Parametric Optimization of Warm Deep Drawing Process of 304 Stainless Steel Cylindrical Cups

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ABSTRACT

This dissertation delves into the comprehensive parametric optimization of the warm deep drawing process of 304 stainless steel. The warm deep drawing process is a crucial metal forming technique that leverages elevated temperatures to enhance the material's formability and reduce defect occurrence. This study systematically investigates the influence of various process parameters, including sheet thickness, temperature, coefficient of friction, and strain rate, on the quality of the final product.

Using the Taguchi method for design of experiments and Finite Element Analysis (FEA) for simulation, the research aims to determine the optimal settings for these parameters. The Taguchi method allows for efficient experimentation and identification of significant factors, while FEA provides a detailed understanding of the material behaviour under different conditions.

The findings reveal the optimal combination of parameters that minimize common defects such as wrinkling, tearing, and thinning. Validation of these results through experimental trials confirms the accuracy and reliability of the simulations. The optimized parameters lead to significant improvements in the formability and structural integrity of the deep-drawn components.

This research holds substantial implications for the manufacturing industry, particularly in applications requiring high precision and reliability. The enhanced understanding of the warm deep drawing process and its optimization contributes to improved manufacturing efficiency, reduced production costs, and higher quality products. The insights gained from this study are expected to benefit sectors such as automotive, aerospace, and electronics, where advanced sheet metal forming processes are critical.

CONCLUSION

These insights can guide the optimization of process parameters in sheet metal forming to achieve desired outcomes in terms of effective stress, strain, surface expansion, and damage.

A. Temperature:

- Effective stress: Increased temperature leads to decreased effective stress of the sheet metal.
- Surface Expansion Ratio: The surface expansion ratio increases with increasing temperature.
- Damage: Damage initially decreases with increasing temperature but then increases again.

B. Thickness:

- Effective Stress: Thickness has a low percentage of contribution, indicating it is not a highly significant factor. However, thinner materials (0.5 mm) experience more effective stress.
- Effective Strain: There is a notable effective strain at 0.5 mm thickness, but not much change is observed for thicknesses of 1 mm and above.
- Surface Expansion Ratio: The surface expansion ratio increases with increasing thickness.
- Damage: Damage is inversely proportional to increasing thickness, meaning thicker materials tend to have less damage.

C. Coefficient of Friction:

- Effective Strain: The effective strain fluctuates with changes in the coefficient of friction.
- Surface Expansion Ratio: Less surface expansion at low coefficients of friction, remaining steady at higher coefficients.

D. Strain Rate:

- Effective Strain: Effective strain increases with increasing strain rate and then decreases towards the end.
- Surface Expansion Ratio: The variation in surface expansion ratio with strain rate mirrors the variation with the coefficient of friction.
- Damage: Damage increases with increasing strain rate.

