Chapter 13

Multi-Objective Genetic Algorithms for Optimizing Cold Roll Forming of Advanced High Strength Steels

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ABSTRACT

The roll forming of Advanced High Strength Steels (AHSS) is characterized by several challenges, mainly because of their specific mechanical properties: springback, tool wear, material fracture, and lubrication inefficiencies. This chapter presents an optimized manufacturing process using MOGAs, balancing opposing objectives like low springback and tool life by utilizing MOGAs. The study examines the impact of advanced tooling materials, coatings, finite element analysis process simulations, and lubrication techniques on joint effect. Case studies demonstrate successful application of solutions, resulting in higher quality products, reduced costs, and improved operational efficiency. The proposed approach will enhance the durability and strength-to-weight ratio of AHSS, thereby overcoming the limitations of the cold roll forming technique, thereby enabling its wider industrial applications in automotive and construction sectors.

INTRODUCTION

Cold roll forming is one of the very critical areas of development within modern manufacturing that could be utilized with unique advantages in making complex, high-strength components necessary to both automotive and construction industries. Despite being linked with myriad technical complications resultant to the intrinsic nature of those steels like higher tensile strength as well as lesser formability

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compared with the conventional one, a good number of the book addresses the optimizing of AHSS by cold roll forming while utilizing multi-objective genetic algorithms, MOGAs that effectively approach the posed challenges and allow for superior performance and a more efficiency on production lines(-Dadgar Asl et al., 2020).

The demand for AHSS is on the increase due to the critical need for strength-to-weight ratios that help to better serve the stringent safety requirements and improve fuel efficiency. Use in the automotive field: AHSS are critical in providing automotive companies with the capacity to design lightweight structures that can absorb substantial impact forces without compromising overall vehicle performance. However, the introduction of AHSS into cold roll forming has exposed some stubborn challenges. These include the elastic recovery of the material after deformation, which is known as springback, and introduces deviations from the intended shape(Qazani et al., 2023). Springback complicates achieving a precise geometry, thus raising the need for corrective measures and potentially the cost of production. Another critical problem is the tool wear, which progresses at a much faster rate due to the higher hardness of AHSS, requiring higher tool replacement or reconditioning rates that ultimately affect the overall productivity and profitability(Bu et al., 2019).

Material fracture is another problem that occurs during the cold roll forming of AHSS. The strength properties are excellent for the end application, but it reduces elongation capacity, which makes it vulnerable to cracking in the process of forming. This is a strong challenge both to control in the forming process and to the development of sophisticated simulation tools for the prediction of failure points. Proper lubrication is also essential in controlling high friction forces that occur in cold roll forming of AHSS. Poor lubrication, besides resulting in higher tool wear, affects the quality of the finished product with respect to surface defects or dimensional inaccuracies(Babajamali et al., 2022).

To address such complex issues, manufacturers are resorting to various optimization techniques. MOGAs are among these promising techniques that this chapter explores. Traditional single-objective optimization methods have been incapable of addressing more than one or two often conflicting objectives in a single problem. As the name suggests, MOGAs can tackle multiple, mostly conflicting objectives simultaneously. Therefore, MOGAs tend to provide balanced solutions for such problems where performance can be optimized along various parameters. For example, MOGAs can minimize springback while maximizing tool life to get the balance between production efficiency and quality of the product. In this regard, genetic algorithms are flexible in making successive improvements and identifying solutions that conventional optimization methods may not find immediately(Yan & Lü, 2021).

In addition to MOGAs, this chapter continues with complementary strategies to complement the performance of cold roll forming processes. Advanced tooling materials and coatings contribute significantly to the prolongation of tool life and prevention of wear. Coatings such as titanium nitride (TiN) or diamond-like carbon (DLC) have been demonstrated to reduce friction and wear significantly, thereby allowing for longer tool life and better forming quality. Process simulation and FEA are very useful for predicting outcomes and fine-tuning process parameters before full-scale production. These simulations allow engineers to model the distribution of stress, strain localization, and springback so as to make more rational decisions and fewer ones of trial and error in actual production(Jin et al., 2020).

The other vital ingredient within this chapter includes enhanced lubrication techniques. Lubricants that are especially developed to withstand higher pressures and temperatures in AHSS forming may reduce friction and tool wear. Advances in lubrication application methodologies, including focused or machine-based dispensing systems, improve uniform lubricant delivery while ensuring that overall process consistency is achieved. This positively impacts product quality and ensures environmentally