method is suitable for the corresponding complexity.

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

For obtaining the accurate deflection of turbine blade for each case, finite element model without using multipoint constraints requires more than 25 times computational time than the model with multipoint constraints. To attain a nearly accurate value of deflection, the model with multipoint constraints requires only 131 elements whereas the model without MPC require 2112 number of elements as shown in table 2.2. The analysis of composite beam with one end fixed and both ends fixed with three-layer have been thoroughly studied. It has been found that for obtaining an accurate solution, a greater number of elements are needed as shown in fig 2.1. An attempt has been made to suggest a guideline for choosing a suitable formulation based on the complexity of the problem [fig 2.3].

Figure 2.1: Comparison of FEA value with the Analytical value for composite beam with both ends fixed subjected to a point load at its center.

2.1. a) For 40 number of elements



2.1.b) For 80 number of elements

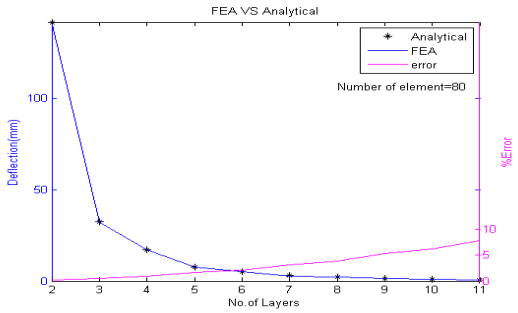
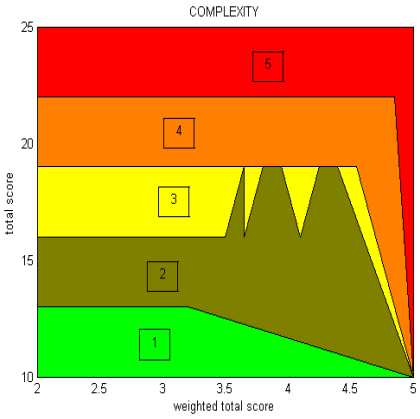


Table 2.2: Computational time with and without using MPC equations for turbine blade and turbine

	Point load		UDL	
	2D elements	**2D and Beam elements**	**2D elements**	**2D and Beam elements**
Load	5KN	5KN	10N/mm	10N/mm
Number of elements	2112	131	2112	131
Maximum Deflection(mm)	4.039	4.4118	2.0864	2.0078
Time (s)	478.2	19.661	481.822	20.154

Figure 2.3: Graph for Complexity



From the selected simulation results, conclusions are drawn. For the less complex model with only bonded contact, the Master-Slave method provides the best solution. Among all formulations attempted, the Penalty Method provides a fair result for every model.

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