REFERENCES

1. A. C. Reddy, V. M. Shamraj, Reduction of cracks in the cylinder liners choosing right process variables by Taguchi method, Foundry Magazine, 10 (4), 47-50, 1998.
2. A. C. Reddy, Finite element analysis of reverse superplastic blow forming of Ti-Al-4V alloy for optimized control of thickness variation using ABAQUS, Journal of Manufacturing Engineering, 1(1), 6-9, 2006.
3. A. C. Reddy, Evaluation of local thinning during cup drawing of gas cylinder steel using isotropic criteria, International Journal of Engineering and Materials Sciences, 5(2), 71-76, 2012.
4. A. C. Reddy, T. Kishen Kumar Reddy and M. Vidya Sagar, Experimental characterization of warm deep drawing process for EDD steel, International Journal of Multidisciplinary Research & Advances in Engineering, 4(3), 53-62, 2012.
5. A. C. Reddy, Formability of Warm Deep Drawing Process for AA1050-H18 Rectangular Cups, International Journal of Mechanical and Production Engineering Research and Development, 5(4), 85-97, 2015.
6. A. C. Reddy, Formability of Warm Deep Drawing Process for AA1050-H18 Pyramidal Cups, International Journal of Science and Research, 4(7), 2111-2119, 2015.
7. A. C. Reddy, Formability of superplastic deep drawing process with moving blank holder for AA1050-H18 conical cups, International Journal of Research in Engineering and Technology, 4(8), 124-132, 2015.
8. A. C. Reddy, Homogenization and Parametric Consequence of Warm Deep Drawing Process for 1050A Aluminum Alloy: Validation through FEA, International Journal of Science and Research, 4(4), 2034-2042, 2015.
9. A. C. Reddy, Parametric Optimization of Warm Deep Drawing Process of 2014T6 Aluminum Alloy Using FEA, International Journal of Scientific & Engineering Research, 6(5), 1016-1024, 2015.
10. A. C. Reddy, Finite Element Analysis of Warm Deep Drawing Process for 2017T4 Aluminum Alloy: Parametric Significance Using Taguchi Technique, International Journal of Advanced Research, 3(5), 1247-1255, 2015.
11. A. C. Reddy, Parametric Significance of Warm Drawing Process for 2024T4 Aluminum Alloy through FEA, International Journal of Science and Research, 4(5), 2345-2351, 2015.
12. K. Chandini and A. C. Reddy, Parametric Importance of Warm Deep Drawing Process for 1070A Aluminium Alloy: Validation through FEA, International Journal of Scientific & Engineering Research, 6(4), 399-407, 2015.
13. T. Srinivas and A. C. Reddy, Parametric Optimization of Warm Deep Drawing Process of 1100 Aluminum Alloy: Validation through FEA, International Journal of Scientific & Engineering Research, 6(4), 425-433, 2015.

14. T. Srinivas and A. C. Reddy, Finite Element Analysis of Warm Deep Drawing Process for Rectangular Cup of AA1100 Aluminum Alloy, International Journal of Advanced Research, 3(6), 1383-1391, 2015.
15. A. C. Reddy, Performance of Warm Deep Drawing Process for AA1050 Cylindrical Cups with and Without Blank Holding Force, International Journal of Scientific Research, 4(10), 358-365, 2015.
16. A. C. Reddy, Simulation analysis of four-pass shape roll forming of I-sections, International Journal of Mechanical and Production Engineering Research and Development, 5(1), 35-44, 2015.
17. B. Yamuna and A. C. Reddy, Parametric Merit of Warm Deep Drawing Process for 1080A Aluminium Alloy: Validation through FEA, International Journal of Scientific & Engineering Research, 6(4), 416-424, 2015.
18. B. Yamuna and A. C. Reddy, Finite Element Analysis of Warm Deep Drawing Process for Conical Cup of AA1080 Aluminum Alloy, International Journal of Advanced Research, 3(6), 1309-1317, 2015.
