Chapter 10
Nonlinear Transient Analysis

ABSTRACT

In this chapter, the author begin by presenting the main causes of non-linearity, which are geometric and material source, change in boundary condition. The last presented source is pretensions. Then they go to the physical understanding of non-linear behavior by presenting the different phases of hysteresis curve sequence of a reinforced concrete structure. In this chapter, readers pass over various numerical formulation, which allow them to deal with non-linearity, namely Lagrange and Euler formulation, total Lagrangian formulation, Piola-Kirchhoff 2, and corotational formulation. Some examples are exposed at the end of the chapter.

INTRODUCTION

The nonlinear mechanics of continuous, solid and structural media is an extremely vast and rich field of study and research. Since about 1970, the interest of researchers and practitioners for the "nonlinear" has increased considerably, because numerical methods coupled with electronic programs make it possible to effectively solve problems of amazing complexity, and this in all domain: structure, flow, diffusion, heat, fluid, dynamics, soils, plasticity, etc.

We begin by presenting the main causes of non-linearity (Belytschko, Kam, Moran. Elkhodary. 2014), there are usually 04 sources of non-linearity.

The first is the geometric (kinematic) source, which includes large displacements (second order, instabilities ...) and large deformations (James (2001)). The second is a material source that takes into account the non-linearity of the material used, plasticity (metals, concrete, soil ...), viscosity, creep (concrete, wood, plastics, soils ...), and the hyper-elasticity (rubber ...); in this same source we also take into account semi-rigid nodes, fissures, fractures, damage and finally temperature (fire ...), all these phenomena fall within the framework of material non-linearity.

The third source of non-linearity is that of changes in boundary conditions, namely: variable (essential and / or natural) limit conditions, "follower" forces (pressure, etc.), unilateral connections, contact, sliding, friction and construction phases. The fourth source is Haubans, cables; pretensions etc see (Belytschko, Kam, Moran and Elkhodary. 2014).The first two types will be covered in this chapter.

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LARGE DISPLACEMENTS (CINEMATIC)

Lagrange and Euler Formulation

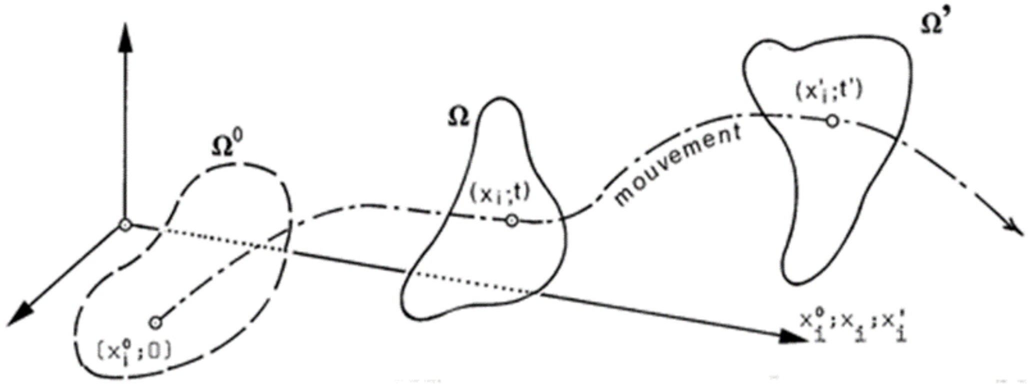
In Euclidean space, a body can be considered to be composed of a set of particles. The position of each of them can be identified by three real numbers, for example its coordinates in an arbitrary system of axes. All of these positions define the configuration of the body. The evolution of this configuration in space and time is called the movement of the body.

Let W be a configuration of the body, in which the particles occupy positions well defined by the coordinates xi; if these quantities are taken as independent variables, W is called the reference configuration and the formulation (or description) of the movement is called Lagrangian (or material).

Let W 'be a subsequent configuration of the body; it is called the current configuration and the particles called xi in W occupy new positions characterized by the coordinates xi '. These coordinates are respectively called material (xi) and spatial (xi '). For simplicity, they will all be measured in a single straight Cartesian system figure 1. (Frey 2005)

We call initial configuration W0 a conventional configuration generally corresponding to the resting, unloaded state of the body. Any other configuration is called deformed configuration (W, W '...).

Figure 1. Movement and successive configurations



MEASUREMENT OF THE STRAIN (GREEN TENSOR)

Movement, Jacobian, Deformation Gradient

Let W (xi) be a reference configuration, usually initial, of the body and W '(xi ') a deformed configuration (fig. 2.2). The movement is described by the continuous and differentiable application (mapping) (Frey 2005)

$$x_i' = x_i' (x_1, x_2, x_3) \qquad (1)$$