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An energy-saving design method for additively manufactured integrated valve-controlled cylinders

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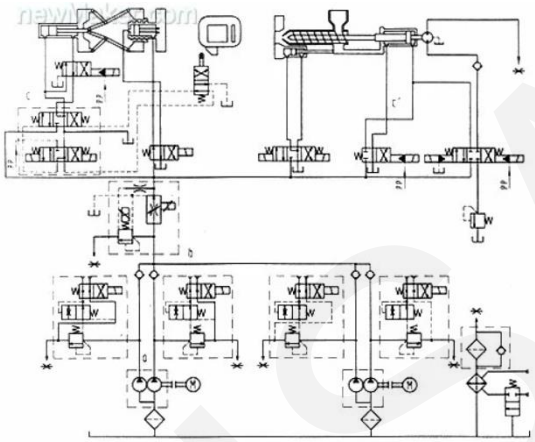
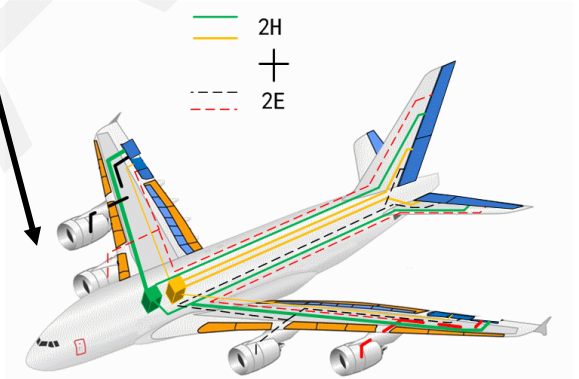
Widespread Applications of Hydraulic Systems



Hydraulic transmission and control systems

Mobile machinery



Aerospace engineering

Robotics

Construction equipment

Stress distribution in a shared wall

- Stress concentration tends to occur on the thin-walled side

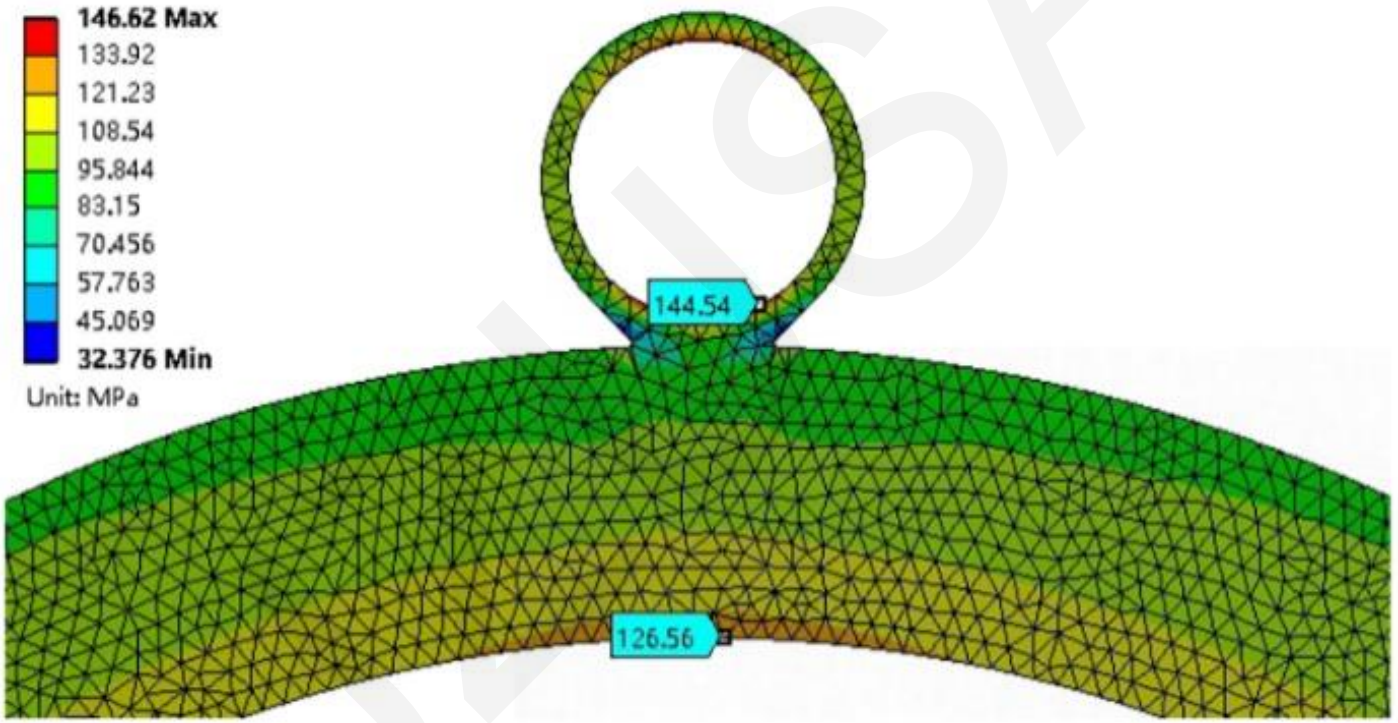


Fig. 1. Stress distribution in a shared wall.

