Formability of sheet metals – A review

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Abstract. The deep drawing process is a forming process which occurs under a combination of tensile and compressive conditions. Formability is the ability of a given metal work piece to undergo plastic deformation without being damaged. The plastic deformation capacity of metallic materials, however, is limited to a certain extent, at which point, the material could experience tearing or fracture. Formability of sheet metal can be evaluated by various tests like swift cup drawing test, Fukui’s conical cup drawing test, Erichsen cupping test, OSU Formability Test, Hydraulic Bulge Test, Duncan Friction Test. These tests are widely used to evaluate the formability for different sheet metals. In this paper, swift cup and Erichsen cupping tests presented.

1. Introduction

Deep drawing is a process to obtain objects like cup shaped, pressure vessels, gas cylinders etc. In deep drawing process sheet metal placed on a die cavity and sheet can be held by blank holding device then with required force the punch can be applied on blank to get desired shape. In this process to avoid the shearing effects of the blank the die and punch should be provided with corner radius. In this process the clearance can be provided between punch and die [1]. The process of deep drawing is shown in fig 1.

Figure 1. Deep drawing
Processes included in sheet metal forming are rolling, extrusion, forging, roll forming, stamping, and hydro forming. The material properties affect the formability because of the fact that the properties of sheet metals vary considerably during the forming process. As well as depending on the base metal on the alloying elements present, Processing method of metals, heat treatment and the level of cold work the forming behaviour will be[2-7].

2. Methodology

Formability is defined as ability to undergo plastic deformation without taking failure in forming operation. These operations contain like deep drawing, cup drawing, bending and involves tensile deformation. Common failures of deep drawing processes are wrinkling, tearing, necking.

2.1 Forming limit diagram (FLD):

Forming limit diagram is used for optimizing sheet metal forming. Engineering stress–strain curves for several metals shown in fig 2. The sheet deformed in to cup shape drawing by applying punch on the die and varies widths of strips are used for tests [8-12].

![Figure 2: Engineering stress–strain curves for several metals](image)

In this process the strain calculated along the two principal direction major axis and minor axis [13-17]. The graph shows limiting strains for the safe deformation. Formability limiting diagram is shown in fig 3. Formability of a sheet can be determined in many experimental methods. Some of the tests are erichsen Cup Test, Swift Cup Test.
Formability tests: limiting drawing ratio is defined as ratio of initial diameter of blank to the diameter of the drawn. The sheet specimen with diameter $D_0$ is placed on the holding device and with required force the punch with diameter $d_0$ is applied on the specimen to get cylindrical cups. For measuring deep draw ability the maximum blank diameter $D_0$ determined[18-22]. The swift cup drawing test is shown in fig 4.

To calculate the formability of sheet metal under the plastic deformation formability tests are performed [13-16]. The erichsen cup test shown in fig 5. In this process punch is applied on sheet which is holded by blank holder until failure occurred and depth of the cup calculated [23-26].
Under erichsen Cupping Test, the metal strip is placed into the test cylinder and located diagonally. The blank holder is adjusted by regulating valve. The testing machine is operated with automatic conditions for stop so when maximum deformation occurs in the strip the machine stops automatically [27-28]. The erichsen cupping value is obtained of 0.1 mm.

Figure 5: Erichson cup test

Figure 6: Cup height with strain-hardening exponent, [29]
3. Results and Discussion

Limiting drawing ratio with higher value then increases formability of material. In the shown graph due to strain hardening the decremental steps are obtained l and the comparison of drawing ratio of swift cup and erichsen formability tests with respect to stretching ratio is drawn as shown in fig 8.

4. Conclusions

Formability of strips measured by forming tests like Swift cup drawing test, erichsen cupping test. LDR is evaluated in swift cup drawing test. Formability index expressed in limiting drawing ratio (LDR). Erichsen cup test ; Formability index expressed in cup height at fracture is known as erichsen number, higher in erichsen higher in formability index. This work provides theoretical analysis for the determination of formability of sheet metals by using varies formability tests in the actual strain path. The main achievements of this research can be listed such as forming limit diagram of the sheets is sensitive to strain path and using the FLD that is obtained in linear strain path for predicting the forming process.
References

[1] D.Y. Yang, J.B. Kim, D.W. Lee, Investigation into manufacturing of very long cups by deep drawing and ironing, Ann. CIRP 57 (1999) 346–354.

[2] R. Uday Kumar, “A study on deep drawing and spinning process in sheet metal forming,” International Journal of Application, 2012.

[3] J. Timosh, Rupture instability in deep drawing process, International Journal of Mechanical sciences 27-35 [1997] .

[4] Henry S. Valberg an. el.: “Applied Metal Forming including FEM Analysis”; 1st edition; Cambridge University Press; 2010; ISBN- 978-0-521-5183-9.

