International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 3, May-June-2026, ISSN (Online): 2395-566X

DrawabilityAssessmentofASS304SheetsUsedin Dairy Industry in Terms of Limiting Drawing Ratio (LDR)

[1] Aditya Menasagi,[1] Basavaraj Sali,[1] Shridhar Kotrashetra,[1] Veerendragowda Patil ,[2] B.H.Vadavadagi and [2] H.V.Bhujle
[1] Students (6th semester) Department of Mechanical Engineering, SDM College of Engineering and Technology, Dharwad, Karnataka, India
[2] Faculty, SDM College of Engineering and Technology, Dharwad, Karnataka, India

Abstract- — The current trend shows a significant increase in the application and use of sheet metal in manufacturing processes. Stainless steels are selected for dairy applications because they are resistant to corrosion, inert, easily cleaned and sterilized without loss of properties, and can be fabricated by a variety of techniques into robust structures. For this study, Austenitic Stainless Steel (ASS) 304material was selected and cut into circular shapes of varying diameters but with thickness of 1mm and 0.8mm. These circular cut materials are referred to as blanks. Before testing,a lubricant(grease)is applied to the blanks.The blanks are then subjected to as with cup drawing test using a hydraulic deep drawing press to determine the limitingdrawingratio(LDR). During the deep drawing process, the cup is formed by the punch force. At a certain blank diameter, the bottom of the cup may fracture due to the punch force. The diameter of the blank just before the fracture occurs represents the maximum. diameter of the blank.The addition of lubricant helps to analyze the impact of friction between the blank and the punch during the deep drawing process. The drawability of sheet metals is measured in terms of the LDR, which indicates the maximum deformation a cup can undergo without failure using a hydraulic press. The LDR is defined as the ratio of the maximum diameter of the blank to the diameter of the punch. Experiments were conducted on ASS 304 sheets using a hydraulic press deep drawing setup, and load-element were generated. The LDR value for 304 sheets was determined.

Keywords— drawability,stainless,deepdrawing and limitingdrawingratio.

I. INTRODUCTION

Stainless steel has received significant attention in dairy industries because of its excellent properties like resistance to corrosion, inertness, can be easily cleaned and sterilized without loss of properties, and can be fabricated by a variety of techniques into robust structures [1-3]. Sheet metal forming involves transforming flat, thin sheet metal blanks into components of a desired shape. Processes like deep drawing, stretching, and bending are extensively used in the automobile and aircraft industries to produce a wide range of components, from simple to complex designs. In deep drawing, also known as cup or radial drawing, a flat sheet is shaped into a cup-like component by pressing its center into a die opening using a punch.

The metal is drawn into the desired shape, and the blank can be circular, rectangular, or a more complex form [4-6]. A blank holder applies force to prevent wrinkling and control the material flow into the die cavity. As the punch is pushed into the die cavity, the sheet metal conforms to the shape of thepunch and die, undergoing both compressive and tensile stresses. If a very high blank holding force is applied, the process transitions from deep draw to stretching.

During deep drawing, the sheet bends over the die curvature, resulting in localized strains: tensile on the outer side of the neutral axis and compressive on the inner side. Most deformation in deep drawing occurs in the flange of the cup, where the metal is subjected to three types of stresses, influencing thickness variation in the drawn cup.The primary deformation occurs asbending around the die radius, while the third deformation zone involves uniaxial stretching in the cup wall (plane strain),leading to metal thinning.The bottom of the cup, under biaxial tension, typically retains a thickness close to the initial sheet thickness.

In this work the deep drawing experiments were conducted on ASS-304 sheets using different size blanks and LDR was determined.

II. METHODOLOGY

The experiments were conducted using a specially designed test rig for deep drawing operations. ASS 304 blanks,each with a thickness of 1 mm and 0.8mm, werecut into circular shapes using laser cut. The deep drawing process was performed on ASS 304 blanks with diameters ranging from 85 mm to 100 mm. A 40-ton capacity hydraulic press was utilized fordeep drawing both materials. To account for the tendency of materials to alter dimensions at elevated temperatures, Inconel-600 was used in the design and manufacture of the die, blank holder, and punch. Lubricant was applied to minimize friction between the punch and die. The blank was securely clamped between the upper and lower dies, and the punch was driven downward to draw the blank into a cup shape. The forming load was transmitted from the punch radius through the wall of the drawn part into the deformation region, specifically the sheet metal flange. The tensile forces acting on the part wall caused significant wall thinning, leading to uneven wall thickness. The maximum stress that can be safely transferred from the punch to the blank determines the maximum blank size, specifically the initial blank diameter for rotationally symmetric blanks. Because determining the Limiting Drawing Ratio (LDR) for complex components can be challenging ,critical areas of the part are inspected to allow for approximate assessments.