Mathematical model of pressure loss

■ Relationship between pressure loss and bending angle, bending radius, and flow rate

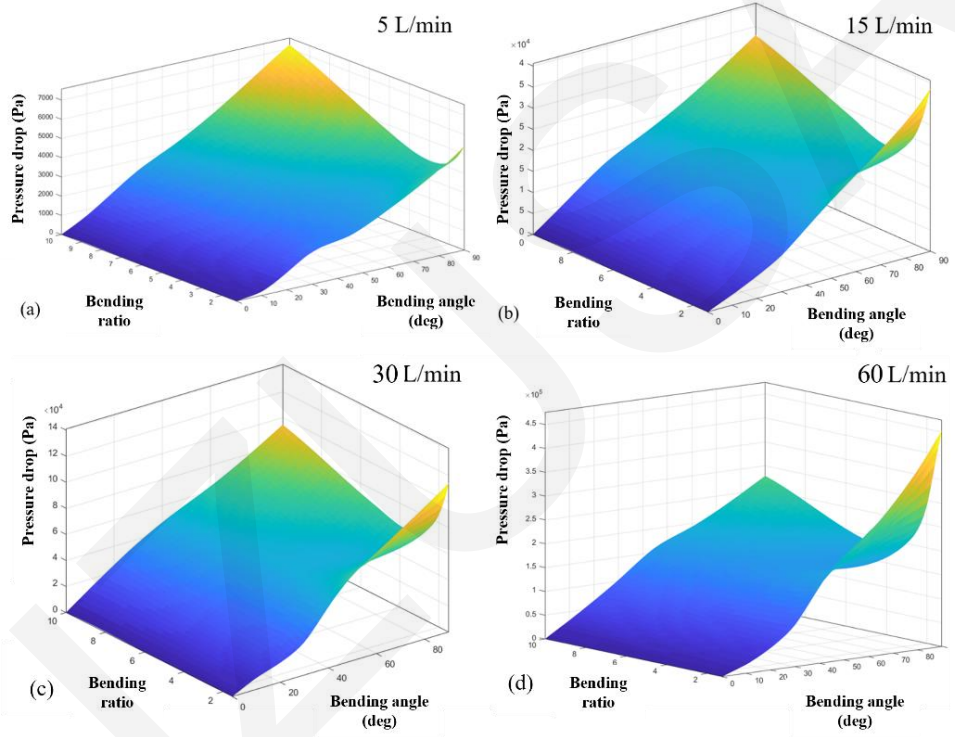


Fig. 2. Plots of bending angle, bending ratio, and pressure loss in the inflection channel for operating flow rates of (a) 5 L/min; (b) 15 L/min; (c) 30 L/min; and (d) 60 L/min, respectively.

