APEM journal
Advances in Production Engineering & Management
Volume 17 | Number 1 | March 2022 | pp 33–44
https://doi.org/10.14743/apem2022.1.419
ISSN 1854-6250
Journal home: apem-journal.org
Original scientific paper

Modelling and simulation of hot direct extrusion process for optimal product characteristics: Single and multi-response optimization approach

Elplacy, F.[a,*], **Samuel, M.**[b], **Mostafa, R.**[b]

[a]Mechatronics Department, Faculty of Engineering, Horus University, New Damietta, Egypt
[b]Production Engineering & Mechanical Design Department, Faculty of Engineering, Mansoura University, Mansoura, Egypt

ABSTRACT

The study of eccentricity minimization in cylindrical products helps to reduce the mechanical vibrations and wear of related mechanical parts such as bearings, columns and gears which positively affects in maintenance costs savings and increasing production quality reliability. The main purpose of this paper is to investigate the effect of the eccentricity between the billet material and the die parts on the quality of the final product in the direct extrusion process. The input parameters to produce a cylindrical product shape are optimized in MINITAB based on Taguchi method and ANOVA. The selected material of the billet is the aluminium alloy AA2024, and the die material is Steel H13. The inputs parameters are the temperature, the die angle, the ram speed, and the presumed eccentricity. The finite element model of the process is simulated in DFORM-3D for providing the extrusion information such as the pressure, the effective stress and strain, the final product eccentricity, and the roundness error. The study is carried out on two cases of the presumed eccentricity in addition to a case of zero eccentricity. The single and multi-response optimizations are executed to obtain the optimum parameters for the minimum product eccentricity and roundness error.

ARTICLE INFO

Keywords:
Metal forming;
Hot direct extrusion;
Eccentricity;
Roundness;
Modelling;
Simulation;
Optimization;
Single response;
Multi-response;
DEFORM-3D;
MINITAB

**Corresponding author:*
Email: fsoliman@horus.edu.eg
(Elplacy, F.)

Article history:
Received 11 January 2022
Revised 25 February 2022
Accepted 28 February 2022

References

[1] Jabbar, J.K. (2010). Calculation of relative extrusion pressure for circular section by local coordinates system by using finite element method F.E.M, *Diyala Journal of Engineering Sciences,* Vol. 3, No. 2, 80-96.
[2] Summers, P.T., Chen, Y., Rippe, C.M., Allen, B., Mouritz, A.P., Case, S.W., Lattimer, B.Y. (2016). Overview of aluminium alloy mechanical properties during and after fires, *Fire Science Reviews,* Vol. 4, Article No. 3, doi: 10.1186/s40038-015-0007-5.
[3] Arif, A.F.M., Sheikh, A.K., Qamar, S.Z., Raza, M.K., Al-Fuhaid, K.M. (2002). Product defects in aluminium extrusion and its impact on product defects in aluminium extrusion and its impact on operational cost, In: *Proceedings of 6th Saudi Engineering Conference,* Dammam, Saudi Arabia.
[4] Yanran, Z., Wang, Z.R., Weimin, C. (1995). Numerical simulations for extrusion and ironing and die-angle optimization, *Journal of Materials Processing Technology,* Vol. 55, No. 1, 48-52, doi: 10.1016/0924-013(95)01811-5.

