Low-Cost Prototyping of the Fresnel Lens Solar Concentrator

H. Qandil[1], W. Zhao[1]

1. Department of Mechanical and Energy Engineering, University of North Texas, Denton, TX, USA

INTRODUCTION: Most Fresnel-lens-based solar concentrators are manufactured through a time-consuming and expensive process known as injection molding - a process where a heated material is injected into a desired mold.

Due to the recent growth of solar research, the injection molding process has become inconvenient and creates a need for rapid and cheap prototyping of optical elements.

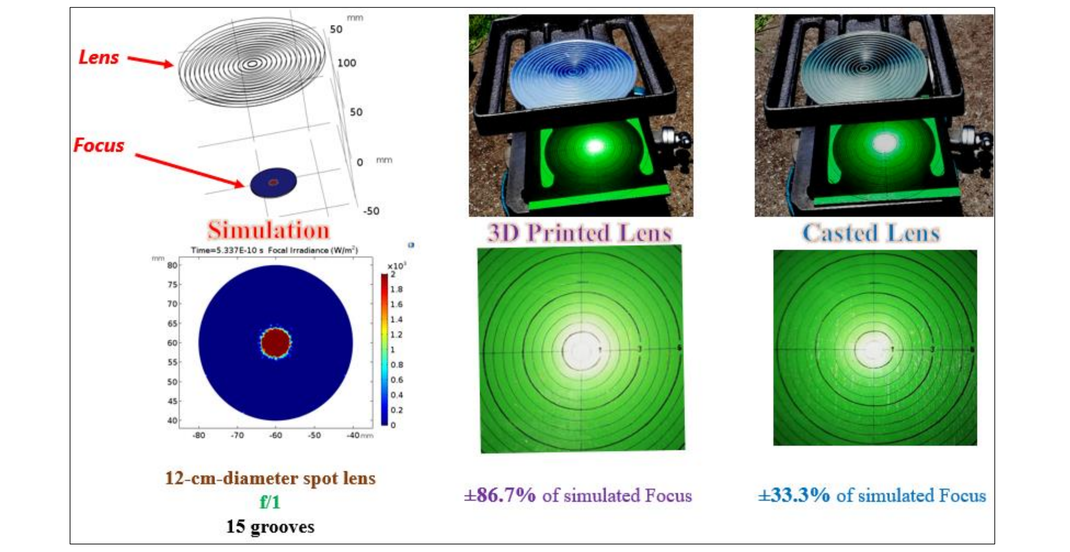
In this work, linear and spot Fresnel lenses, designed by an earlier study of the authors, are prototyped in four methods and then tested and compared to ray-tracing simulation results. The purpose is to proof the design concept of the Fresnel lenses and evaluate the best prototyping method for future work.

COMPUTATIONAL METHODS: The Fresnel lenses were designed by the algorithmic method of Qandil and Zhao [1, 2], then prototyped in 3D by AutoCAD and imported into COMSOL.

EXPERIMENTAL METHODS: To verify the lens prototyping process, four methods of manufacturing, in Fig.1, were selected; two mold-free prototypes made by 3D printing and acrylic CNC machining, and two mold-based prototypes made by acrylic casting and hot embossing. The purpose of this experiment was to prove the design concept of the Fresnel lenses and evaluate the best prototyping method for future work.

Figure 1. Lens Prototyping Methods Used

RESULTS: All four lenses were tested under direct sunlight, where each resulting focal irradiance was compared to that achieved by COMSOL's Monte-Carlo Ray Tracing (MCRT) simulations, seen in Fig.2.



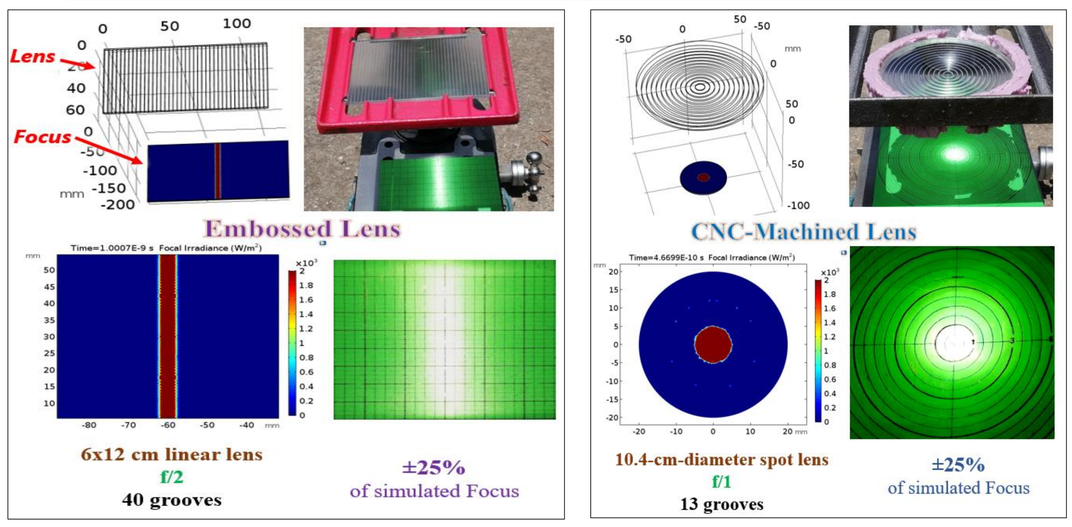


Figure 2. Focal Irradiance Comparison to Simulation Results Using the Ray-Tracing Module of COMSOL

CONCLUSIONS: From Fig.3, the methods of CNC machining and hot embossing were found superior in terms of light-focusing accuracy and required time of fabrication. Casting and 3D printing methods were only preferable for simplicity and overall cost, but the hot embossing was still very cost-competitive for multiple design replications.

