Impact Factor:

ISRA (India) = 6.317
ISI (Dubai, UAE) = 1.582
GIF (Australia) = 0.564
JIF = 1.500
SIS (USA) = 0.912
РИНЦ (Russia) = 0.191
ESJI (KZ) = 8.100
SJIF (Morocco) = 7.184
ICV (Poland) = 6.630
PIF (India) = 1.940
IBI (India) = 4.260
OAJI (USA) = 0.350

SOI: 1.1/TAS DOI: 10.15863/TAS

International Scientific Journal

Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2025 **Issue:** 05 **Volume:** 145

Received: 24.05.2025
Accepted/Published: 30.05.2025

https://T-Science.org

Issue Article

Denis Chemezov
Vladimir Polytechnic College
MEng, Honorary Worker of the Education Field of the Russian Federation, Academician of International Academy of Theoretical and Applied Sciences, Lecturer, Russian Federation
https://orcid.org/0000-0002-2747-552X
vpk-science@yandex.ru

Denis Korkunov
Vladimir Polytechnic College
Student, Russian Federation

Ekaterina Suslova
Vladimir Polytechnic College
Student, Russian Federation

Mariya Gladilkina
Vladimir Polytechnic College
Student, Russian Federation

Rodion Yurenko
Vladimir Polytechnic College
Student, Russian Federation

Andrey Ovsyannikov
Vladimir Polytechnic College
Student, Russian Federation

Egor Drozdov
Vladimir Polytechnic College
Student, Russian Federation

Aleksandr Tsygankov
Vladimir Polytechnic College
Student, Russian Federation

CRITICAL ANALYSIS OF DEFORMATION OF THE MATERIAL OF A THIN-WALLED PART MADE BY DEEP DRAWING

***Abstract**: This article analyzes the degree of deformation of the outer and inner surfaces of a thin-walled part made by deep drawing. Based on the conducted testing, the ratio of stress state of the material to the degree of plastic strain of the part was obtained.*

***Key words**: deep drawing, outer and inner surfaces, pressure, cup, compression, tensile, radius bend, plastic strain.*

***Language**: English*

***Citation**: Chemezov, D., et al. (2025). Critical analysis of deformation of the material of a thin-walled part made by deep drawing. *ISJ Theoretical & Applied Science, 05 (145),* 282-284.

Soi: https://s-o-i.org/1.1/TAS-05-145-35 ***Doi***: crossref https://dx.doi.org/10.15863/TAS.2025.05.145.35
Scopus ASCC: *2201.*

1. Introduction

Plastic strain of metal blanks is characterized as a technological process of waste-free production of parts. During plastic deformation, the configuration of the metal blank undergoes changes, while the volume remains constant. Thus, when changing the geometry of the metal blank of medium and large dimensions, significant technological efforts of pressing equipment tools are required, which causes large stresses and strains in the volume of the metal alloy.

Sheet metal drawing is used to produce thin-walled parts of various configurations [1]. The process is complicated by the variable deformation of the material in conditions of low thickness of the blank, which can lead to partial rupture of the semi-finished product in the most stressed areas (for example, significant wall thinning near radius bends) [2-5]. Deep drawing can be accompanied by the process of wrinkle formation due to excess material on the flange of the semi-finished product, which helps to increase the pressure force of the punch on the blank [6-8]. In the latter case, special blank holders are used to reduce the wrinkle formation.

Thus, the identification of patterns of stresses and deformations of the material during plastic strain will make it possible to analyze dangerous local volumes in the manufactured part and the main variables that affect the technological process of drawing [9-10]. The results of computer modeling of the sheet metal deep drawing process will be useful in the design and implementation of technological equipment for the manufacture of cylindrical thin-walled parts, improvement of plastic deformation technology to reduce defects in production.

2. Materials and methods

A metal sheet (steel AISI 4340) with a thickness of 20 mm was subjected to plastic deformation. The part ("cup") with a spherical bottom was obtained by deep drawing. After drawing, the height of the part was more than 400 mm, and the internal radius bend, which defines the boundary of the transition from the side wall to the bottom of the product, was 52 mm. The cylindrical punch applied pressure (approximately 20 N/m^2) to the blank with its working part and formed the inner contours of the part by moving along the axis of the blank. Accordingly, the die hole provided the formation of the outer contours of the part. Thus, to analyze the degree of plastic strain of the metal cup, experimental values of the stress state of the outer and inner surfaces of side walls, radius bends and the bottom of the part were investigated.

3. Results and discussion

To analyze the results of testing the deformation of the material of a thin-walled part made by deep drawing, the calculated values of pressure and coefficient of plastic strain of the outer and inner surfaces of the product were processed. The following part elements were analyzed: the outer and inner surfaces of side walls, the outer and inner surfaces of side walls near the radius bends, the outer and inner surfaces of the radius bends, and the outer and inner surfaces of the spherical bottom.

3.1. The outer and inner surfaces of side walls

The estimated length of side wall of the part on the outer and inner surfaces is 400 mm. The outer and inner surfaces of side walls are subjected to compression deformation, as the calculated pressure values vary in the ranges from -178 to -252 MPa for the outer surface and from -188 to -71 MPa for the inner surface. Thus, a greater material stress is observed on the outer surface of the cup. An increase in pressure was noted along the outer surface of side wall in the direction of the radius bend, and an increase in pressure was noted along the inner surface of side wall in the direction of the flange of the cup. The coefficient of plastic strain of the material is almost zero on the outer and inner surfaces of side wall of the part.

