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Title of the Thesis: Investigation of Hot Forging Die to Improve its Life

ABSTRACT

One of the established process where in metal is plastically deformed with the help of temperature and pressure is hot forging. In closed die hot forging, the dies are subjected to the high temperature and contact pressure. The die cost ranges from 10% to 15% of whole forging process cost, so die cost plays an important role in the overall process cost. To increase the profit by reducing the forging cost it is necessary to improve the die life and material utilization in closed die hot forging process. The selection of die material is based on its ability to retain the hardness and toughness at elevated temperature. One among them is chromium die steel which can retain its hardness upto 425 ^{0}C. The die life is not only depending on the material used but also on the process parameters like preform size, number of blows, forging force, temperature, coefficient of friction and so on. To the enhance lifecycle of a die the die stress and forging force should be minimized during closed die hot forging process. The die stress and forging force are depended on the preform size and shape, and for the economical forging, it is necessary to optimize the preform volume. For the volume of the preform, it is necessary to consider the volume of the finished part, the scale and the volume of flash. Burning loss and machining allowances are also to be considered to achieve the high quality of the forged part. It is very difficult to accurately calculate the volume requirement for the preform and it is impractical and uneconomical to do the sample try-outs on the shop floor. Now a day's finite element analysis (FEA) is very useful for the simulation of the closed die hot forging process to optimize the preform volume and to reduce the forging force and effective stress of preform. Most forging operations are of a non-steady-state type in terms of metal flow, stresses and temperatures these variables vary continuously during the process. The finite element analysis is useful to optimize the forging load and effective die stress. In the hot forging process, 70% of die failures are only due to abrasive wear. The chromium based die material DIN 1.2714 is available in hardened and tempered metallurgical conditions. The hardness of DIN 1.2714 is in the range of 39 HRC to 42 HRC.

The failure mechanism of hot forging die is mainly abrasive wear assisted by thermal cyclic load. By increasing the surface hardness and hence the wear resistance once can improve the die life. The main objective of this research is to optimize the preform volume and improve the die life by increasing the surface hardness. In this study finite element analysis (DEFORM 3D) is utilised to reduce the forging force, effective stress and improve the yield of material for the economical forging. Four preform have been designed in CreO 4.0 and analysed for the completely filled cavity of die at the end of the simulation process using DEFROM 3D. The plasma nitriding process has been selected for improving the surface hardness of DIN 1.2714 die steel from 42 HRC to 65 HRC. Around 9% of material yield improvement is observed by using the FEA analysis and the life of plasma nitrided DIN 1.2714 die steel material is increased by two fold than that without plasma nitriding, which resulted in an overall profit increase of 15%.

This PhD Thesis would be useful to the forging industries for improving the die life, material yield and profit margin during closed die hot forging process.

List of Publications:

1) Vishal A. Pandya and P M George, "Preform optimization for the anchor shackle during closed die forging process on one ton hammer", Materials Today : Proceedings (Elsevier)
DOI: https://doi.org/10.1016/j.matpr.2021.06.45
2) Vishal A. Pandya and P M George, "Analysis of die stress and forging force for DIN 1.2714 die material during closed die forging of anchor shackle", Materials Today: Proceedings (Elsevier) volume 45P6 (2021) 4695 – 4701, DOI: https://doi.org/10.1016/j.matpr.2021.01.121
3) Vishal A. Pandya and P M George, "Effect of preform design on forging load and effective stress during closed die hot forging process of pin", Materials Today: Proceedings (Elsevier) volume 44 (2021) 106 – 112, DOI: https://doi.org/10.1016/j.matpr.2020.08.028