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In-Mold Assembly: A New Approach to Assembly Automation

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Sponsors: NSF and ARO MURI

Advanced Manufacturing Laboratory (AML)

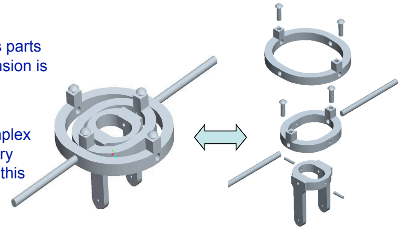
In-Mold Assembly Concept

Goals

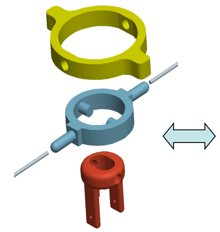
- Develop mold design templates to develop mesoscale joints
- Develop model to estimate deformation of premolded components and alternate ways to control it
- Develop an understanding of in-mold assembly clearances
- Develop design templates to embed electronics and actuators in mold
- Develop models to understand heat dissipation of actuators embedded in polymers

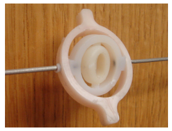
This design contains parts whose largest dimension is less than 2 mm

Small parts and complex geometry make it very difficult to assemble this MAV swashplate



Traditional design created by machining and manual assembly
Consists of 11 parts and 10 assembly operations

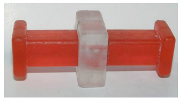




Part comes out of the mold fully assembled

New design enabled by in-mold assembly
Consists of 5 pieces and no assembly operation

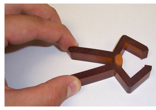
Capabilities



Prismatic joint

Universal Joint

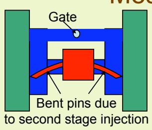
Spherical joint

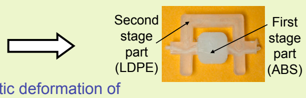


Compliant Clip

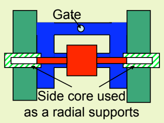
Process Characterization and Modeling

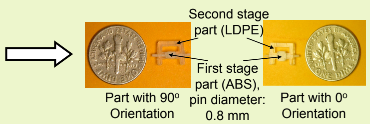
Unidirectional Filling for In-Mold Assembly of Mesoscale Revolute Joints



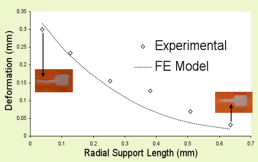


Plastic deformation of premolded components





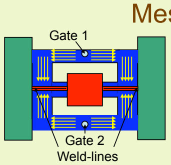
Second stage Injection with supported premolded components



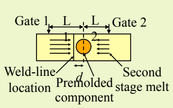
Computational model for plastic deformation

- We were the first research group to successfully realize mesoscale revolute joint using in-mold assembly
- 25% radial support found to be optimum for mold geometry and ABS/LDPE combination

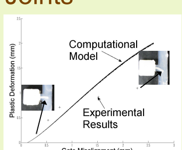
Bi-directional Filling for In-Mold Assembly of Mesoscale Revolute Joints



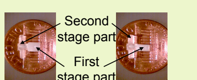
Bi-directional filling



Temporal misalignment of gates



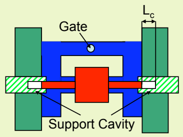
Computational model for plastic deformation

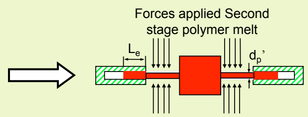


0º Orientation
90º Orientation

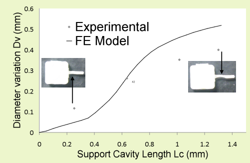
- Alternative filling strategy to inhibit plastic deformation of premolded component
- Premolded component deformation dependent on temporal misalignment of gates

Joint Clearances during In-Mold Assembly of Mesoscale Revolute Joints





Change in premolded component dimensions due to second stage melt flow

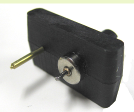


Computational model for change in diameter

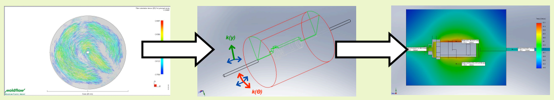
- Premolded component undergoes axial plastic deformation due to compressive force applied by second stage polymer melt forming assembly clearances
- Change in diameter (D_v) of the premolded component found to be related to support cavity length (L_c)

Embedding Actuators

- We use thermally conductive polymer composites to create multi functional structures with embedded actuators
  - Anchoring of the embedded actuator
  - Dissipation of heat produced by the actuator
- Coupled modeling approach:
  - Polymer melt flow inside the mold to obtain fiber orientations
  - Orthotropic thermal conductivity models from molding process to assess heat dissipation



In-mold assembled gearbox

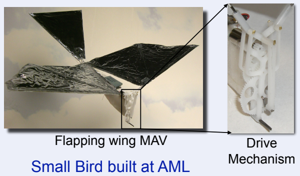


Coupled computational modeling approach

- Research results:
  - 40% reduction in the operating temperature of the embedded actuator
  - Polymers with k > 2 W/m-K do not require orthotropic thermal conductivity modeling

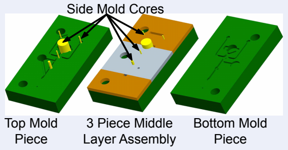
Applications

Flapping Wing MAV

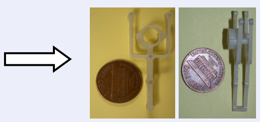


Small Bird built at AML

- AML has built several versions of flapping wing MAVs using advances in injection molding. Molded drive mechanism converts rotary motor motion to flapping action for wings
- In-mold assembly methods used to
  - Automate assembly process
  - Eliminate fasteners
  - Decrease weight



Mold assembly for drive mechanism

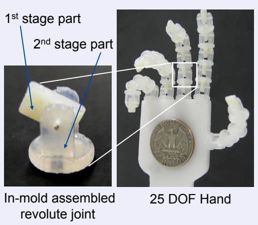


Molded drive mechanism frame for Small Bird

	Small Bird	Big Bird	Big Bird with vision	Big Bird with folding wings
Overall Weight	12.8 g	35.0 g	42.2 g	36.9 g
Wing Span	34.3 cm	57.2 cm	57.2 cm	57.2 cm
Flapping frequency	12.1 Hz	4.5 Hz	4.5 Hz	4.5 Hz
Payload Capacity	2.5 g	12.0 g	4.8 g	10.0 g

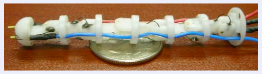
Attributes of different MAVs built at AML

Miniature Robot



Mesoscale in-mold assembly methods utilized to manufacture 25 DOF hand

- Shape memory alloy (SMA) actuated robot developed by AML in collaboration with Robotics Automation Manipulation and Sensing (RAMS) Lab
- In-mold assembly methods used to
  - Downscale overall robot size
  - Significantly reduce part count
  - Eliminate fasteners



SMA actuated robot suitable for Neurosurgery