[5] Serhat Yalcın an. el: “Analysis And Modeling Of Plastic Wrinkling In Deep Drawing”; Master Of Science Dissertation; Dept. Mechanical engineering; Middle East Technical University; Turkey.

[6] Mohammad Reza Morovvati an. el.: “ Experimental and finite element investigation on wrinkling of circular single layer and two-layer sheet metals in deep drawing process”; International Journal of Advance Manufacturing Technology; volume-54 (2011); pp-113-121.

[7] Mikell P. Groover: “Fundamentals Of Modern Manufacturing”; Materials,Processes,andSystems; 4th edition; John Wiley & Sons, Inc; 2010; ISBN 978-0470-467002.

[8] M. El Sherbiny an. el: “Thinning and residual stresses of sheet metal in the deep drawing process”; Materials and Design 55 (2014) 869–879.

[9] Kakandikar G.M an. el.: “Optimization of forming load and variables in deep drawing process for automotive cup using Genetic Algorithm”; On-line Journal, www.optimzationonline.org/DB_FILE/2007/03/1606

[10] Ter verkrijging van: “Modelling of contact and friction in deep drawing Processes”; Printed by FEBO druk B.V., Enschede; Printed by FEBO druk B.V., Enschede

[11] Amir Atrian an. el.: “Deep drawing process of steel/brass laminated sheets”, international journal of Composites: Part B 47 (2013) 75–81.

[12] Johnson W an. el.: “Engineering plasticity”; John Wiley & Sons; 1983.

[13] O.A. Sokolova an. el.: “Deep drawing properties of lightweight steel/polymer/steel sandwich composites”; archives of civil and mechanical engineering; 12 (2012) 105–112.

[14] Conry T. F. an. el.: "Optimization of die profiles for deep drawing", Journal of mechanical design, Vol. 102, no. 3, pp. 452-459.

[15] Abdalla S. Wifi an. el.: “A review of the optimization techniques applied to the deep drawing process” International Conference on Computers and Industrial Engineering,October 20-23, 2007, Alexandria, Egypt, edited by M. H. Elwany, A. B. Eltawil.

[16] Yusofi M, an. el.: “Theoretical and experimental analysis of stress and strain in deep drawing process” ; Proceedings of the 5th Iranian conference of manufacturing engineering; Tehran, Iran, Conference; Conference; 2002.

[17] Fereshteh-Saniee F an. el.: “A comparative estimation of the forming load in the deep drawing process”; J Mater Process Technology 2003; 140(1–3):555–61.

[18] Zein H et al.: “Thinning and spring back prediction of sheet metal in the deep drawing process”, J Mater Des 2014; 53(2014):797–808.

[19] Fereshteh-Saniee F an. el.: “A comparative estimation of the forming load in the deep drawing process”; J Mater Process Technol 2003; 140:555–61.

[20] Danckert J an. el.: “The residual stress distribution in the wall of a deep drawing and ironed cup determined experimentally and by finite element method” Ann CIRP 1994; 43:249-52.

[21] Vishtal, A.; and Retulainen, E.: The improvement of paper extensibility, wet and dry strength by spray addition of agar solutions, NPPRJ 29 (3), (2014), 434-444.

[22] Zeng, X.; Vishtal, A.; Retulainen, E.; Sivonen, E.; Fu, S.: The Elongation of Paper – How fibres should be deformed to make paper extensible?, BioRes. 8(1), (2013), 472-486.

[23] Vishtal, A.; Hauptmann, M.; Zelm, R.; Majschak, J.-P.; and Retulainen, E.: 3D forming of paperboard: The influence of paperboard properties on formability, Packag. Technol. Sci,
DOl: 10.1002/pts.2056. It was now published offline issue 27(9), pages 677-691.

[24] Ankerfors, M.; Lindström, T.: Mouldable material, Intern. Patent WO 2011/087438A1, (2011).

[25] Poppel, E.; Malutan, C.; Malutan, T.; Orleschi, N.: Correlation between the standard, rheological and technological parameters in Clupack extensible paper manufacturing, Cellulose Chem. Technol. 34, (1996), 385-398.

[26] Marsh, K.; and Bugusu, B.: Food Packaging Roles, Materials, and Environmental Issues, Journal of food science, 72 (3) (2007), 39-55.

[27] Vishtal, A.; and Retulainen, E.: Deep-drawing of paper and paperboard: the role of material properties, BioRes. 7(3), (2012), 4424-4450.

[28] Östlund, M.; Borodulina, S.; and Östlund, S.: Influence of paperboard structure and processing conditions on forming of complex paperboard structures, Packaging Technology and science 24(6), (2011), 331-341.

[29] Seth, R. S.: Understanding sheet extensibility, Pulp & Paper Canada 106(2), (2005) 33-40