REVIEW PAPER ON SHEET METAL FORMABILITY TESTS

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Abstract

Mechanical behaviour of sheet metal in forming operations such as deep drawing is very much essential for quality forming of articles widely used in automobile, beverage, aerospace, kitchenware, etc. A variety of tests are available and selection of proper tests according to the need is very much essential. By thorough understanding of them helps the craftman to reduce production time and cost involved in rejections. This paper gives an insight on various formability tests commonly used for establishment of deep drawing operations.Aluminum have been used in this tests

Keywords: Deep drawing, LDH test, Erichsen test, Limiting Drawing Ratio, Olsen test.

1. Introduction

The deep drawing process is indeed one of the important sheet metal forming operations used in conversion of 2D blank sheet into 3D component of hollow shape such as beverage cans, automobile body components, kitchenware and household articles. The tool setup for deep drawing consists a combination of die, punch and blankholder. As the punch descends, it pushes the blank through the gap between bunch and die and the applied force transforms the 2D blank into 3D cup shaped component. As it needs to design necessary calculations, well in advance of the real production, needs to have through knowledge on forming characteristics of the sheet used in deep drawing. It is to be noted that in deep drawing the blank material can be subjected to stretching and hence stretching tests are mainly needed in deep drawing process.

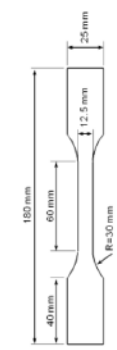
2. sheet metal tests

2.1. strip tensile test

The tensile test is one of the most widely used test for finding the basic characteristics of the blank material. For this test a tensile testing machine can be used and the specimen from the blank can be prepared in the form of dog bone shape as shown in Figure 1. Through this test young's modulus, yield strength and strain ratio can be found by using the standard specimen.

Tensile testing specimens can be prepared according to the standard methods such as ISO, ASTM or DIN. Electric discharge machining (EDM) and grinding with abrasive paper may be used in preparation of specimen. A sample preparation technique that results in defect-free edges with no post preparation dressing would be ideal for material testing as shown in Figure 1. Tensile test reveals the yield strength, strain ratio, strain hardening exponent.

(a) Tensile testing machine



(b) Tensile testing specimen

Figure 1: Tensile testing operates

Figure 2: Tensile specimen after test

2.2. *Indentation test*

The springback characteristic in deep drawing process depends on yield strength and elastic deformation, path of deformation and the level of cumulative plastic deformation in severely deformed regions. To obtain local plastic strain values of deformed metal sheets, it is essential to use the instrumented indentation test. The indenter of the test enters into the material due to applied load and the formability of the material can be estimated by means of force vs depth curve obtained. The indentation test has the advantage of identifying the parameters that are locally influencing the hardening parameters of the material. But this indenter test has the disadvantage of having a complex deformation field developed under the indenter [1].

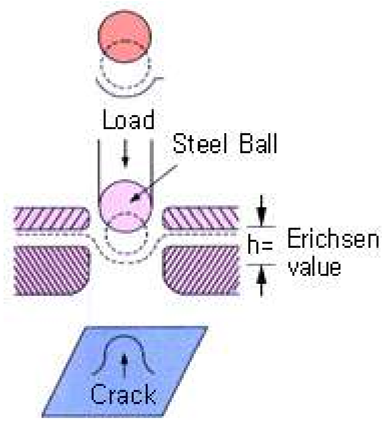


Figure 3: Erichsen test

2.3. *Erichsen test*

The Erichsen cupping test is the ductility test being used to test the pullout of the sheet metal. The forming test consists of spherical punch and a test piece clamped between a blank holder and a die, until a through crack develops and clearly appears as shown in Figure 3.

2.4. *Olsen test*

Olsen test evaluates the stretchability of sheet metal. A strip of material is locked over a 25mm diameter hemispherical punch as shown in Figure 4.

The test material had been subjected to biaxial stretching until the formation of tears and that gives

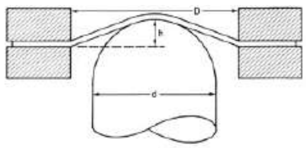


Figure 4: Olsen test

the maximum height of the punch travel and can be recorded. these tests may be performed manually or automatically, but the automatic test gives very accurate results in comparison to manual tests as it is not possible to stop the machine soon after the development of tear on the hemispherical dome shape of the specimen. When manual testing methods need to use, it is better to take four or five tests and average value can be recorded. The lubricant may be applied to the sheet metal but proper care needs to take when test is used for comparison of formability test of different materials otherwise it may not give correct values.

2.5. deep-drawing cup test

circular blank is stamped from the main sheet metal and formed into a cup in deep drawing cup test. The greatest possible ratio between the blank and punch diameter that just permits the quality production of a cup is called the Limiting Drawing Ratio [2]. The LDR is the important characteristic in forming ability of the sheet material. The ears formed if any due to metal planar an-isotropic characteristics are undesirable and demands rework. Hence, it again requires to estimate best blank size while considering the ears formed due to anisotropic nature of the material.