19. K. Chandini and A. C. Reddy, Finite Element Analysis of Warm Deep Drawing Process for Pyramidal Cup of AA1070 Aluminum Alloy, International Journal of Advanced Research, 3(6), 1325-1334, 2015.
20. C. R. Alavala, High temperature and high strain rate superplastic deep drawing process for AA2618 alloy cylindrical cups, International Journal of Scientific Engineering and Applied Science, 2(2), 35-41, 2016.
21. C. R. Alavala, Practicability of High Temperature and High Strain Rate Superplastic Deep Drawing Process for AA3003 Alloy Cylindrical Cups, International Journal of Engineering Inventions, 5(3), 16-23, 2016.
22. C. R. Alavala, High temperature and high strain rate superplastic deep drawing process for AA5049 alloy cylindrical cups, International Journal of Engineering Sciences & Research Technology, 5(2), 261-268, 2016.
23. C. R. Alavala, Suitability of High Temperature and High Strain Rate Superplastic Deep Drawing Process for AA5052 Alloy, International Journal of Engineering and Advanced Research Technology, 2(3), 11-14, 2016.
24. C. R. Alavala, FEM Analysis of Single Point Incremental Forming Process and Validation with Grid-Based Experimental Deformation Analysis, International Journal of Mechanical Engineering, 5(5), 1-6, 2016.
25. C. R. Alavala, Development of High Temperature and High Strain Rate Super Plastic Deep Drawing Process for 5656 Al Alloy Cylindrical Cups, International Journal of Mechanical and Production Engineering, 4(10), 187-193, 2016.
26. C. R. Alavala, Effect of Temperature, Strain Rate and Coefficient of Friction on Deep Drawing Process of 6061 Aluminum Alloy, International Journal of Mechanical Engineering, 5(6), 11-24, 2016.
27. G. Devendar, A. C. Reddy, Study on Deep Drawing Process Parameters - A Review, International Journal of Scientific & Engineering Research, 7(6), 149-155, 2016.
28. G. Devendar, A. C. Reddy, Formability Limit Diagrams of Cold Deep Drawing Process for Nickel 201 Cylindrical Cups, International Journal of Science and Research, 5(8), 1591-1598, 2016.
29. T. Santhosh Kumar, A. C. Reddy, Single Point Incremental Forming and Significance of Its Process Parameters on Formability of Conical Cups Fabricated from Aa1100-H18 Alloy, International Journal of Engineering Inventions, 5(6), 10-18, 2016.
30. V. Srija, A. C. Reddy, Numerical Simulation of Truncated Pyramidal Cups of AA1050-H18 Alloy Fabricated by Single Point Incremental Forming, International Journal of Engineering Sciences & Research Technology, 5(6), 741-749, 2016.
31. A. Raviteja, A. C. Reddy, Finite Element Analysis of Single Point Incremental Deep Drawing Process for Truncated Pyramidal Cups from AA 1070 Alloy, International Journal of Innovative Science, Engineering & Technology, 3(6), 263-268, 2016.
32. T. Santhosh Kumar, A. C. Reddy, Finite Element Analysis of Formability of Pyramidal Cups Fabricated from AA1100-H18 Alloy, International Journal of Science and Research, 5(6), 1172-1177, 2016.
33. A. Raviteja, A. C. Reddy, Implication of Process Parameters of Single Point Incremental Forming for Conical Frustum Cups from AA 1070 Using FEA, International Journal of Research in Engineering and Technology, 5(6), 124-129, 2016.
34. V. Srija, A. C. Reddy, Single Point Incremental Forming of AA1050-H18 Alloy Frustum of Cone Cups, International Journal of Science and Research, 5(6), 1138-1143, 2016.
35. T. Santhosh Kumar, V. Srija, A. Ravi Teja, A. C. Reddy, Influence of Process Parameters of Single Point Incremental Deep Drawing Process for Truncated Pyramidal Cups from 304 Stainless Steel using FEA, International Journal of Scientific & Engineering Research, 7(6), 100-105, 2016.

