12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

DESIGN OF STAMPING AND SHEET HYDROFORMING TEST UNIT

Murat Dilmeç
Selcuk University, Mechanical Engineering Department
Alaeddin Keykubat Campus 42250, Konya
Turkey

Mevlüt Türköz
Selcuk University, Institute of the Natural and Applied Sciences
Alaeddin Keyk. Campus 42250, Konya
Turkey

H.Selçuk Halkaci
Selcuk University, Mechanical Engineering Department
Alaeddin Keyk. Campus 42250, Konya
Turkey

ABSTRACT
In order to determine the formability of sheets and obtain the optimum process parameters for the processes, various experiments have to be performed. Some of these experiments are Limiting Dome Height (LDH) and Marciniak tests which are traditional biaxial tests and sheet hydroforming tests. For the purpose of determining process limitations and estimation of stamping characteristics in sheet metal forming, the forming limit diagram (FLD) is used.
In this study, a test unit has designed for simulating the processes. In this test unit, traditional biaxial tests and hydroforming tests can be conducted. Detailed system shame for the unit is given. The punch has 35 ton punch force, 300 mm punch stroke and 5-250 mm/min punch velocity. The blank holder has 40 ton force. The hydraulic system's properties are; the fluid medium capable to have 10-700 bar, the pressurized fluid has 10 lt/min volume of flow. The electronic system is composed of a computer and an electronic circuit which are used for adjusting the blank holder force, pressure of fluid medium and punch velocity as using convenient hydraulic elements.
Keywords: Limiting dome height, Marciniak test, Sheet hydroforming, Forming limit diagram.

1. INTRODUCTION
There are various sheet metal forming processes such as stretching, stamping, deep drawing, tube forming and hydroforming. In tooling and process designing most of these processes are all made up of relatively few elemental operations such as stretching, drawing, bending and sliding over a tool surface [1]. There are some tests for drawing and stretching whose names are Marciniak and LDH (Limiting Dome Height) respectively. But there is no consensus about hydroforming tests except of bulge test.
For sheet materials, the ability to be shaped in a given process, often called its formability. To assess formability, we must be able to describe the behavior of the sheet in a precise way and express properties in a mathematical form; we also need to know how properties can be derived from mechanical tests.
There are some failure modes in sheet forming processes. These are diffuse and localized necking, fracture, wrinkling and springback. If the punch force exceeds a limit value firstly diffuse necking develops after the punch force reached its maximum value. Then localized necking develops which results with fracture. When blank holder force is inadequate one principal stress in an element is compressive and the wrinkle failure develops. In order to avert developing these failures optimum process parameters must be attained. Designing of dies and adjusting process parameters with trial

and error is an expensive way and usually an optimum solution can not be obtained. Because of this FEM simulations must be used for sheet forming processes.
If accurate material parameters are inputted to FEM software, under variant process conditions, then real material behavior can be estimated. These process conditions are process parameters such as friction, geometry of dies, punch and blank holder forces, punch velocities and fluid pressure in hydroforming. Material parameters are flow curve, Poisson's ratio, strength coefficient, strain hardening exponent, normal and planer anisotropy. These parameters can be obtained from tensile test. Another data which are inputted in FEM software is FLD (Forming Limit Diagram). Forming limit diagram is an effective tool to evaluate the formability of sheet metals in various strain conditions and it is commonly used determining production problems in the forming processes. The formability limit of sheet metal is usually determined by the initiation of localized necking that introduces fracture. In this diagram, the forming limit curve (FLC) is obtained by joining the maximum strain points before localized necking occurs [2]. With using the FLC, the state of the sheet can be known by making simulation. As an example the areas which the sheet fracture and wrinkle, dangerous in the matter of fracture and wrinkle or formed in suitable way. FLD data is obtained by the way of Marciniak and LDH and bulge tests.
In this study a test unit to perform drawing, stretching and hydroforming tests has designed. Hydroforming tests includes SHF-P (Sheet Hydroforming with Punch) and SHF-D (Sheet Hydroforming with Die).

