# Enhancing Friction Stir Welding Quality of Inconel 718: An Approach of Numerical Modeling and Fuzzy Logic-Based Temperature Controlling

Friction stir welding (FSW) is a preferred method for joining high-strength materials due to its superior mechanical properties. However, ensuring optimal surface quality in Inconel 718 is challenging due to temperature sensitivity. This study examines how numerical modeling and fuzzy logic control can overcome these challenges.

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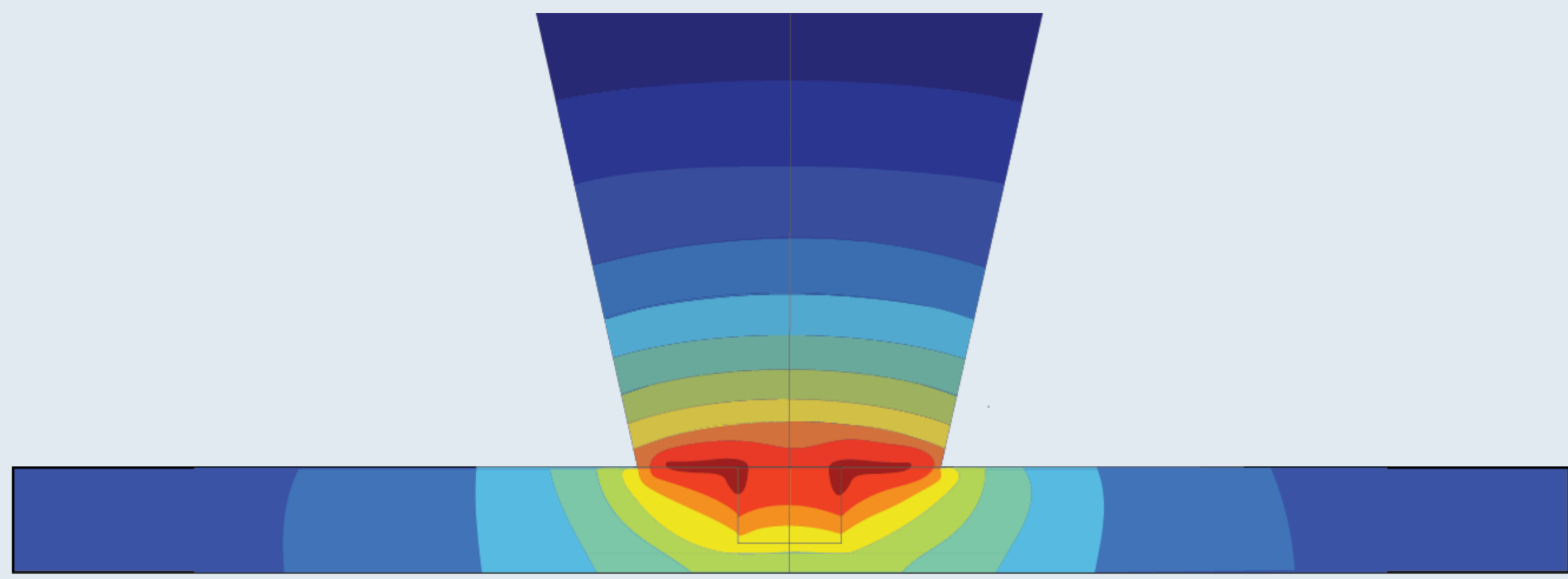
Introduction

