Energy Savings Analysis of Automated Chilled Water Supply Pump Control in HPF Process

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***Abstract*— The Hot Press Forming (HPF) process is highly energy-intensive. While extensively researched, energy reduction in industrial HPF operations often relies on manual control. This study systematically analyzes operational data to find practical energy-saving opportunities. Based on this, we designed and implemented an automated control strategy for the Chilled Water Supply Pump (CWSP), a target selected for its high impact with minimal disruption to the operational workflow. A comparative analysis demonstrated that the automated system reduced the pump's energy use by approximately 51% and its Specific Energy Consumption (SEC) by approximately 60%. This study validates that field-data analysis can yield practical, empirically supported solutions for energy conservation, contributing to the sustainable operation of HPF processes.**

Keywords—hot press forming, water pump control, energy conservation measures

I. Introduction

The HPF process consists of various equipment, including presses, furnaces, and cooling systems, often configured in complex layouts [1]. This process is known for its substantial electrical energy consumption, and previous studies have characterized the energy consumption patterns of each major component [2].

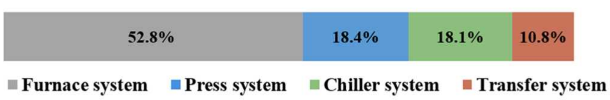

Fig. 1. Energy Consumption Distribution of HPF Equipment

Analysis of operational data, as shown in Fig. 1, revealed that the furnace, the largest energy consumer, presents the most significant potential for savings. However, adopting furnace control changes is challenging for site managers due to process complexity and potential disruption to operators [3]. Therefore, this study focuses on an automated control strategy for the CWSP as an alternative that promises energy savings while minimizing interference with the operational workflow. Previous research on pump energy conservation has predominantly focused on optimal control or replacing constant-speed pumps with variable-speed pumps (VSPs) [4]. In contrast, this study develops an energy-saving strategy for an existing constant-speed pump system and reports the results of its practical implementation, aiming to improve the adoption of data-driven solutions in the field.

II. System and Methodology

The core objective of the HPF process is to achieve high material strength by simultaneously forming and quenching a heated blank within a press mold. Consequently, maintaining the target mold temperature via a continuous supply of chilled water is indispensable for product quality.

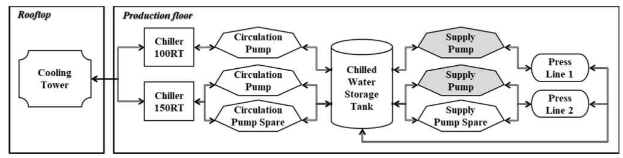

Fig. 2. Schematic Diagram of the HPF Cooling System

Fig. 2 illustrates the schematic of the cooling system at the target HPF plant. The system comprises two chillers that maintain a chilled water storage tank at a setpoint temperature. From this tank, two dedicated CWSPs deliver chilled water to each of the two HPF lines.

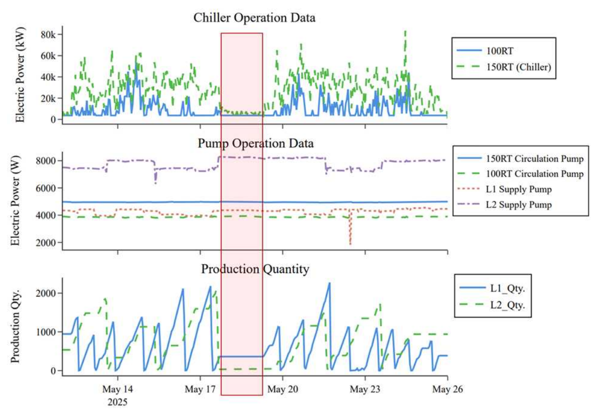

Fig. 3. Operational Data of the HPF Cooling System

An analysis of the cooling system's operational data is presented in Fig. 3. This revealed that the equipment often ran continuously, irrespective of the production status. Controlling the entire system posed risks to process stability and operator tasks. Therefore, this study narrowed its focus to the two CWSPs, which could be controlled efficiently with minimal impact. The specifications of the target pumps are provided in Table I.

TABLE I. Specifications of the CWSPs

Category	Specifications
Line1 Chilled Water Supply Pump (one spare)	Rated Power: 7.5 kW (55 HP) Operating Voltage: 440V, 3-phase Rated Current: 14.3A (Operating), 50.5A (Starting) Rotational Speed: 1750 RPM Continuous Operation: Available (CONT duty)
Line2 Chilled Water Supply Pump	Rated Power: 11 kW (15 HP) Operating Voltage: 440V, 3-phase Rated Current: 19.8A Rotational Speed: 1770 RPM Continuous Operation: Available (CONT duty)

The proposed control strategy, outlined in Table II, manages CWSP operation based on the press's production status. It involves monitoring the press in real-time to interlock the CWSP, shutting it down during inactivity.

