Procedia Manufacturing
Volume 1, 2015, Pages 404–415
43rd Proceedings of the North American Manufacturing Research Institution of SME http://www.sme.org/namrc

A Framework for Optimizing the Design of Injection Molds with Conformal Cooling for Additive Manufacturing

Tong Wu[1], Suchana A. Jahan[1], Praveen Kumaar[1], Andres Tovar[1], Hazim El-Mounayri[1]*, Yi Zhang[1], Jing Zhang[1], Doug Acheson[1], Kim Brand[2] and Razi Nalim[1]

[1] *Indiana University-Purdue University Indianapolis, IN*
[2] *3DPARTS Manufacturing,LLC*
* *Corresponding author: helmouna@iupui.edu*

Abstract

This work presents a framework for optimizing additive manufacturing of plastic injection molds. The proposed system consists of three modules, namely process and material modeling, multi-scale topology optimization, and experimental testing, calibration and validation. Advanced numerical simulation is implemented for a typical die with conformal cooling channels to predict cycle time, part quality and tooling life. A multi-scale thermo-mechanical topology optimization algorithm is being developed to minimize the die weight and enhance its thermal performance. The technique is implemented for simple shapes for validation before it is applied to dies with conformal cooling in future work. Finally, material modeling using simulation as well as design of experiments is underway for obtaining the material properties and their variations.

Keywords: Injection Molding, Topology Optimization, Additive Manufacturing

1 Introduction

Plastic injection molding is a versatile process that uses heat and pressure to convert thermoplastic and thermosetting materials into a variety of complex shapes with high-quality surface finish and dimensional precision (Kauffer, 2011). The design of tooling for plastic injection is considered critically important for the quality of the product and the economy of the entire injection molding process.

Presently, the design features of injection tooling are limited by the manufacturing methods used to fabricate them, particularly in terms of geometry freedom and the ability to include innovative features. Current design and manufacturing practices often lead to sub-optimal solutions for an industry in need of increasingly shorter lead times and lower costs as well as higher injection performance and

Peer-review under responsibility of the NAMRI Scientific Committee
doi:10.1016/j.promfg.2015.09.049

product quality. Additive manufacturing holds the promise of cleaner and environmentally friendlier operation, and allows complex injection tooling production. However, local mold manufacturers have reported directly to our group that due to high initial investment, specialized maintenance, and substantial material cost, metal Additive Manufacturing (AM) is about 50% more expensive than traditional machining. The current high cost of metal AM constitutes the main obstacle to its implementation in the injection tooling industry. Fortunately, novel simulation-based design optimization methods (e.g., multi-scale thermo-mechanical topology optimization) allow the generation of lightweight, high-performance, and cost-effective injection tooling through additive manufacturing.

In this research, we propose a framework for optimizing the design of dies with conformal cooling for additive manufacturing (Fig. 1). We have started the research on three components in this framework, namely, numerical thermal finite element (FE) modeling, thermal-mechanical topology optimization at macroscale level, and material characterization. Particularly, a literature review for additive manufacturing principles is carried out at first. Secondly a CAD model is established based on these principles and then a transient thermal Finite Element Analysis (FEA) is performed. The resulting iis used as input to the thermal-mechanical topology optimization. This step aims to find the optimum materials distribution between the cavity and the coolants. Finally, a material characterization procedure is proposed to validate the structure of the optimum layout.

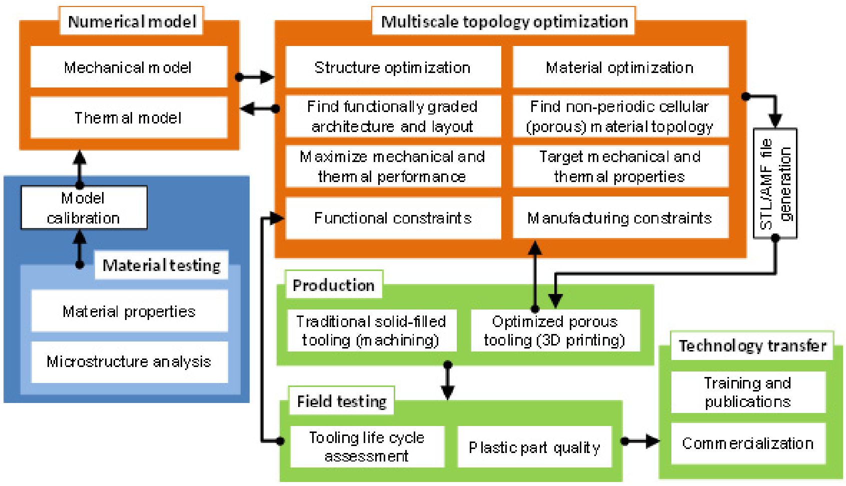

Fig. 1: Framework for optimizing the design of dies with conformal cooling for additive manufacturing

2 Background

Additive Manufacturing. Additive Manufacturing (AM) has already revolutionized the manufacturing technology in producing real functional parts including metals, ceramics and polymers(Mognol et al., 2012). The AM technologies have proven their potential to create injection molds with conformal cooling channels(Petrovic et al., 2011). The quality of the AM part has its own specific characteristics no matter what type of AM technology has been used. Tools with conformal cooling channels manufactured by this process have improved part quality and production rate as compared with conventional production tools.

Even though it provides a lot of benefits and potentials in producing complex structures, the complete establishment of AM process at industrial level is not accomplished yet (Hague et al., 2003). Also the classic design approach for traditionally machined dies restricts AM application. A systemat-