Deep Drawing Experiments

The Limiting Drawing Ratio (LDR) is experimentally evaluated for ASS 304 sheets using the deep drawing process. The significance of the LDR lies in its role in selecting materials that can successfully form cups during deep drawing operations. LDR is defined as the ratio of the maximum blank diameter (Dmax) that results in a successful cup formation to the diameter of the punch (d).

LDRisrepresentedby LDR= eq.(1)

Where,
Dmax=Maximumdiameterofblank,and d = Diameter of punch
According to the experiment, a higher Limiting Drawing Ratio (LDR) indicates greater formability, while a lower LDR signifies reduced formability of metals. The draw ratio (DR) in a deep drawing process is calculated as the ratio of the blank diameter to the cup diameter. To achieve a very high draw ratio, processes such as redrawing, ironing, or annealing between successive drawings are employed. The maximum draw ratio that can be attained under ideal deep drawing conditions is known as the Limiting Drawing Ratio (LDR) and is considered an effective measure of a material's drawability.

III. RESULTS AND DISCUSSION

1. Limiting drawing ratio of ASS-304

The formation of cup from ASS 304 circular blanks from Diameters range D is 85 mm – 97 mm with incremental3mm.Thickness of each blank is 1mm and 0.8mm. The failure of ASS 304 cup occurred at 97 mm diameter. Just before this diameter of blank is gives successful formation of cup, this diameter is called maximum diameter of blank .Therefore the maximum diameter of blank which is given successfully formation of cup is denoted by Dmax. Dmax = 94mm, diameter of punch d = 50mm
LDR==94/50=1.88

The failure of ASS 304 cup occurred at 97 mm diameter with thickness of 1 mm and 0.8mm and the maximum load of 80726 N(0.8mm) and 92618N (1mm) is taken from Graph. From this result, the limiting drawing ratio (LDR) of 1.88 was observed. The experiments have been performed with utmost care and the results are presented in Maximum punch force v/s sheet thickness for ASS304 sheets as shown in Figure 1 below.

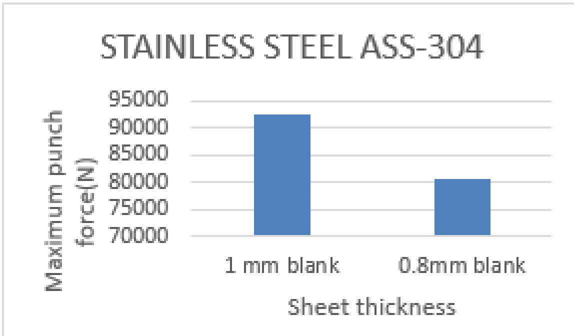

Figure1:Maximum punch force v/s sheet thickness graph of ASS304 sheets.

IV. CONCLUSION

The Limiting Drawing Ratio (LDR) for ASS 304sheets has been determined to be 1.88. Based on this finding, the maximum blank sizes that can be safely deep drawn are 94 mm for ASS 304 sheets under the given conditions. Beyond these sizes, fractures were observed; Since LDR is direct measure of formability, ASS 304 sheets are suitable materials used for industrial applications.

Acknowledgements

The authors are grateful toVision Group on Science and Technology (VGST) and Karnataka Science and Technology Promotion Society (KSTePS), Government of Karnataka for providing the funding and facilities to carry out this research work under KFIST-Level 2 Scheme with grant number: KSTePS/VGST/GRD-658/K-FIST (L2)/2018.

REFERENCES

1. Covert RA, Tuthill AH (2000) Stainless steels: an introduction to their metallurgy and corrosion resistance. Dairy Food Environmental Sanitary 20: 506-517.
2. Ryan MP, Williams DE, Chater RJ, Hutton BM, McPhall DS (2002) Whystainless steel corrodes in nature. Food Processing 415: 770-774.
3. Weeks DT, Bennett TM (2006) How to specify equipment for high-purityprocesses. Pharmaceutical Processing 23: 16-20.
4. Jain, M., J. Allin, and M. J. Bull. "Deep drawing characteristicsof automotivealuminiumalloys." Materials Science and Engineering: A Vol.256, No.1, pp.69-82, 1998.
5. G. Behrens, F. O. Trier, H. Tetzel and F. Vollertsen, "Influence of tool geometry variationsonthelimitingdrawingratioin micro deep drawing ", International Journal ofMaterialFormingVol.9,No.2,pp.253-258,2016.
6. Xiao-bo Fan, Zhu-bin He , Wen-xuan Zhou and Shi-jian Yuan. "Formability and strengthening mechanism of solution treatedalloy steels under hot stamping conditions, JMPT, Vol 228, pp-179-185, 2016