

Evaluation of Linear and Nonlinear Gap Elements Using Finite Element Method

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ABSTRACT

This paper deals with the difference between Linear and Non linear Gap elements for various Gaps using Finite element techniques. Linear Gap elements have been developed using Multi Point Constraint equation. How similar are the Computational results provided by linear and Non linear Gap element results. In this paper we are going to evaluate how Gap elements are used in Linear and Non linear Static analysis. Gap element plays a major role to simulate the Gaps in Finite element modeling, it is therefore necessary to study the behavior of the Linear and Non linear Gap elements and its characteristics and controlling factors.

INTRODUCTION

Computer Aided engineering is an integral part of Product Development. The performance of a component can be easily simulated using commercially available software like MSC.PATRAN/NASTRAN. The power of numerical modeling along with improved trends in computational methods enables us to replicate any physical structure/ real time system. The most common means of replicating a real time scenario is done by Finite element analysis which comprises of the meshed model with nodes and elements to depict the structure, the boundary conditions and the model constraints.

There are large class of problems that involve contact surfaces and friction. Pin bearing against the side of a hole in a plate, bolt threads bearing against the inner threads of a threaded hole, or any two surfaces in contact. To address such contact problems, many developers of finite element analysis software have included gap elements, more precisely called interface elements, in their element libraries Gap elements simulate contact between two surfaces by generating

restoring (contact) forces when the two surfaces approach each other and by removing the contact forces when the two surfaces move away from each other. This means that gap elements have two stiffness values associated with them, a finite value (usually quite large) when the surfaces are in contact and zero (or nearly zero) when the surfaces are not in contact. For this reason, gap elements are frequently called bilinear elements another useful feature of gap elements is their ability to simulate sliding with friction.

When subjected to a shearing force, gap elements generate a counteracting friction force. When the shearing force exceeds the maximum friction force that the gap elements can generate, then the gap elements let the contact surfaces slip past each other. The maximum friction force is governed by the user-defined coefficient of friction and the contact force. The user-defined stiffness of gap elements is a key parameter. If a finite element model includes gap elements that are defined with a stiffness that is too small, then the displacements calculated with that model will be incorrect. If the gap elements are defined with a stiffness value that is too large, then the model may not yield a solution at all. Instead, it may fall prey to a phenomenon called bouncing. Bouncing simply means that the gap elements change their status (open/closed/open) with each iteration of the solution process. Therefore, the stiffness of gap elements must be chosen with some care.

We compute and simulate the model using two methods are Linear Gap elements with Linear Static analysis and Gap elements with Non linear Static analysis. We document substantial differences in algorithmic complexity, time performance and accuracy of the solution and how our findings depend on parameter values, specially the degree of risk aversion. In this

Paper we are going to evaluate the Linear Gap elements using Linear Static Analysis and Gap elements using Non Linear Static analysis.

LINEAR GAP ELEMENT TECHNIQUES

Linear static analysis is straight forward (ie) displacement is directly proportional to applied load (**F**).

$$\mathbf{F} = \mathbf{k} \cdot \mathbf{u}$$

The deflection is directly related to applied load via the constant stiffness (**k**). The displacement (**u**) is readily obtained from

$$\mathbf{u} = \mathbf{F} / \mathbf{k}$$

Multi-Point Constraints (MPCs) plays a major role in Linear Gap element. MPCs are equations (Eq-1) in which the user explicitly provides the coefficients of the equations. Each MPCs is described by a single equation that specifies a linear relationship for two or more degrees of freedom. Linear gaps are implemented in SOL 101 by using explicit MPCs to define the gaps. Because MPCs are used, there is no gap stiffness; adjacent grids are either "constrained" or "free" in the user specified degrees of freedom. The linear gaps provided for contact to simulate compressive and tensile forces. By virtue there is no friction, but a large class of problems can be solved efficiently.

DEFINING THE MPC:

Consider 2 Nodes 1 and 2 which are separated by an initial opening 0.2 inches in the Z direction:

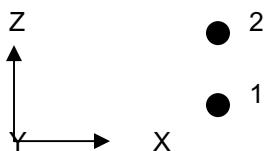


Fig – 1 - Node 1 and 2 used to define MPC

$$U_{Z1} - U_{Z2} + U_{Zgap} - U_{Zinit} = 0 \quad (\text{Eq 1})$$

Here, U_{Z1} is the dependent

$$U_{Z1} = \text{Opening Node} + \text{Disp opens gap}$$

$$U_{Z2} = \text{Closing Node} + \text{Disp Closes gap}$$

$$U_{Zgap} = \text{Initial Opening}$$

$$U_{Zinit} = \text{Gap Opening, Including init opening}$$

Functions of Linear Gap Elements:

Gap elements involves in two aspects:

- 1) The opening and closing of the Gap between two bodies.
- 2) Friction between the contacting surfaces.

Contact between two deformable bodies, linear Gap applies Multi-point constraints in the form of ties. The ties link the motion of one node on the contactor body to two adjacent nodes on the contacted body. In each iteration as nodes enter and leave contact or slide between adjacent node segments on contacted bodies, a bandwidth optimization is performed to reduce the computer processing time required. Model shown in Fig.2)

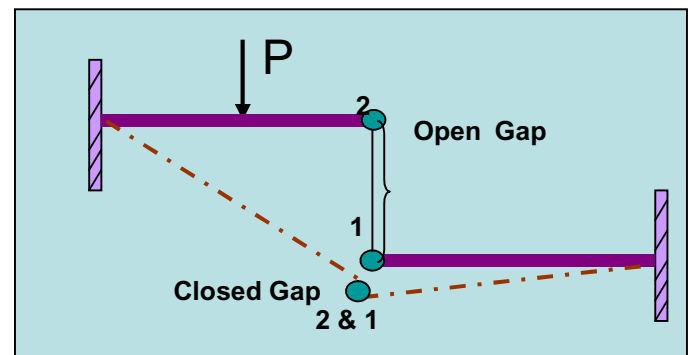
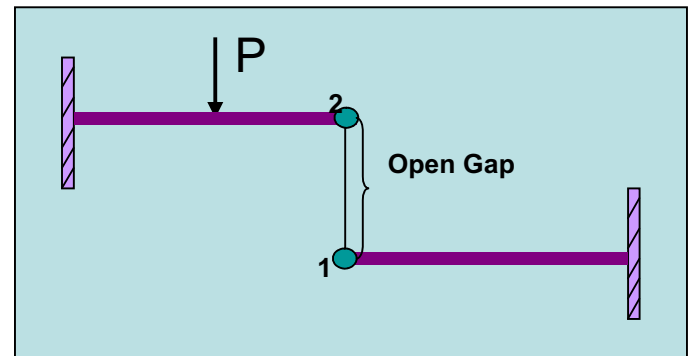


Fig – 2 - Functions of Gap element