2. DESIGNED TEST UNIT

The designed test unit's system schema is shown in Figure 1. In this test unit, traditional biaxial tests and hydroforming tests can be conducted. In order to conduct hydroforming test there is a pressurized fluid supply system in the test unit as well as traditional test units.
In the test unit the maximum size of the blank is 420x260 mm. The blank holder is actuated by two hydraulic cylinders which have the capacity of 40 ton totally and have dimensions of 450x650 mm. The value of blank holder force is kept stationary or adjusted variably by blank holder force control system. This system includes proportional pressure control valve and related elements. Blank holder was supported by linear ball bearing for decreasing the effects of frictions. The punch is actuated by a cylinder which's capacity is 35 ton. The punch velocity and its position are adjusted by "Punch position and velocity control system" which includes a servo flow control valve and related hydraulic elements. Servo flow control valve adjusts punch velocity between the range of 5~250 mm/min. Moreover the punch has 300 mm strokes and its position is measured by an extensometer and the position data of the punch is sent to "Computer and electronic control unit". The punch and the blank holder force information are taken by load cells and are sent to the computer. So punch force versus punch position graph can be obtained. Another control system is "High pressure control system". This system supplies pressurized fluid to the pressure chamber. A radial reciprocating pump is used to obtain the needed pressure of between 10 and 700 bar. In hydroforming technology higher pressures such as 2000 bars is needed to form sheets. But simpler shapes will be formed in the test unit, 700 bar fluid pressure is sufficient for us. When there is a necessity for obtaining very high pressures "pressure intensifiers" are used. A pressure sensor measures the fluid pressure and sends this data to the computer. So that the real fluid pressure versus punch stroke graph can be obtained.

3. THE TESTS TO BE CONDUCTED

LDH test is used for modeling of stretching. Marciniak test is used for modeling of drawing. Sheet hydroforming tests will be made for investigate optimum process parameters and obtain a forming knowledge about formability of sheets during hydroforming. SHF-P, SHF-D and bulge tests will be made. These tests are described below.

3.1. LDH and Marciniak Tests

LDH test had standardized by ASTM [3] and Marciniak test has been introduced by Marciniak [4]. At LDH test, a sheet blank is clamped at the binder between the upper die and the lower blank holder, while a hemispherical center punch stretches the material until failure. Marciniak is used a flat punch instead of hemisphere.

