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Deconstructing the effectiveness of opposition control in turbulent pipe flow[1] MITUL LUHAR, California Institute of Technology, ATI S. SHARMA, University of Southampton, BEVERLEY J. MCKEON, California Institute of Technology — We develop a simple model for opposition control based on the resolvent analysis of McKeon & Sharma (2010, *J Fluid Mech*). This model decomposes the velocity field for turbulent pipe flow into a series of highly-amplified response modes, identified via a gain analysis of the Fourier-transformed Navier-Stokes equations. Changing the boundary conditions to reflect control alters the structure and amplification of these velocity responses, such that a reduction in gain signifies a reduction in drag. With basic assumptions, this rank-1 model reproduces trends seen in previous DNS and LES. Further, a wavenumber-frequency breakdown helps explain the deterioration of opposition control performance with increasing sensor elevation and Reynolds number. We show that opposition control only suppresses attached modes localized near the wall; detached modes, which are more energetic at higher Reynolds number and active far from the wall, are further amplified. Such detached modes require a phase lag between sensor and actuator velocity for suppression. Thus, the efficacy of traditional opposition control is determined by a tradeoff between modes sensed, but it may be possible to prescribe an optimal scheme tailored to individual mode behavior.

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