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Surface Roughness in the Incremental Forming of Drawing Quality Cold Rolled CR2 Steel Sheet

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Abstract : The aim of this study is to verify the resulting surface roughness of parts formed by the Single-Point Incremental Forming (SPIF) process for an ISO 3574 Drawing Quality Cold Rolled CR2 Steel. The chemical composition of drawing quality Cold Rolled CR2 steel is comprised of 0.12 percent of carbon, 0.5 percent of manganese, 0.035 percent of sulfur, 0.04 percent phosphorous, and the remaining percentage is iron with negligible impurities. The experiments were performed on a 3-axis vertical CNC milling machining center equipped with a tool setup comprising a fixture and forming tools specifically designed and fabricated for the process. The CNC milling machine was used to transfer the tool path code generated in Mastercam 2017 environment into three-dimensional motions by the linear incremental progress of the spindle. The blanks of Drawing Quality Cold Rolled CR2 steel sheets of 1 mm of thickness have been fixed along their periphery by a fixture and hardened high-speed steel (HSS) tools with a hemispherical tip of 8, 10 and 12mm of diameter were employed to fabricate sample parts. To investigate the surface roughness, hyperbolic-cone shape specimens were fabricated based on the chosen experimental design. The effect of process parameters on the surface roughness was studied using three important process parameters, i.e., tool diameter, feed rate, and step depth. In this study, the Taylor-Hobson Surtronic 3+ surface roughness tester profilometer was used to determine the surface roughness of the parts fabricated using the arithmetic mean deviation (R_a). In this instrument, a small tip is dragged across a surface while its deflection is recorded. Finally, the optimum process parameters and the main factor affecting surface roughness were found using the Taguchi design of the experiment and ANOVA. A Taguchi experiment design with three factors and three levels for each factor, the standard orthogonal array L9 (3^3) was selected for the study using the array selection table. The lowest value of surface roughness is significant for surface roughness improvement. For this objective, the ''smaller-the-better'' equation was used for the calculation of the S/N ratio. The finishing roughness parameter Ra has been measured for the different process combinations. The arithmetic means deviation (R_a) was measured via the experimental design for each combination of the control factors by using Taguchi experimental design. Four roughness measurements were taken for a single component and the average roughness was taken to optimize the surface roughness. The lowest value of R_a is very important for surface roughness improvement. For this reason, the ''smaller-the-better'' Equation was used for the calculation of the S/N ratio. Analysis of the effect of each control factor on the surface roughness was performed with a ''S/N response table''. Optimum surface roughness was obtained at a feed rate of 1500 mm/min, with a tool radius of 12 mm, and with a step depth of 0.5 mm. The ANOVA result shows that step depth is an essential factor affecting surface roughness (91.1 %).

Keywords : incremental forming, SPIF, drawing quality steel, surface roughness, roughness behavior
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