# CHAPTER I

# INTRODUCTION

## 1.1 GENERALITY

Sheet metal forming is the process of converting a flat sheet of metal into a part of desired shape without fracture or excessive localized thinning. The process may be simple, such as a bending operation, or may be a sequence of very complex operations such as those performed in high-volume stamping plants. In the manufacture of most large stampings, a sheet metal blank is held on its edges by a blank holder ring and is deformed by means of a punch and die. The movement of the blank into the die cavity is controlled by pressure between the upper and lower parts of the blank holder ring.

This control is usually increased by means of one or more sets of draw beads. These consist of an almost semi-cylindrical ridge on the upper part of the blank holder and a corresponding groove in the lower part (the positions are sometimes reversed). The draw beads force the perimeter of the blank to bend and unbend as it is pulled into the die, which increases the restraining force considerably.

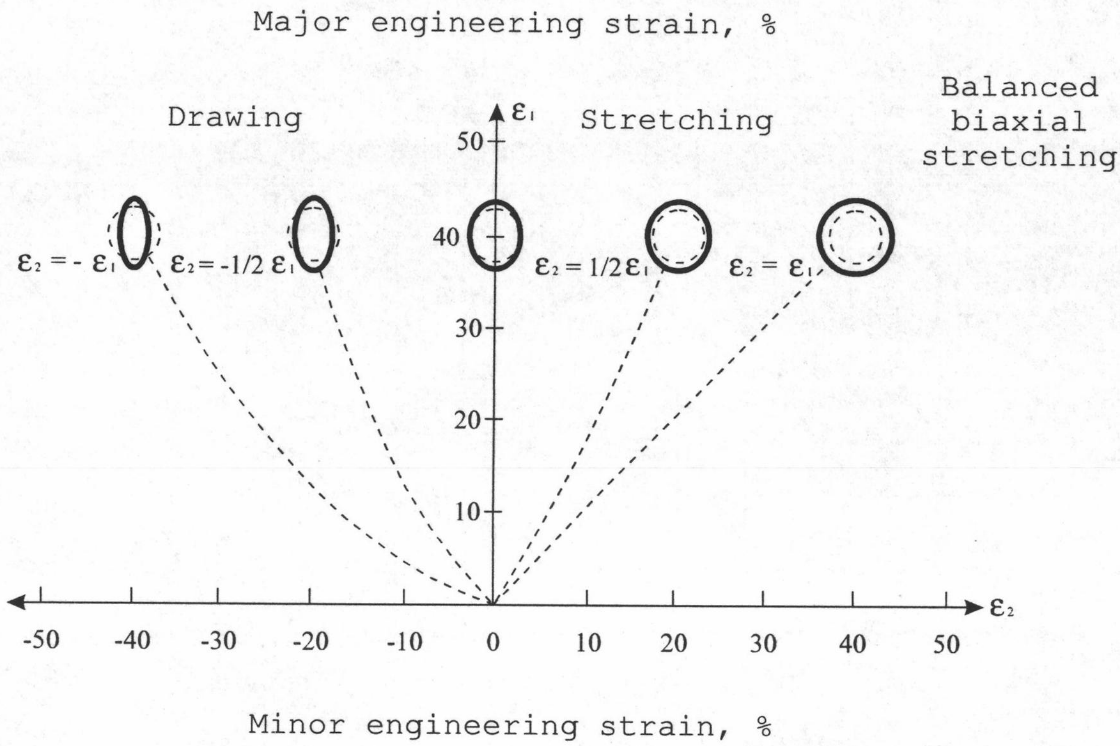


Fig.1-1 Schematic of several major strain / minor strain combinations

(From Metals Handbook, American Society for Metals, p549, 1987)

Sheet metal forming operations are so diverse in type, extent, and rate that no single test provides an accurate indication of the formability of a material in all situations. Sheet metal forming processes, broadly classified as deep drawing or stamping operations, represent a wide spectrum of flow conditions. The material properties that control formability vary with the specific sheet forming operations. At the one end of the spectrum (Fig.1-1) is the forming of flat bottom cylindrical cups by radial drawing. In this case one of the principal strains in the plane of the sheet is positive and the other is negative, the change of thickness being small. At the other end of the spectrum are operations involving biaxial stretching of the sheet, where two of the principal strains are tensile, and thinning is required. Many operations fall between these extremes.

In plastic sheet metal forming or press forming, the extent of plastic deformation before breakage is of paramount importance. Therefore, the variables governing the forming limit strain have been extensively investigated both experimentally and theoretically.

Hill(1950) developed theory of anisotropy plasticity based on modifications to the Von Mises yield criterion and its associated flow rule. Hill's theory (1950) is the most widely used today. The anisotropy is assumed to be orthotropic, i.e., possessing three mutually orthogonal symmetry planes, with normal or planar anisotropy being special cases. The plastic properties are considered uniform and homogeneous and neither Bauschinger nor strain hardening is also assumed; implying that the plastic properties do not depend on the strain state or stress.

When only normal anisotropy is considered, that is, all directions in the sheet plane are equivalent, the only parameter to be measured for application of the theory is the average plastic anisotropy ratio, R. Once this parameter is determined from tensile tests the theoretical predictions are fixed; that is, there are no other adjustable parameters.

Hill's theory(1950) has been tested using various sheet alloys. The most common test is a comparison of stress-strain curves obtained in balanced biaxial tension with curves predicted using the theory based on tensile test data. A similar analysis has been applied to experiments carried out in plane-strain compression.