36. C. R. Alavala, Validation of Single Point Incremental Forming Process for Deep Drawn Pyramidal Cups Using Experimental Grid-Based Deformation, International Journal of Engineering Sciences & Research Technology, 5(8), 481-488, 2016.
37. B. Navya Sri, A. C. Reddy, Formability of Elliptical SS304 Cups in Single Point Incremental Forming Process by Finite Element Method, International Journal of Research in Engineering & Technology, 4(11), 9-16, 2016.
38. K. Sai Santosh Kumar, A. C. Reddy, Die Less Single Point Incremental Forming Process of AA6082 Sheet Metal to Draw Parabolic Cups Using ABAQUS, International Journal of Advanced Technology in Engineering and Science, 4(11), 127-134, 2016.
39. T. Manohar Reddy, A. C. Reddy, Numerical Investigations on The Single Point Incremental Forming of 60-40 Brass to Fabricate Hyperbolic Cups, International Journal of Advance Research in Science and Engineering, 5(11), 161-170, 2016.
40. G. Soujanya, A. C. Reddy, Analysis of Single Point Incremental Forming Process to Fabricate Phosphorous Bronze Hemispherical Cups, International Journal of Innovative Science, Engineering & Technology, 3(11), 139-144, 2016.
41. A. C. Reddy, Evaluation of Single Point Incremental Forming Process for Parabolic AA6082 Cups, International Journal of Scientific & Engineering Research, 8(1), 964-970, 2017.
42. A. C. Reddy, Experimental and Numerical Studies on Formability of Stainless Steel 304 in Incremental Sheet Metal Forming of Elliptical Cups, International Journal of Scientific & Engineering Research, 8(1), 971-976, 2017.
43. Shashank Chagalamarri, G. Devendar, A. C. Reddy, Assessment of Strain and Stress – Based Formability Diagrams of Inconel 600 Hemispherical Cups Drawn by Single Point Incremental Forming Process Using ABAQUS, International Journal of Advanced Technology in Engineering and Science, 5(5), 710-719, 2017.
44. B. Sumanth Kumar, G. Devendar, A. C. Reddy, Formability Analysis of Parabolic Cups Drawn from Ni 201 Using single Point Incremental Forming Process, International Journal of Engineering Sciences & Research Technology, 6(5), 619-628, 2017.
45. A. C. Reddy, Formability Analysis of 6063 Al Alloy for Deep Drawn Cylindrical Cups with Constant and Progressive Blank Holding Force, SSRG International Journal of Mechanical Engineering, 4(5), 26-32, 2017.
46. A. C. Reddy, Effect of Recrystallization Temperature on Formability of Hot Deep Drawn Cylindrical Cups from 6082 Al Alloy, Indian Journal of Engineering, 14(36), 157-166, 2017.
47. A A. C. Reddy, Numerical and Experimental Investigation of Single Point Incremental Forming Process for Phosphorus Bronze Hemispherical Cups, International Journal of Scientific & Engineering Research, 8(1), 957-963, 2017.
48. A. C. Reddy, Evaluation of Formability Limit Diagrams of Arsenic Brass (70/30) Using Finite Element Analysis, International Journal of Mechanical Engineering and Information Technology, 5(6), 1651-1656, 2017.
49. A. C. Reddy, Formability of 5083 Al Alloy Hemi-Spherical Shells Using Hot Deep Drawing Process, International Journal of Mechanics and Solids, 9(3), 257-266, 2017.
50. A. C. Reddy, Pilot Studies on Single Point Incremental Forming Process for Hyperbolic Brass Cups, International Journal of Scientific & Engineering Research, 8(1), 977-982, 2017.
51. Teniya Choppala, A. C. Reddy, Elastoplastic Behavior of AA2124 Alloy used to make Hemispherical Cups, International Journal of Science and Research, 7(6), 1295-1300, 2018.
52. M. Jaswanth Krishna, A. C. Reddy, Evaluation of Process Parameters of Conical Cups in Incremental Deep Drawing Process, International Journal of Science and Research, 7(6), 1345-1350, 2018.
53. S. Nirupam, G. Devendar, A. C. Reddy, Parameter Optimisation for Warm Deep Drawing of Inconel-600 Cylindrical Cup, International Journal of Mechanical and Production Engineering, 8(9), 43-49, 2020.
54. Nithin Sai, G. Devendar, A. C. Reddy, Parametric Optimization of NI201 Deep Drawn Conical Cups, International Journal of Material Sciences and Technology, 10(2), 81-93, 2020.
55. S. Sai Gaurav, G. Devendar, A. C. Reddy, Optimization of Process Parameters by Warm Deep Drawing of Cylindrical Cup of Nickel 201, International Journal of Mechanical Engineering, 10(1), 1-10, 2021.

56. P. Shiv Raj, G. Devendar, A. C. Reddy, Optimization of Process Parameters in Deep Drawing of Monel-400 Conical Cup, International Journal of Mechanical Engineering, 10(1), 11-20, 2021.
57. K. Bargavi, G. Devendar, A. C. Reddy, Optimization of Process Parameters of Deep Drawing Process for Inconel-600 Conical Cups, International Journal of Materials Science 15(1), 97-109, 2020.
58. K. A. Chowdary, G. Devendar, A. C. Reddy, Simulation and Parametric Optimisation of Conical Cups in Warm Deep Drawing of Monel 400 at Elevated Temperatures, International Journal of Materials Science 16(1), 1-15, 2021
59. G. Devendar, A. C. Reddy, Parametric Importance of Warm Deep Drawing Process for Monel 400 Cylindrical Cups: Validation through FEA, Journal of Critical Reviews 7(16), 3796-3809, 2020.
60. A. C. Reddy, Formability of High Temperature and High Strain Rate Superplastic Deep Drawing Process for AA2219 Cylindrical Cups, International Journal of Advanced Research, 3(10), 1016-1024, 2015.