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Harnessing Synchronization as a Means of Communication Between Two Independent Motor-Driven Mechanisms via Vibrational Energy Transfer

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Abstract. This paper investigates synchronization as a tool for enabling indirect communication between two independently driven mechanical systems without any kinematic linkage. The setup involves two DC motor-driven scotch yoke mechanisms, coupled not physically but through a series of intermediate vibrating blocks connected by spring-damper elements. As each yoke excites one end of this vibrational chain, energy propagates through the structure, facilitating interaction between the otherwise kinematically uncoupled mechanisms. The study begins with a single block and extends to a chain of multiple blocks placed between the two yokes, forming a distributed vibrational network. Simulations using multi-body dynamics and multi-energy domain modeling capture the emergence of self-organizing behavior. Synchronization is shown to arise purely from vibrational energy transfer, even under large input power mismatches. The results reveal that such energy-mediated coordination offers a novel framework for achieving cooperative dynamics in distributed mechanical systems, with potential applications in robotics, automation, and intelligent machines.

Keywords: Synchronization · Cooperative dynamics · Scotch yoke mechanism · Non-ideal drive · Non-ideal system · Bond graphs

1 Introduction

Synchronization is nature's way of creating order from chaos—a self-organizing rhythm evident in fireflies, heartbeats, and even machines [1]. In engineering, this principle appears when components move in unison, not through external control, but via 'vibrational energy exchange'—the key impetus that allows independent parts of a dynamical system to interact and align. In real-world settings, many power sources like electric motors, pumps, and engines operate as non-ideal drives, where the dynamics of the drive are influenced by the load it powers [2].