[5] Jang, D.H., Ok, J.H., Lee, G.M., Hwang, B.B. (2006). The forming characteristics of AA 2024 aluminium alloy in radial extrusion process combined with backward extrusion, *Materials Science Forum,* Vol. 519-521, 955-960, doi: 10.4028/www.scientific.net/MSF.519-521.955.
[6] Jurkovic, Z., Jurkovic, M., Buljan, S. (2006). Optimization of extrusion force prediction model using different techniques, *Journal of Achievements in Materials and Manufacturing Engineering,* Vol. 17, No. 1-2, 353-356.
[7] Zhang, C., Zhao, G., Chen, H., Guan, Y., Li, H. (2012). Optimization of an aluminium profile extrusion process based on Taguchi's method with S/N analysis, *International Journal of Advanced Manufacturing Technology,* Vol. 60, No. 5-8, 589-599, doi: 10.1007/s00170-011-3622-x.
[8] Jajimoggala, S. (2019). Optimization of hot extrusion process parameters using Taguchi based grey relation analysis: An experimental approach, *International Journal of Materials Forming and Machining Processes,* Vol. 6, No. 1, 1-18, doi: 10.4018/IJMFMP.2019010101.
[9] Bressan, J.D., Martins, M.M., Bandini, C. (2019). Validation of Finite volume method by hot extrusion analysis of aluminium alloy, *Materials Today: Proceedings,* Vol. 10, Part 2, 234-241, doi: 10.1016/j.matpr.2018.10.401.
[10] Mai, N.T., Trung, D.D., Quy, T.D., Nghe, P.V. (2019). Determining RAM speed and billet temperature to ensure two indicators of surface roughness and extrusion pressure when extruding aluminium alloy, In: Fujita, H., Nguyen, D., Vu, N., Banh, T., Puta, H. (eds.), *Advances in Engineering Research and Application, ICERA 2018, Lecture Notes in Networks and Systems,* Vol 63, Springer, Cham, 253-260, doi: 10.1007/978-3-030-04792-4_34.
[11] Francy, K.A., Srinivasa Rao, C., Gopalakrishnaiah, P. (2019). Optimization of direct extrusion process parameter on 16MnCr5 and AISI1010 using DEFORM-3D, *Procedia Manufacturing,* Vol. 30, 498-505, doi: 10.1016/j.promfg.2019.02.070.
[12] Fernández, D., Rodríguez-Prieto, A., Camacho, A.M. (2020). Effect of process parameters and definition of favourable conditions in multi-material extrusion of bimetallic AZ31B–Ti6Al4V billets, *Applied Sciences*, Vol. 10, No. 22, Article No. 8048, doi: 10.3390/app10228048.
[13] Medvedev, A., Bevacqua, A., Molotnikov, A., Axe, R., Lapovok, R. (2020). Innovative aluminium extrusion: Increased productivity through simulation, *Procedia Manufacturing,* Vol. 50, 469-474, doi: 10.1016/j.promfg.2020.08.085.
[14] Parghazeh, A., Haghighat, H. (2016). Prediction of central bursting defects in rod extrusion process with upper bound analysis method, *Transactions of Nonferrous Metals Society of China,* Vol. 26, No. 11, 2892-2899, doi: 10.1016/S1003-6326(16)64418-7.
[15] Ngernbamrung, S., Suzuki, Y., Takatsuji, N., Dohda, K. (2018). Investigation of surface cracking of hot-extruded AA7075 billet, *Procedia Manufacturing,* Vol. 15, 217-224, doi: 10.1016/j.promfg.2018.07.212.
[16] Yang, D.Y., Kim, Y.U., Lee, C.M. (1992). Analysis of centre-shifted backward extrusion of eccentric tubes using round punches, *Journal of Materials Processing Technology,* Vol. 33, No. 3, 289-298, doi: 10.1016/0924-0136(92)90214-D.
[17] Ojstersek, R., Javernik, A., Buchmeister, B. (2021). The impact of the collaborative workplace on the production system capacity: Simulation modelling vs. real-world application approach, *Advances in Production Engineering & Management,* Vol. 16, No. 4, 431-442, doi: 10.14743/apem2021.4.411.
[18] Crnjac, M., Aljinovic, A., Gjeldum, N., Mladineo, M. (2019). Two-stage product design selection by using PROMETHEE and Taguchi method: A case study, *Advances in Production Engineering & Management,* Vol. 14, No. 1, 39-50, doi: 10.14743/apem2019.1.310.
[19] Saud, H.M., Abdulrazzaq, M.A. (2020). Study the effect of cold working on the mechanical properties of aluminium alloy 2024 T4, *IOP Conference Series: Materials Science and Engineering,* Vol. 928, Article No. 022125, doi: 10.1088/1757-899X/928/2/022125.
[20] Zhang, M., Li, C., Gao, Q., Fang, J., Wu, T.L., Wang, K.H. (2020). The effect of heat treatment on microstructure and properties of laser-deposited TiC reinforced H13 steel matrix composites, *Optik,* Vol. 206, Article No. 164286, doi: 10.1016/j.ijleo.2020.164286.
[21] Mat Web. Material Property Data – Databases, from *http://www.matweb.com,* accessed May 26, 2021.
[22] Sui, W., Zhang, D. (2012). Four methods for roundness evaluation, *Physics Procedia,* Vol. 24, Part C, 2159-2164, doi: 10.1016/j.phpro.2012.02.317.