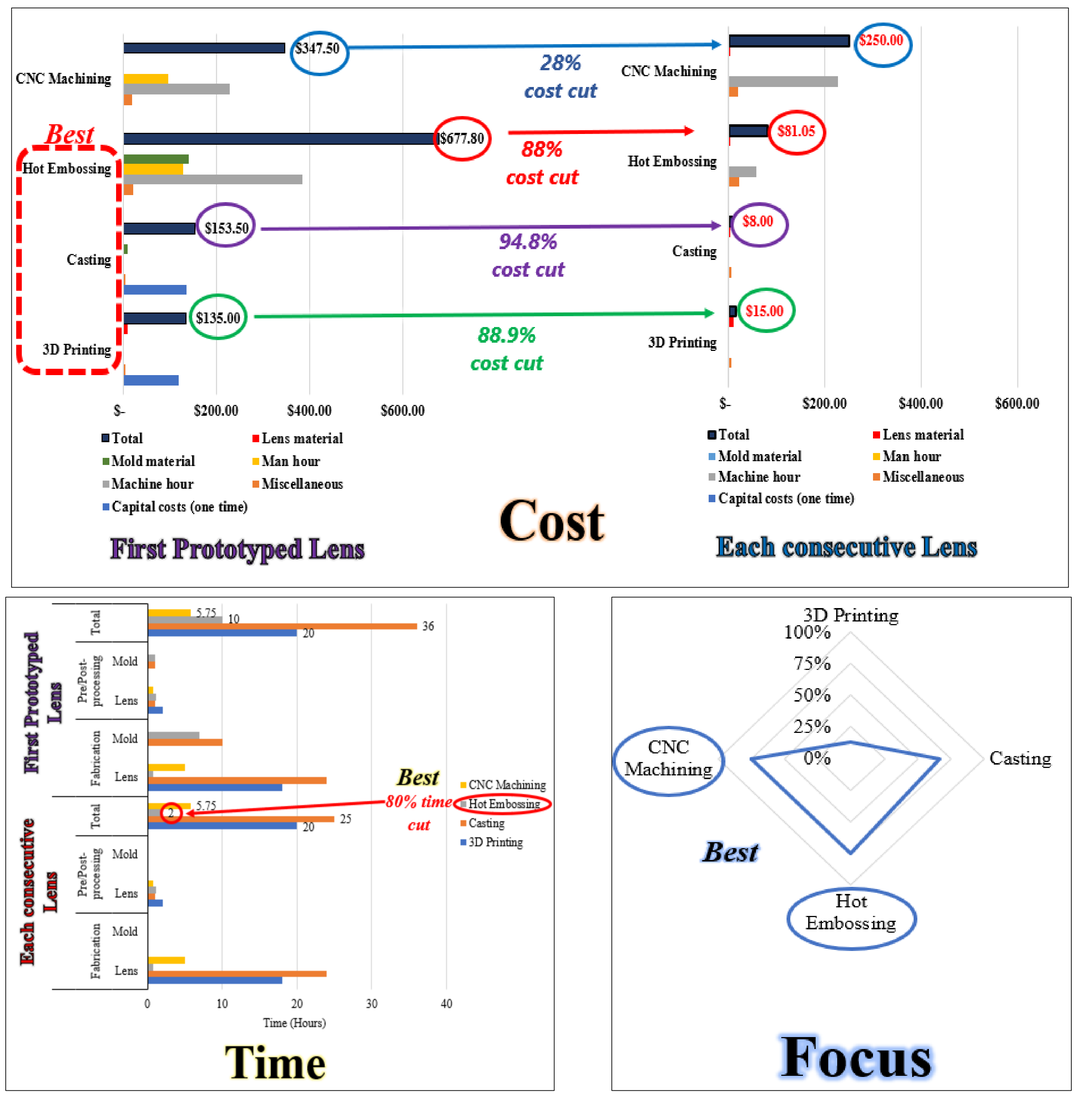


Figure 3. Comparative analysis for fabrication methods

REFERENCES:

1. H. Qandil., W. Zhao, *Design and Evaluation of the Fresnel-Lens Based Solar Concentrator System through a Statistical-Algorithmic Approach*, Proceedings of IMECE 2018, 52125, (2018)
2. H. Qandil., W. Zhao, *Algorithmically-Optimized Hemispherical Dome as a Secondary Optical Element for the Fresnel-Lens Solar Concentrator*, Applied Sciences, 9(13), 2757, (2019)