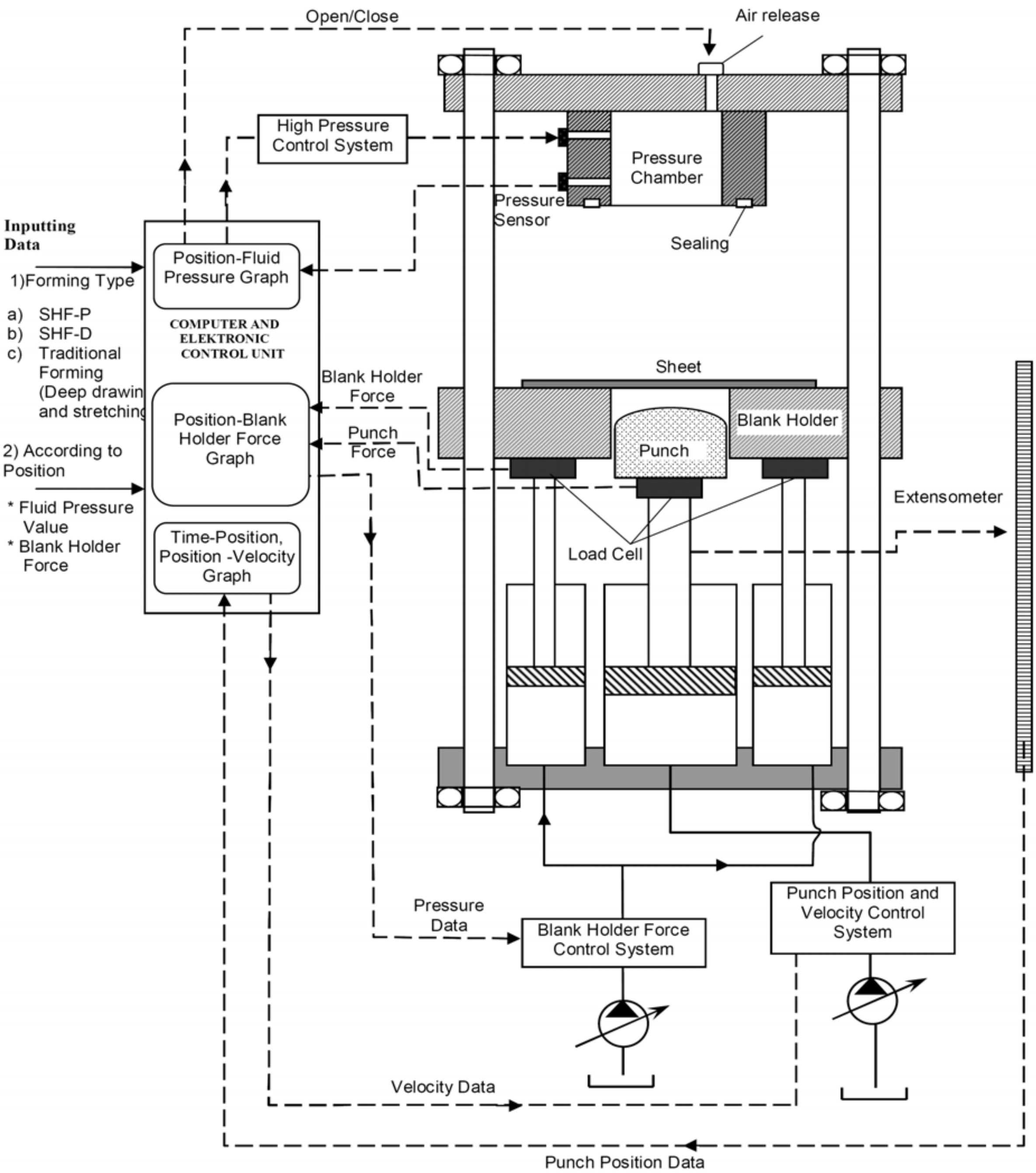

Figure 1. Hydroforming test unit system schema

After the sheet deformed with these tests the major and minor strains are measured by means of grid pattern. For FLD determination, it is most desirable to stop the test at the onset of incipient necking in order to measure strains corresponding to the FLC. Then these strains are plotted on a FLD and the FLC is drawn to connect the highest measured (ε_1 and ε_2) strain combinations that include good data points [3].
While the LDH test is complicated by strain gradients due to friction, normal loading, and bending, the Marciniak test provides in-plane stretching without the influence of friction condition that is difficult to quantify, the in-plane method may be more sensitive to material defects, and could provide more accurate and repeatable results that are useful for FEA simulations [5].

3.2. Sheet Hydroforming Tests

Sheet hydroforming (SHF) is a sheet forming method which is cost effective and alternatively used instead of forming sheets between two die and deep drawing. In this technology a fluid medium is used instead of one of the die half which is punch or die. During the hydroforming process, the punch penetrates into the fluid medium and pressurized fluid wraps the material around the tool creating a part. This process name is SHF-P. Also hydroforming uses fluid pressure instead of the punch in a conventional tool set to form the part into the desired shape of the die and this process name is SHF-D. Hydroforming has become a competitive metal forming method because of ability to forming complex shapes in one operation, higher drawing ratios, reduced tool costs, less thinning and high dimensional and geometric accuracy.

3.2.1 SHF-P Test

In SHF-P test, the sheet is clamped by the blank holder. Then while the sheet is being formed by the punch, pressure of the fluid and the blank holder force are adjusted. So many forming combinations are performed by changing these parameters and other processes parameters. Moreover some special test can also be conducted, such as flex forming [6], pre-bulging tests [7], hydro-dynamic and hydro-static deep drawing [8].

3.2.2 SHF-D Test

In this test blank is expanded by high-pressurized fluid in the die cavity. The blank is clamped between die and pressure chamber to prevent leakage of pressurized fluid. Due to the effect of high pressure fluid the sheet gets the die form. Also bulge test can be performed in this manner, but the die does not be used then.

4. CONCLUSIONS

In this study, a test unit that can be conducted the traditional biaxial tests and the hydroforming tests have been designed. For conducting these tests necessary processes parameters have been determined. The punch velocity and position, the blank holder force, the fluid pressure, versus punch positions can be controlled by a computer. The capacity and the sizes of the unit have been specified.

The processes parameters should be optimized, due to increasing sheet formability, using such a test unit.

Increasing of the sheet formability can be achieved by decreasing of sheet metal forming failures, as follows;

- FEM software must be used for numerical solving of forming process with FLD as an input parameter.
- For obtaining best results from FEM analysis accurate material and process parameters must be determined according to the type of forming process.
- Considering the numerical approach of determining the FLD, it is necessary to conduct LDH, Marciniak and bulge tests and determine at which point where on the specimen the material rupture occurs.
- Due to determine an accurate FEM analysis result, sheet hydroforming tests will be conducted and the results should be compared.

5. REFERENCES

[1] Marciniak Z., Duncan J.L., Hu S.J.: Mechanics of Sheet Metal Forming, Butterworth Heinemann, 2002

[2] Ozturk F., Lee D.: Analysis of forming limits using ductile fracture criteria, Journal of Materials Processing Technology 147, 2004.

[3] Test Method for Determining Forming Limit Curves, ASTM 2218-02.

[4] Marciniak Z. and Kuczynski K.: Limit Strains in the Processes of Stretch-Forming Sheet Metal, Int. J. Mech. Sci., 9, 1967.

[5] Emilie H., Carsley J. E., and Verma R.: Development of Forming Limit Diagrams of Aluminum and Magnesium Sheet Alloys at Elevated Temperatures, ASM International, 2007.

[6] Zhang S.H.: Developments in hydroforming, Journals of Materials Processing Technology,1999.

[7] Lang L., Danckert J., Nielsen K. B.: Investigation into the effect of pre-bulging during hydromechanical deep drawing with uniform pressure onto the blank, International Journal of Machine Tools & Manufacture 44, 2004.

[8] Zhang S.H., Danckert J.: Development of hydro-mechanical deep drawing", Journal of Materials Processing Technology 83, 1998.