Supplementary Materials for

Flow-structure interaction of the starting jet through the flexible circular nozzle

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List of figures

Measurement of the structural stiffness of the nozzle

The structural stiffness (Eh) is defined as the multiplication between the Young's modulus (E) and the averaged wall thickness (h) of flexible nozzle. To measure the Young's modulus, we designed the tensile test machine (figure S1*a*), which can extend the specimen of the rubber with the smallest unit of 1 μm using the micrometer and also measures the tension through the scale (with the smallest unit of 10 mg). The dumbbell-shaped specimen is made of silicon rubber (SortaClear 40A, SmoothOn) with a thickness of 10 mm while varying the mass fraction of the silicon thinner (which decreases the Young's modulus and reduces the wall thickness, thereby lowering the structural stiffness). The width and length of a narrower part of specimen are 80 and 10 mm, respectively, on which the speckle pattern is printed using oil-based ink for applying two-dimensional digital image correlation technique (2D DIC). During the extension, the high-resolution camera captures the shadow of the speckle pattern, which deforms with the specimen surface. Using the in-house code, we quantified the longitudinal (ε_x) and transverse strain (ε_y) with respect to the applied tension (figure S1*b*) and obtain the strain-tension curve depending on the mass fraction of the silicon thinner (figure S1*b*). To calculate the Young's

modulus, the initial slope of the strain-tension curve at $\varepsilon_y = 0$ is obtained by polynomial fitting, and the tension is converted to the tensile stress by dividing it from the cross-section of the specimen in its original state.

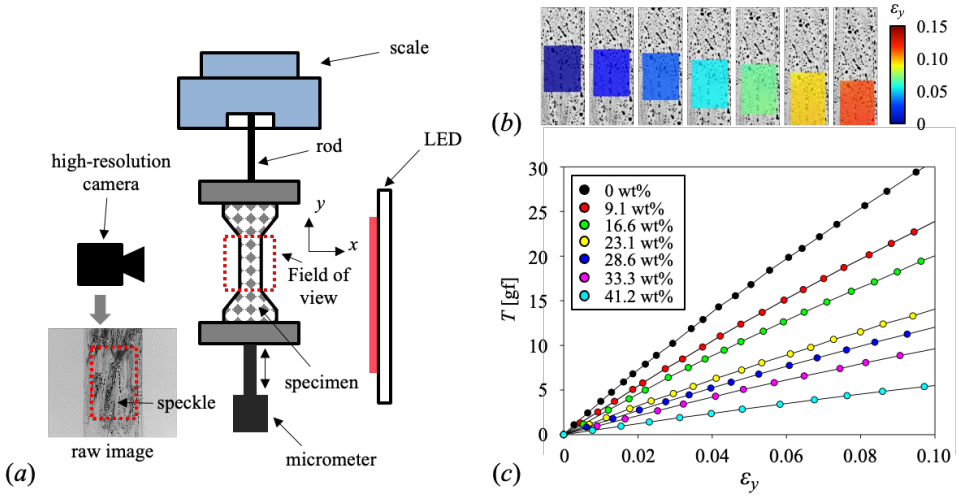

Figure S1. (a) Schematic diagram of experimental setup for measuring the tension of the specimen. (b) Raw images and visualized longitudinal strain (ε_y) evaluated by two-dimensional digital-image correlation (DIC). (c) Strain-tension curve depending on the mass fraction of silicon thinner.

To measure the wall thickness, the flexible nozzle being attached to the acrylic mold (cylinder) is axially cut into slices for four azimuthal locations (figure S2*a*). We measured the wall thickness using the microscope at five different axial locations. As we specified in the manuscript, the wall thickness slightly gets thinner for higher y/L; thus, they are averaged vertically for $y/L = 0.13 - 1$ and azimuthally for four locations, which defines the averaged wall thickness (h). Figure S2(*b*) shows that h decreases from 260 to 65 μm while varying the mass fraction of the silicon thinner from 0 to 41.2 wt%.

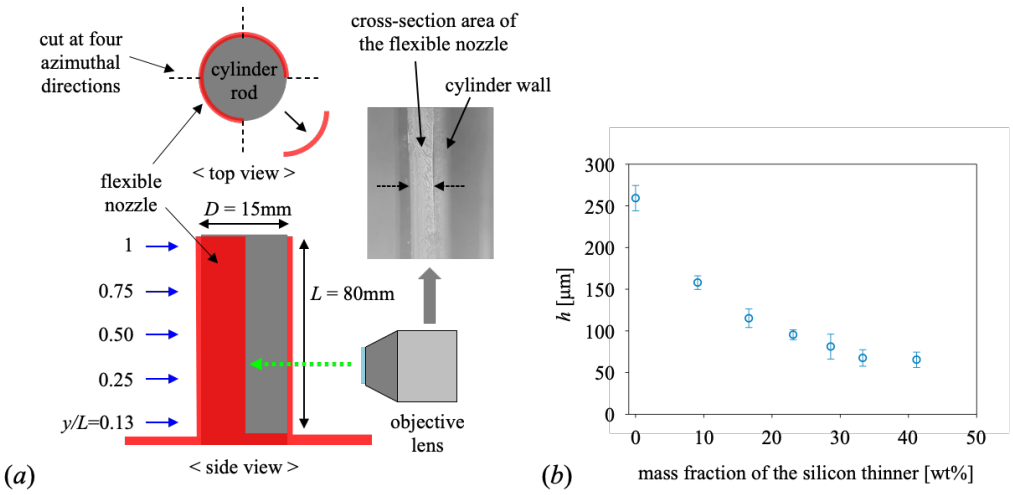

Figure S2. (a) Schematic diagram of experimental setup for measuring the wall thickness of flexible nozzle. (b) Averaged wall thickness (h) depending on the mass fraction of silicon thinner.