2.6. Conical cupping test

Cupping tests can be used to determine anisotropy of the sheet material. If the material is isotropic, a circular fracture may occur over the ball. In contrast

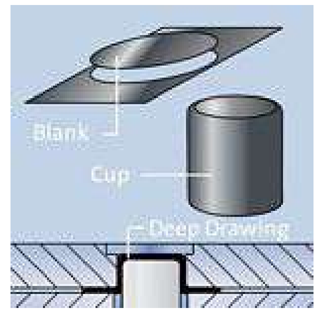


Figure 5: Deep drawing test

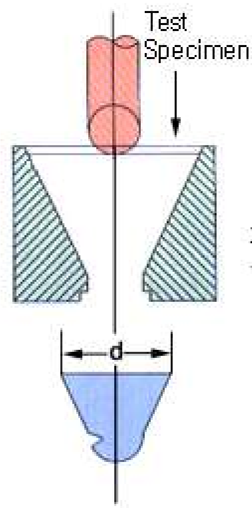


Figure 6: Conical cupping test

to that straight crack may develop in case of isotropic material [3].

2.7. Hole expansion test

In this test suitable hole is created at the centre of the blank as shown in Figure 7. The square blank with hole created at the enter is placed on a die and clamped by the blank holder. A punch essentially conical in shape expands the hole until the edges of the blank begin to crack. Edge stretchability expressed as percent of hole expansion is determined by averaging the increase in hole diame-

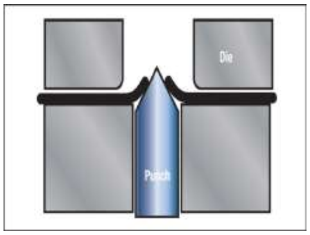


Figure 7: Hole expansion test

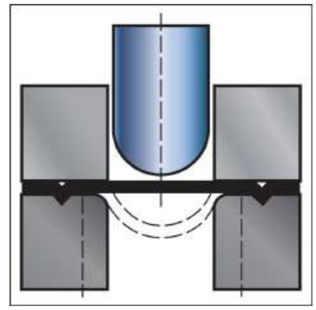


Figure 8: LDH test

ters around the circle. The hole expansion testing is widely accepted test in industry for testing formability of sheets [4].The forming capacity of the material in the hole expansion test can be described by

$$\lambda = \frac{f d_f - d_o}{d_o} x100\% \quad (1)$$

whered_f is the size after testing and d_o is the initial diameter of the hole. Krempaszky, C., et al[5] worked on more efficient hole expansion testing. The determination of hole expansion ratio involves identification of limiting configuration and limiting hole expansion ratio. They proposed new method that the instrumented test setup was attached with video and the evaluation strategies were efficient in terms of time and cost in hole expansion testing.

2.8. Limiting Dome Height (LDH) test

The LDH test is an another popular sheetmetal-stretchability test uses a 100 mm diameter hemispherical punch to deform 250 mm x 125 mm blank. Blank width is set for no deformation in the width direction. A test gives the maximum height of the hemisphere without failure. Though the concept behind this test is good, still there exists a possibility of poor formability details so many formability personnel use tensile tests to define forming parameters. It is to be noted that the tensile sample has a standard shape and size with no bends, holes or notches, and no contact with any surfaces for lubricant interaction. The LDR test gives a wide range of formability parameters to predict local deformation.

2.9. FLC test

Forming limit curve can be determined by measurement of grid circle diameters that were etched over the specimen. The grid cirle circles can be electro-chemically etched using appropriate marking stencils which are available with circle diameters from 2 mm upwards [6]. Sheet metal markings provide knowledge on the behaviour of sheet metal during forming process. The amount of strain due to elongation or compression is clearly recognizable in direction and size on the basis of the deformation of the applied measuring grid
forming limit curves in accordance with ISO 12004 , the Nakazima or the Marciniak test are being used. The principle is that a hemispherical punch deforms steel sheet billets of different widths until failure. The maximum characteristic deformations achievable before failure of the different shapes of specimens can be determined and FLCs are drawn for the material as Figure 9.

2.10. Ear height test

Ear measuring test is another important test being used to have a numerical value of the size of the ears due to anisotropy nature of the material. There

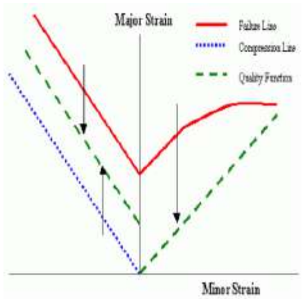


Figure 9: Typical forming limit curve

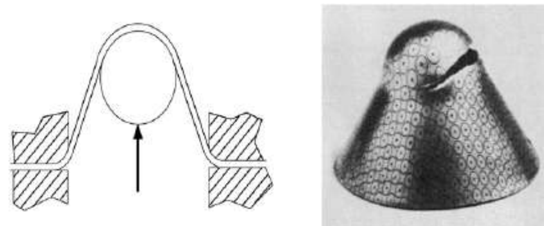
are variety of automated and computerised ear measuring instrument to have an average cup height, the height of the ears in percent and in mm for recording. The tendency of longer ear formation on cups is undesirable. The measurements are being made at heights and valleys of the ears and recorded.

2.11. *Bulge Test*

Beside the FLC test, the bulge test has become most important one in recent days. The figure shows a diagrammatic view of the testing assembly. The test panel is fixed between the drawing die and the blank holder. Below the specimen there is a chamber which is filled with oil. The metal sheet is clamped. The drawing punch presses the oil upwards against the test plate and deforms it. The forming process is effected without any friction

2.12. *Fukui test*

The Fukui conical cup test involves both stretching and drawing over a ball. The opening is much larger than the ball so a conical cup is developed. The flanges are allowed to draw in. Figure 10ashows the setup. A failed Fukui cup is shown in Figure 10b.



(a) Fukui test

(b) Failed cup

Figure 10: Fukui test setup

3. Conclusion

Formability can be determined by various methods explained above but needs to select suitable test methods according to the requirement in order to have thorough understanding of the formability characteristics of the sheet material for deep drawing operation.

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