7. Large Strain Elastic-Plastic Analysis

In this chapter we present a numerical procedure for the analysis of large strain deformations in isotropic plasticity. After short introductory remarks in Section 7.1, we give in Section 7.2 a review of the basic notions of large strain kinematics of deformation. Then in Section 7.3, we give in detail the stress integration procedure in isotropic plasticity based on the multiplicative decomposition of the deformation gradient and the governing parameter method of Section 4.2. The logarithmic strain is employed and the corresponding formulation is called the updated-Lagrangian-Hencky (ULH) formulation. The computational procedure is implemented for the deformations of metals and geomaterials.

7.1 Introduction

In the previous chapters we presented the computational algorithms for stress calculations when considering inelastic deformations assuming small displacements and small strains (within several percent). Hence, the change of geometry was neglected and the inelastic problems are considered to fall into the category of *materially-nonlinear-only* problems (Bathe 1982, 1996).

Frequently, however, in engineering practice the *strains are small* but the *displacements are large*. Such problems are called *geometrically nonlinear*. They are materially linear if the stress-strain relations are linear, and materially nonlinear if these relations are nonlinear, as in inelastic analysis. The corresponding stress and strain measures must reflect these conditions. For example, the Green-Lagrange strain and the second Piola-Kirchhoff stress are effective strain and stress measures used in geometrically nonlinear but small strain analysis (the total Lagrangian formulation is used, Bathe 1982, 1996), see Table 7.1.1.

However, in many types of problems the *strains are also large,* from several percent to hundreds of percent (see Fig.1.3 in Chapter 1). Figure 7.1.1 shows schematically examples representing: (a) small strain and small displacement conditions, (b) small strain and large displacement conditions, (c) large strain conditions.

Table 7.1.1. Stress and strain measures for the three types of problems in inelastic analysis

Problem type	Displacements	Strains	Stresses
Geometrically linear	Small	Infinitesimal	Cauchy
Geometrically nonlinear– small strains	Large	Green-Lagrange	Second Piola-Kirchhoff[1]
Geometrically nonlinear– large strains	Large	Logarithmic	Cauchy

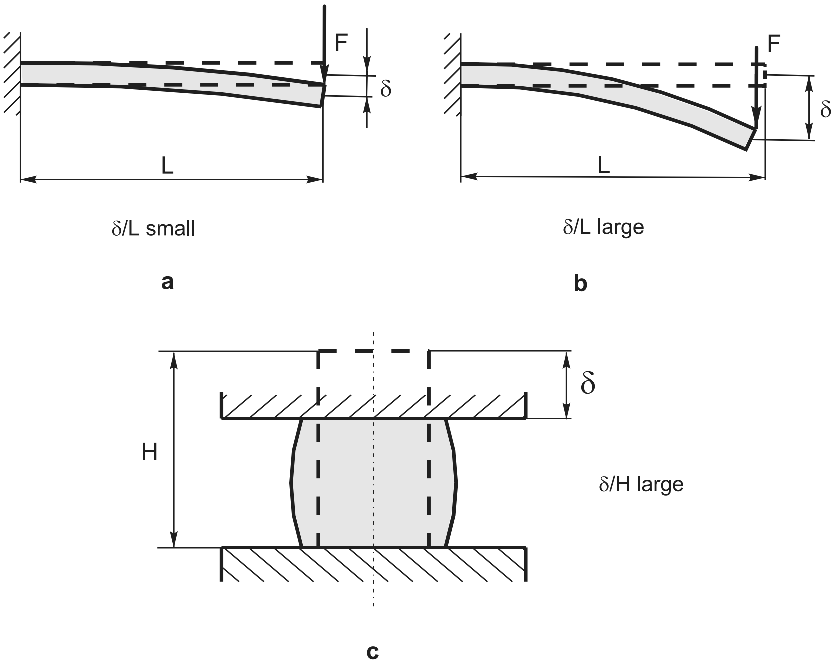

Fig. 7.1.1. Examples of nonlinear problems. **a** Geometrically linear; **b** Geometrically nonlinear, small strains; **c** Geometrically nonlinear, large strains

[1] Of course, Cauchy stresses are always the final calculated results