DiMAT

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Challenges in the simulation process for glass-bending technologies

Universitat Politècnica de València
University Institute of Materials Technology IUTM
Fraunhofer IWM
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Challenges in Glass Bending Process Development

The evolution of glass bending technology presents us with two major challenges: simulation and experimental work. These challenges, while distinct, are deeply interconnected and must be tackled together to achieve precise and efficient manufacturing processes. On the simulation side, researchers struggle with accurately modeling complex phenomena like laser-material interactions and heat distribution. Meanwhile, in the experimental realm, we face challenges in temperature measurement, control, and data management. This article explores these challenges in detail, focusing on how the DiMAT project aims to bridge the gap between theoretical modeling and practical implementation.
Looking at the research from different authors over the last 30 years, we can see how the glass-bending process has evolved significantly. New techniques have emerged that not only reduce manufacturing costs but also open possibilities for creating a whole new range of complex shapes [1], [2], [3]. Researchers are constantly pushing boundaries to develop new procedures for glass forming that can meet current market demands.

While manufacturing techniques have improved, we've found that the programming of process workflow and component simulation are crucial for achieving efficient solutions in today's market. These elements help prevent imperfections and enable customized products. However, the simulation of the glass-bending process still faces several technical hurdles, particularly in defining boundary conditions and contact modeling. Take, for instance, the challenge of simulating laser beam bending. The current approach treats laser power as a unified and concentrated temperature in the incident area during simulation, but reality tells a different story. In-situs experiments reveal insufficient energy transmission to the lower area of the glass workpiece due to the laser beam's absorption decay.

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At the DiMAT project, we're tackling this issue head-on by experimenting with finite element simulation that maps the heat flow along the transverse path of the bending area, considering a moving heat source. Our next step in developing the Material Processing Simulator toolkit (DiMAT MPS) is to investigate how materials of different thicknesses absorb the laser beam.

The glass forming process is incredibly sensitive to temperature conditions – not just how hot or cold the glass gets, but also how quickly these temperature changes occur. Understanding how temperature varies across space and time is essential for achieving precise and stable formed objects. This understanding comes with its own set of challenges in the experimental setup.

Our first major challenge involves getting reliable, localized, and continuous temperature measurements from glass workpieces in furnaces running at temperatures up to 650°C. We initially tried thermocouples – they're economical and reliable, and widely used in industry. However, we discovered that their need for physical contact can damage the glass at high temperatures. Plus, given how unevenly temperature distributes in large furnaces, we'd need hundreds of thermocouples to get a complete picture. Instead, we now use thermocouples mainly for monitoring furnace temperature and have turned to thermal cameras for workpiece measurement. These cameras read the infrared emissions from the material surface and, when combined with temperature-dependent emissivity data, give us detailed temperature mapping down to millimeter-scale resolution. We validate and calibrate the thermal camera readings against thermocouple measurements, giving us comprehensive temperature data for both the glass workpiece and furnace conditions.

Another significant challenge we're tackling is streamlining data generation and acquisition from glass laser bending experiments into a unified pipeline. It gets complicated quickly – different devices often need separate computers and have their own control systems and communication protocols. Add to that the need to integrate material properties and process simulation results, and you can see why organizing and accessing relevant data for specific experiments can become chaotic.
We're addressing this challenge through the DiMAT project's customized digital toolkits for the pilot glass manufacturing process.

Press contacts: Ellie Shtereva, ellie@f6s.com | Sara Canedo, sarafc@f6s.com

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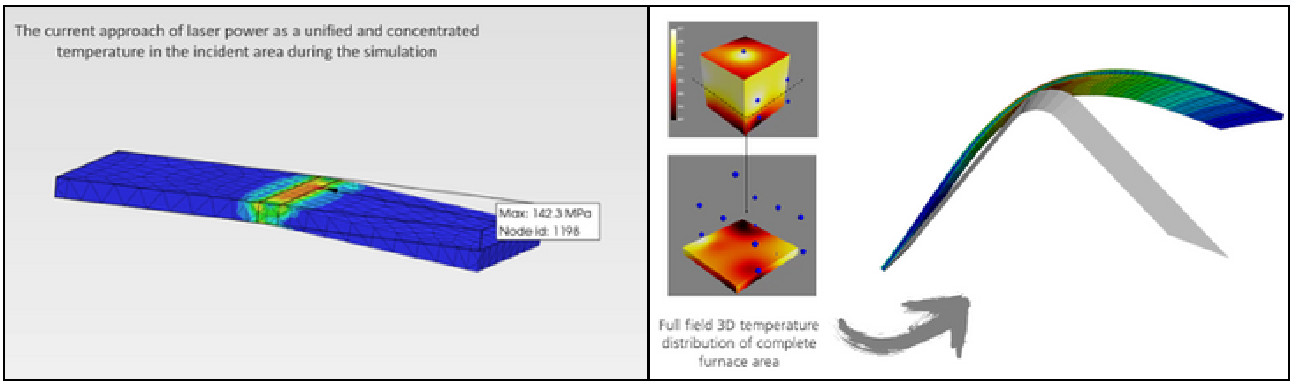

The advancement of glass-bending processes presents us with fascinating challenges in both simulation and experimental work. While our simulation team works on accurately representing laser-material interactions and heat flow patterns, our experimental specialists are developing better ways to measure temperature and integrate data.

The DiMAT project's approach, combining specialized simulation tools with digital toolkits, is helping us bridge the gap between theoretical modeling and practical implementation. This integrated approach is already showing promise in enhancing process control, reducing manufacturing imperfections, and enabling the production of customized glass products that meet current market demands. As we look ahead, continued developments in both simulation accuracy and experimental methodology will be key to pushing glass-bending technology forward.

LINKS:

[1] M. Eekhout, "DESIGN, ENGINEERING, PRODUCTION & REALISATION OF GLASS STRUCTURES FOR 'FREE-FORM' ARCHITECTURE."

[2] K. C. Datsiou and M. Overend, "The mechanical response of cold bent monolithic glass plates during the bending process," Eng Struct, vol. 117, pp. 575–590, Jun. 2016, doi: 10.1016/j.engstruct.2016.03.019.

[3] W. X. Liao, W. T. Lee, C. K. Lin, P. C. Tung, and J. R. Ho, "Innovative laser-assisted glass bending approaches using a near-infrared continuous wave laser," Opt Lasers Eng, vol. 178, Jul. 2024, doi: 10.1016/j.optlaseng.2024.108162.

CONTACTS:

Kuo-I Chang, kuo-i.chang@iwm.fraunhofer.de
Harrison de la Rosa-Ramírez, hardela@epsa.upv.es

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