Flow Channel Path Planning

- **Flow path optimization using SA and PSO algorithms**

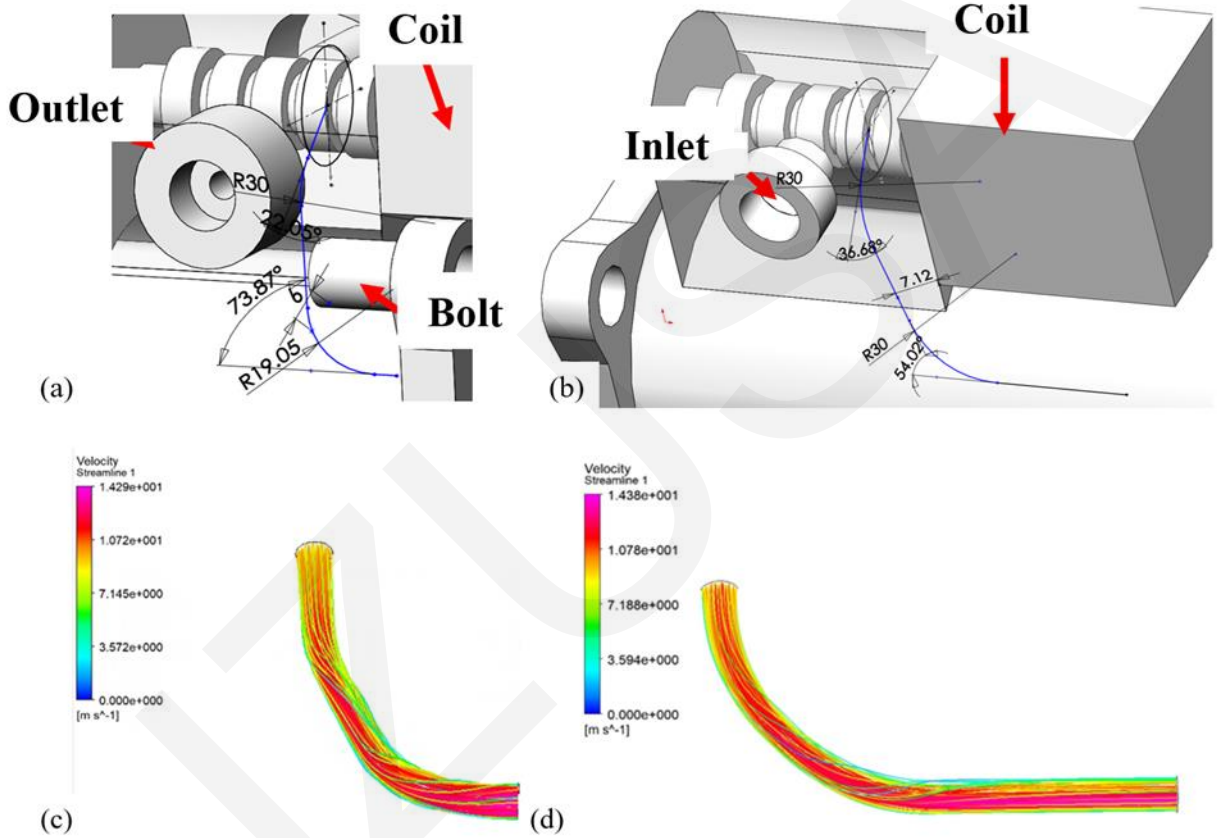


Fig. 3. (a) and (b) Automated design of manifold connections for the integrated valve-controlled cylinder; (c) and (d) Simulation results for the manifold.

Comparison between prototype and integrated valve-controlled cylinders

- The integrated valve-controlled cylinder exhibits significant improvements in mass, volume, and pressure loss

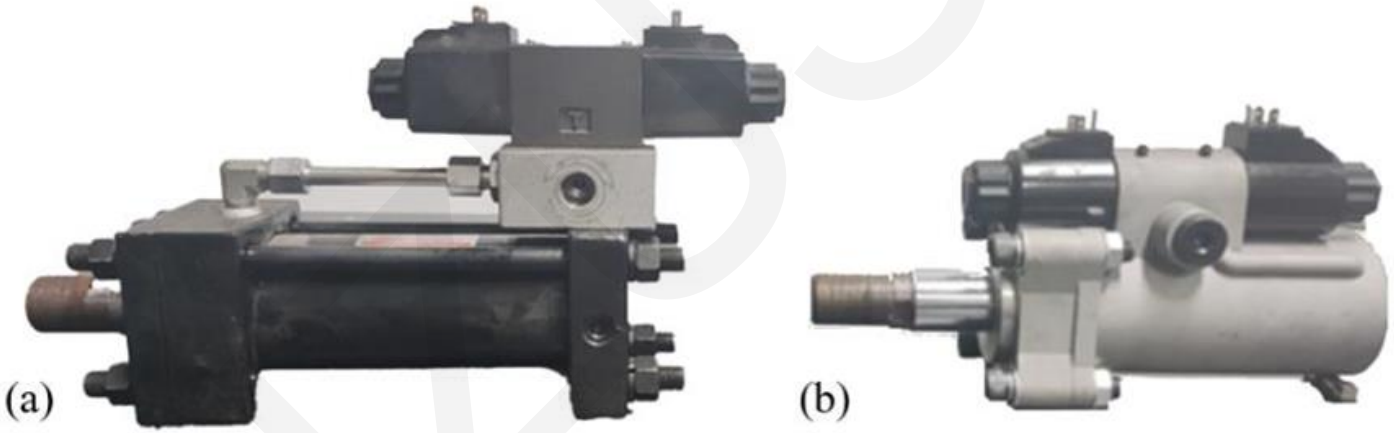


Fig. 4. (a) Prototype of the traditional valve-controlled cylinder; (b) Integrated valve-controlled cylinder.

Conclusions

- We demonstrated that an additive manufacturing approach successfully replicated the traditional prototype's hydraulic principles and allowed for the redesign of valve-controlled cylinder components, eliminating the need for hydraulic valve quick-connects and joints. Moreover, a design guideline for shared wall integration was proposed to minimize the need for print supports and prevent stress concentrations by reducing the distance be-tween the channel and the cylinder. A pressure loss database was also created for channel bends at various operating flow rates, bending angles, and bending ratios. Based on this database, an automated design process for pressure loss-optimized flow channels in valve-controlled cylinders was developed.
- Compared to the traditional prototype, the integrated valve-controlled cylinder's weight was reduced by 31%, its volume was 55% lower, and its pressure loss was decreased by over 30%, all while improving flow performance. Based on the results of this study, our proposed design method bolsters the additive manufacturing of valve-controlled cylinders, and may also help with hydraulic valve manifolds and other components with similar structural and con-nective characteristics.