FSW is an advanced technique for joining high-strength materials, offering better mechanical properties than traditional methods [1]. However, optimizing surface quality in Inconel 718 is challenging due to its temperature sensitivity [2]. This study utilizes COMSOL Multiphysics® software for numerical modeling and MATLAB® for system identification, where a fuzzy logic controller (FLC) is designed to dynamically adjust welding parameters in real-time, ensuring consistent temperature control. This innovative approach mitigates temperature fluctuations, reducing surface defects like roughness and voids. The integration of these tools represents a significant advancement in FSW technology for Inconel 718 and other high-performance alloys.
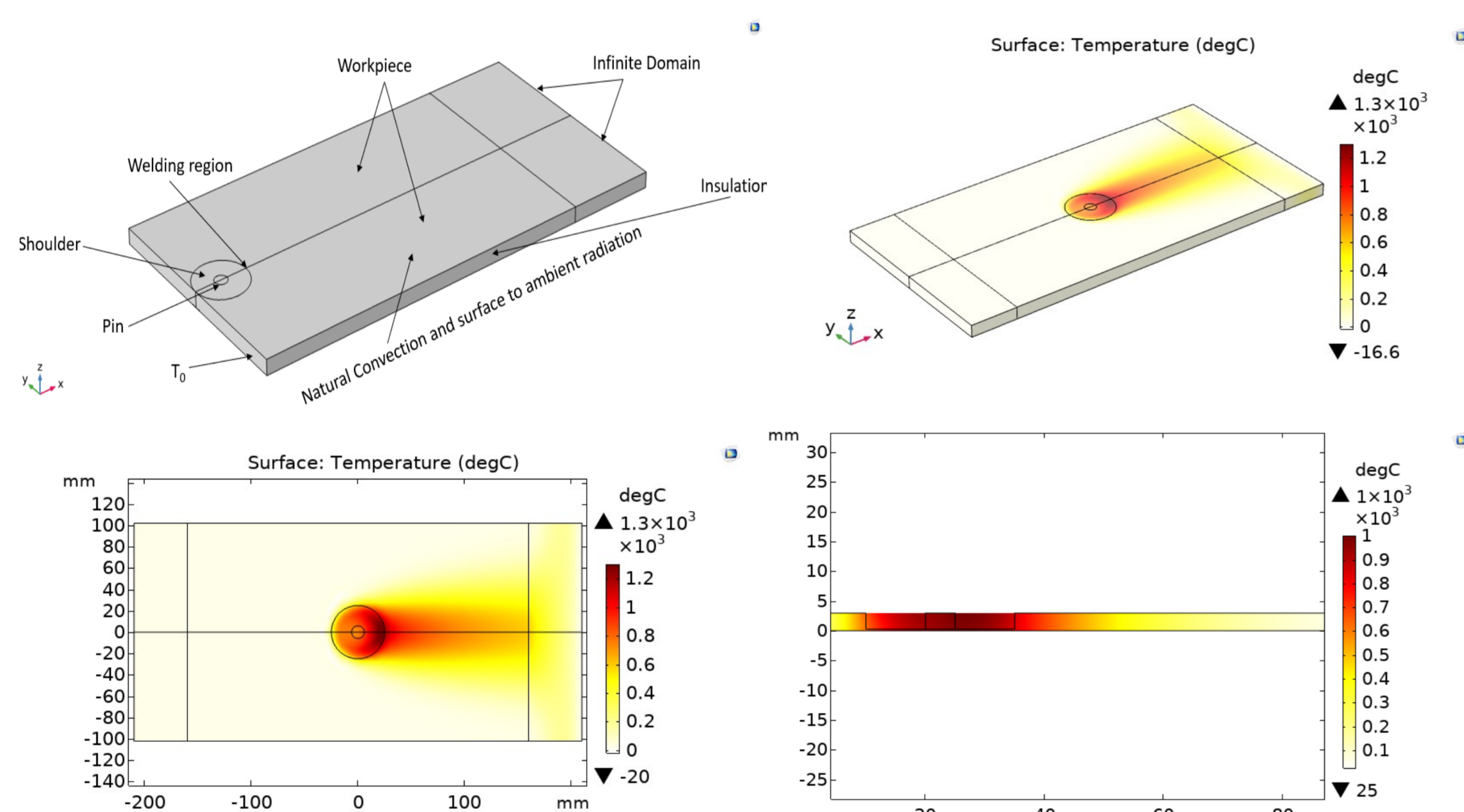

FIGURE 1. System geometry, and 3D/2D temperature profile.

Methodology

FEM using COMSOL Multiphysics were conducted to model the FSW process of Inconel 718. The simulation domain included two plates with adaptive meshing (108,000 elements), and key parameters such as rotational speed, welding speed, and axial force were analyzed. The governing equations used included heat convection and conduction, surface heat source (pin and shoulder friction), surface heat flux, and the Johnson-Cook model for flow stress behavior. A fuzzy logic controller was implemented in MATLAB® to dynamically adjust parameters, maintaining the optimal weld temperature to enhance the workpiece surface quality.