3.2. The outer and inner surfaces of side walls near the radius bends

The estimated length of side walls near the radius bends on the outer and inner surfaces is 70 mm. The outer surface of wall is mainly subjected to compression deformation along its length, however, a slight tensile deformation is observed at the junction with the radius bend. The inner surface of side wall is only subjected to compression. The calculated pressure values on the outer and inner surfaces are determined in the ranges from -252 to 10 MPa and from -70 to -8 MPa, respectively. Thus, a decrease in the pressure on the outer and inner surfaces of side walls of the cup is traced to the interface with the radius bends. It is important to note that the pressure on the inner surface of side wall varies as follows: up to the middle of the section length, the pressure decreases, and up to the radius bend increases to -62 MPa. The coefficient of plastic strain of the material is almost zero on the outer and inner surfaces of side wall near the radius bend.

3.3. The outer and inner surfaces of the radius bends

The estimated lengths of the radius bends along the outer and inner surfaces of the cup are 76 and 56 mm, respectively. In this case, the outer surface of the radius bend is only subjected to tensile deformation, and the inner surface of the radius bend is only subjected to compression deformation. The calculated pressure values on the outer and inner surfaces are determined in the ranges from 17 to 322 MPa and from -62 to -235 MPa, respectively. The peak pressure on the outer and inner surfaces is marked in the middle of the radius bends. The coefficient of plastic strain of the material reaches values of 0.00014 and 0.008 on the outer and inner surfaces of the radius bends, respectively. At the same time, the increase in plastic strain of the outer surface of the radius bend occurs sharply, and on the inner surface of the radius bend more smoothly.

3.4. The outer and inner surfaces of the spherical bottom

The estimated lengths of the spherical bottom along the outer and inner surfaces of the cup are 470 and 450 mm, respectively. The outer and inner surfaces of the spherical bottom of the cup are subjected to variable deformation, i.e. both tensile and compression in different parts of the element. The calculated pressure values on the outer and inner surfaces are determined in the ranges from 115 to -300 MPa and from -214 to 48 MPa, respectively. On the outer surface of the spherical bottom, the tensile deformation is replaced by a compression deformation in the direction of the centerline of the cup. The coefficient of plastic strain of the material reaches values of 0.0014 and 0.0033 on the outer and inner surfaces of the spherical bottom, respectively. At the same time, the greatest plastic strain of the outer surface is determined in the middle of the radial section of the bottom, and on the inner surface, plastic strain prevails near the centerline of the cup.

4. Conclusion

Thus, the steel sheet undergoes tensile and compression deformations in various areas during deep drawing. At the same time, the material of the part is more likely to experience compression deformation. The most loaded (deformed) elements of the cup can be distinguished by a spherical bottom and a radius bend along the outer surface. The least loaded (deformed) element of the cup is the inner side wall near the radius bend. Thus, the inner surfaces of the part are subjected to plastic strain to a greater extent. The surface pressure during the formation of the cup cavity is less than that during the formation of the outer contours.

References:

1. Colgan, M., & Monaghan, J. (2003). Deep Drawing Process: Analysis and Experiment. *Journal of Materials Processing Technology, vol. 132*, 35-41.
2. Pathak, J., & Barnwal, V. K. (2016). Analysis of Different States of Stress in Deep Drawing Process. *IJSRSET, Volume 2, Issue 2*, 826-828.
3. Wifi, A., & Mosallam, A. (2007). Some Aspects of Blank-Holder Force Schemes in Deep Drawing Process. *Journal of Achievements in Materials and Manufacturing Engineering, Vol. 24, Issue No. 1*, 315-323.
4. Padmanabhan, R., Oliveira, M. C., Alves, J. L., & Menezes, L. F. (2007). Influence of Process Parameters on the Deep Drawing of Stainless Steel. *Finite Elements in Analysis and Design, vol. 43*, 1062-1067.
5. Chemezov, D. A., Smirnova, L. V., Seliverstov, V. S., & Zezina, N. A. (2016). Comparison of stress-strain state of thin-walled detail after deep drawing of the direct and reverse methods. *ISJ Theoretical & Applied Science, 03 (35)*, 21-25.
6. Panicker, S. S., Singh, H. G., Panda, S. K., & Dashwood, R. (2015). Characterization of tensile properties, limiting strains, and deep drawing behavior of AA5854-H22 sheet at elevated temperature. *Journal of Materials Engineering and Performance, 24, no. 11*, 4268-4282.
7. Wang, Z. R. (1995). A consistent relationship between the stress- and strain-components and its application for analyzing the plane-stress forming process. *Journal of Materials Processing Technology, 55, no. 1*, 1-4.
8. Haji, A. F., Mahmoud, F., & Mohammad, M. (2012). Numerical Predictions and Experimental Validations of Ductile Damage Evolution in Sheet Metal Forming Processes. *Acta Mechanica Solida Sinica Published by AMSS Press, Wuhan, China, vol. 25*, 648-654.
9. Tommerup, S., & Endelt, B. (2012). Experimental Verification of a Deep Drawing Tool System for Adaptive Blank Holder Pressure Distribution. *Journal of Material Processing Technology, Vol. 212*, 2529-2540.
10. Kim, Y. S., Jain, M. K., & Metzger, D. R. (2012). Determination of Pressure Dependent Friction Coefficient From Draw Bend Test and its Application to Cup Drawing. *International Journal of Machine Tools and Manufacture, vol. 56*, 69-78.