ELECTROMAGNETIC INTERACTION ANALYSIS IN COMBUSTION SYSTEMS

TMS TECHNOV M SYSTEMS P LTD

STUDYING ELECTROMAGNETIC EFFECTS WITHIN COMBUSTION PROCESSES

ELECTROMAGNETIC INTERACTION ANALYSIS OVERVIEW

INTRODUCTION

Role of Electromagnetic Interactions

Electromagnetic effects enhance fuel mixing and efficiency in advanced combustion systems using MHD principles.

Boundary Layer Phenomena

Coupled electromagnetic phenomena occur at the boundary layer between metal conduits and flowing natural gas.

Fundamental Electromagnetic Laws

Maxwell’s equations, Lenz’s law, and Ampère’s law govern electromagnetic interactions in the combustion environment.

Impact on Combustion Dynamics

Displacement currents and magnetic fields influenced by electrostatic potential affect flame stability and fuel efficiency.

BOUNDARY POTENTIAL AND DISPLACEMENT CURRENT

Boundary Potential Formation

Boundary potential arises at the wall–fuel interface due to work function differences and dielectric mismatch during gas flow.

Electrostatic Field Dynamics

The boundary potential creates a time-varying electrostatic field that changes as the fuel moves through the conduit.

Displacement Current Induction

Changing electric fields induce displacement current density, a polarization current essential for electromagnetic interactions.

Impact on MHD Processes

Displacement current initiates downstream electromagnetic effects, enabling magnetic coupling and torque generation in MHD frameworks.

MAGNETIC FIELD INTERACTIONS

INTERACTION WITH ALTERNATING MAGNETIC FIELDS

Charged Fuel in Magnetic Zones

Charged fuel flows through zones with alternating repulsive and attractive permanent magnets creating dynamic magnetic interactions.

Induced Electromotive Force

Changing magnetic flux induces an emf opposing charged fuel motion, acting as magnetic drag or back emf.

Dynamic Flow Modulation

Alternating magnetic fields cause spatial emf variations, enhancing electromagnetic coupling and modulating the flow dynamically.

LORENTZ FORCE ON BOUNDARY CHARGES

Oscillating Lorentz Force

Boundary-layer charges experience an oscillating Lorentz force due to alternating magnetic fields, generating torque impulses.

Micro-vortical Motion

Torque impulses induce micro-vortical motion enhancing mixing between charged gas and core stream near the wall.

Magneto-Hydrodynamic Coupling

Electromagnetic forces influence fluid dynamics through MHD coupling, improving combustion efficiency by better mixing.

ELECTROMAGNETIC COUPLING EFFECTS

NET EFFECT OF ELECTROMAGNETIC COUPLING

Displacement Current and Charge Flow

Displacement current at the boundary layer transports charge density downstream affecting flow dynamics.

Magnetic Interaction and Forces

Interaction with alternating magnetic field produces opposing emf and lateral Lorentz forces enhancing momentum exchange.

Enhanced Mixing and Combustion Efficiency

Resulting forces improve diffusion, charge separation, and mixing, boosting combustion stability and fuel savings.

AMPÈRE’S LAW IN THE SYSTEM

Maxwell–Ampère Equation

The generalized Maxwell–Ampère law links conduction and displacement currents to magnetic field generation and circulation.

Displacement Current Induction

Displacement current induces a magnetic field that superposes with an external alternating magnetic field in the system.

Lorentz Force Interaction

The net magnetic field controls Lorentz forces, affecting torque and mixing in the combustion flow.

Electromagnetic Loop Completion

Ampère’s law completes the electromagnetic loop by linking changes in electric fields to magnetic circulation, reinforcing MHD coupling.

FIELD INTERACTIONS AND TORQUE GENERATION

PHYSICAL PICTURE AND FIELD INTERACTIONS

Boundary Layer Polarization

Polarization of the boundary layer generates displacement currents that act like current sheets around the gas flow.

Induced Magnetic Loops

Displacement currents induce magnetic loops encircling the flow, modifying local magnetic field topology.

Field Interaction Effects

Superposition of induced and external magnetic fields affects B-field gradients, emf profiles, and Lorentz torque distribution.

Enhanced Combustion Dynamics

Dynamic electromagnetic interactions enhance mixing and combustion efficiency through complex field-flow coupling.

MHD TORQUE AND MIXING ENHANCEMENT

Lorentz Force and Torque

The cross product of current density and magnetic field creates tangential forces generating torque near pipe walls.

Fuel Mixing Enhancement

Micro-vortical shear produced by electromagnetic forces improves fuel mixing and activation through energy transfer.

Field–Flow Coupling

Ampère’s law links electric field changes to magnetic circulations, influencing Lorentz force distribution in magnetized fluids.

SUMMARY AND PRACTICAL IMPACT

SUMMARY TABLE AND PRACTICAL IMPACT

PHENOMENON	EQUATION	ROLE IN YOUR MODEL
Boundary potential	$E_b = -\nabla V_b$	Creates interface field
Displacement current	$J_d = \varepsilon_0\, \partial E_b/\partial t$	Transports charge through flow
Ampère’s law	$\nabla\times B = \mu_0 J_d$	Generates induced B field around flow
Lenz’s law	$E_{ind} = -d\Phi_B/dt$	Opposes change, adds back emf
Lorentz force	$F_L = J_d \times B_{total}$	Creates torque, mixing, drag