Results

The COMSOL® model successfully captured the features of FSW, enabling the generation of a dataset that was exported to MATLAB® for controller design. The designed FLC was tested through simulations, demonstrating effective temperature control under varying conditions. The controller exhibited fast response times (2-3 seconds for rise time) and consistent performance, with settling times between 7-10 seconds. Minimal steady-state error confirmed the FLC's ability to maintain the desired temperature setpoints and stabilize the weld temperature, even in the presence of disturbances.
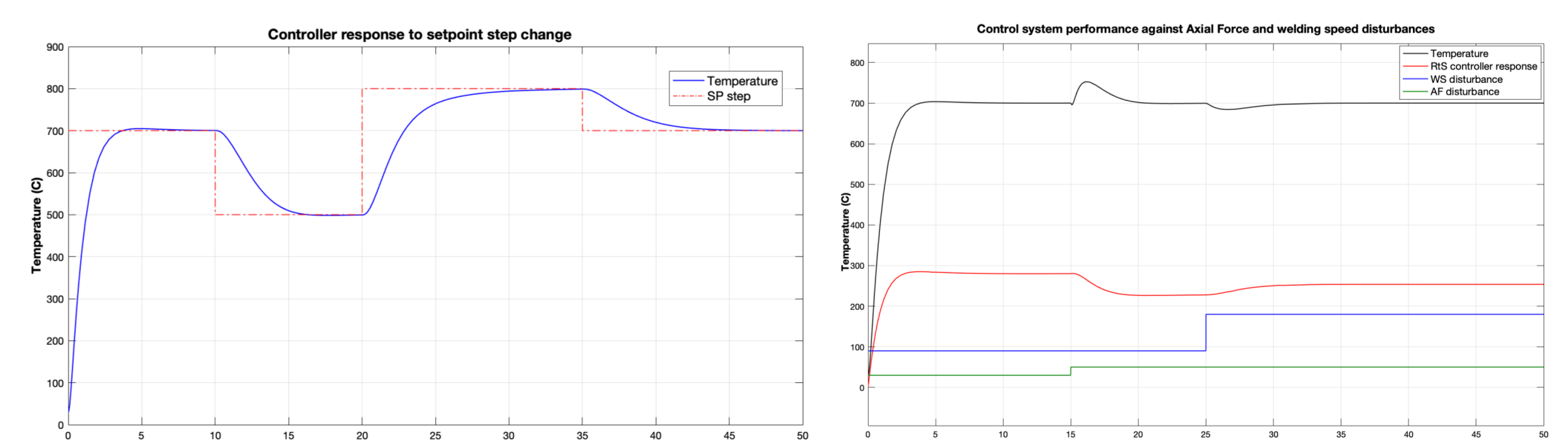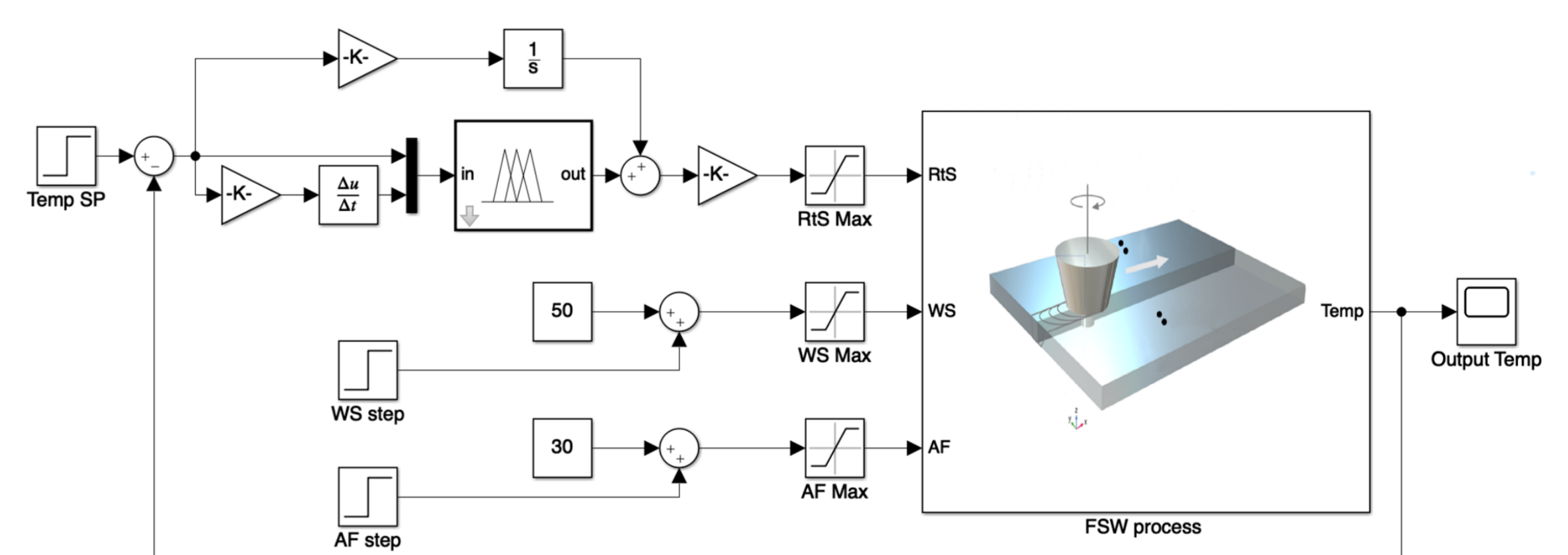

FIGURE 2. SIMULINK® block diagram of the FSW model and MATLAB® plots of FLC performance.

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