TABLE II. CWSP AUTOMATIC CONTROL STRATEGY

Category	Strategy
Internal Door Status	**Door Open:** Press Stop **Door Closed:** Press Start
Internal Chamber Status	**Chamber Occupied:** Press Stop **Chamber Empty:** Press Start
Press Operational Status	**Press Start:** Pump Start **Press Stopped:** Pump Stop

To validate this strategy's feasibility, we measured the mold's temperature stabilization time. As shown in Fig. 4, the mold reached a stable operating range within approximately 5 minutes. Given that operators require approximately 30 minutes for setup, this stabilization period does not adversely affect the overall process lead time.

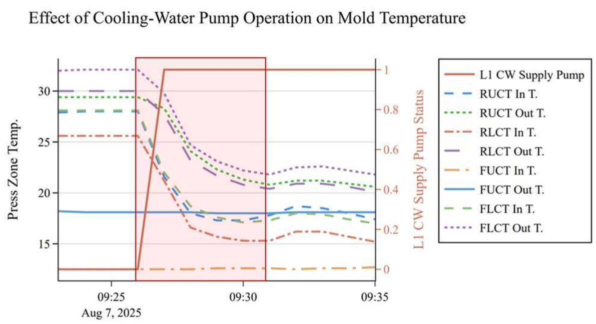

Fig. 4. Effect of CWSP Operation on Mold Temperature

III. RESULTS AND DISCUSSION

To implement the control logic defined in Table II, a PLC-based system was installed to collect real-time process data from the MES and operate the CWSPs automatically. To evaluate performance, we compared data from two consecutive weeks before and after implementation. Fig. 5 summarizes the production volume and energy consumption, while Table III details the energy savings.

As illustrated in Fig. 5, the energy consumption of the CWSPs after implementation fluctuates in real-time, corresponding to the press's operational status. During the post-implementation period, energy consumption of the cooling tower and chillers increased due to higher ambient temperatures and a surge in production. Nevertheless, the energy consumption of the automated CWSPs decreased by an average of approximately 51%. Furthermore, the Specific Energy Consumption (SEC) of the CWSPs was decreased by approximately 60%.

IV. CONCLUSION

This study presents a practical, data-driven strategy for energy conservation in the HPF process. By implementing an automated control system for the CWSPs, which were selected as the target to minimize operational disruption, the on-site system reduced the CWSPs' energy consumption by an average of approximately 51 %. The system demonstrated high field acceptability, without causing any interference with the process or with Operators. This work provides empirical evidence that significant energy savings are achievable without major capital investment, thereby supporting site managers in making informed decisions to implement similar data-driven efficiency improvements.

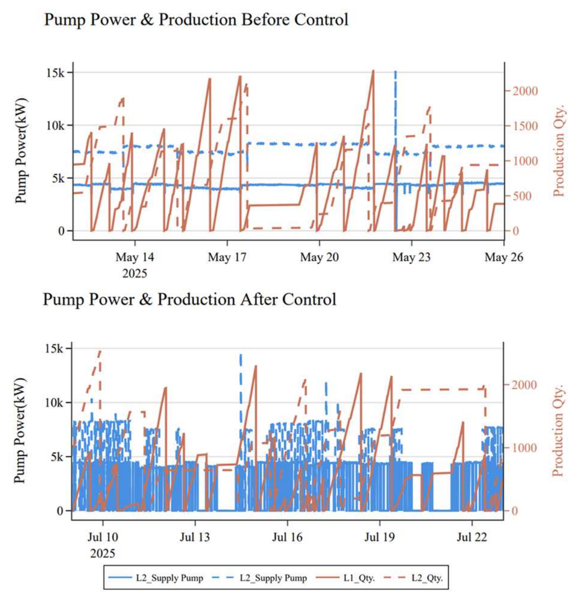

Fig. 5. CWSP Energy Use Before vs. After Control

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TABLE III. FIELD TEST RESULTS: BEFORE VS. AFTER AUTOMATED CONTROL

Category	L1 Qty.	L2 Qty.	Total Qty.	Chiller System Total (MWh)	Supply Pump Total (kWh)	L1 CWSP (kWh)	L2 CWSP (kWh)	L1 CWSP (Wh/unit)	L2 CWSP (Wh/unit)	CWSPs Total (Wh/unit)
Before	21,164	8,610	29,774	19.15	**4,056**	1,437	2,619	67.9	304.2	**136.2**
After	19,227	16,678	35,905	21.06	**1,968**	948	1,020	49.3	61.2	**54.8**
Change Rate	9%	-94%	-21%	-10%	**51%**	34%	61%	27%	80%	**60%**