The purpose of the present work was to experimentally and analytically examine plastic behavior of the low-carbon steel sheets under one of the most widely encountered (and often most critical) strain state in plastic sheet metal forming: plane-strain tension. Low-carbon steel sheets are used primarily in consumer goods. These applications require materials that are serviceable under a wide variety of conditions and that are especially adaptable to low-cost techniques of mass production into articles having good appearance. Therefore, these products must incorporate, in various degrees and combinations, ease of fabrication, adequate strength, excellent finishing characteristics to provide attractive appearance after fabrication, and compatibility with other materials and with various coatings and processes. The steels used for these products were supplied over a wide range of chemical compositions; however, the vast majority were unalloyed, low-carbon steels selected for stamping applications, such as automobile bodies and appliances, and the food-can applications.

In Thailand, there has been no previous research on forming limit strain measurement using the plane-strain tensile test for the low-carbon steel sheets. This study will be useful for the applications of this kind of steel sheet.

## 1.2 OBJECTIVES

The objectives of this study were:

(1) to measure and analyse the work hardening characters of low-carbon steel sheet.

(2) to calculate the forming limit strain (FLS) and the forming limit diagram(FLD)

(3) to evaluate the limit drawing ratios (LDR)

## 1.3 SCOPE

This study attempted to measure and analyse the work hardening characters for the low-carbon steel sheet specimens which were photogrided and pulled under the strain state of plane-strain tension and uniaxial tension in a tensile testing machine while precision photographs of the deformed grid pattern were taken.

The forming limit strain or its diagrams (left hand) of low-carbon steel sheets were experimentally and analytically determined after the specimens broken. The limit drawing ratios of these sheets were examined and calculated.

## 1.4 EXPECTED BENEFITS

The benefits, which were expected from this study, are as follows :

(1) Plane-strain tensile and uniaxial tensile work hardening characters for the low-carbon steel sheet specimens would be shown.

(2) The forming limit strain of steel sheets under plane-strain and uniaxial tensile strain state would be used to avoid the breakage appearance in press shops.

(3) The largest ratios of blank-to-cup diameter, which is called limit drawing ratios, were calculated and tested. These are the most widely used parameters in metal sheets drawing and press die design and making.

## 1.5 METHODS AND PROCEDURES

The simplified flow sheet for the test procedure of this study is shown below:

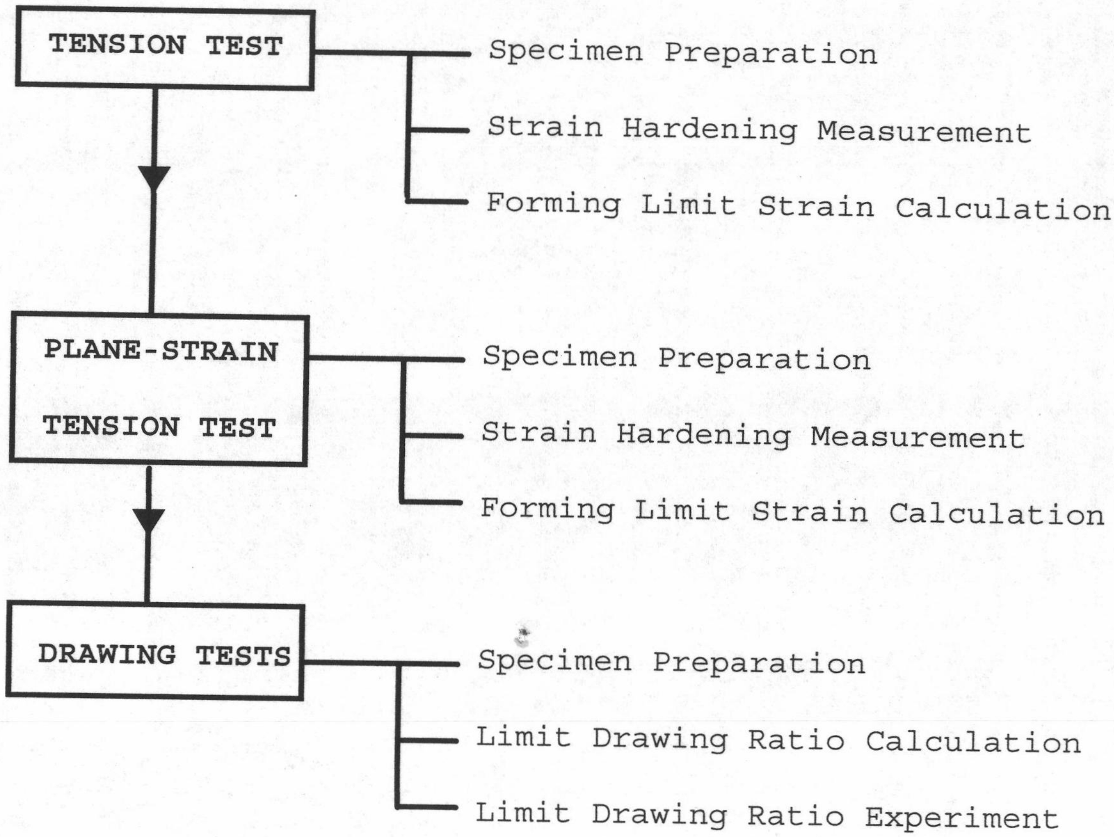


Fig.1-2 Flow sheet for the test procedure