Bearing Installation

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Abstract

This project, developed in partnership with Aero Components, LLC, focuses on designing and fabricating an integrated bearing installation, staking and proof-load testing system that improves efficiency, accuracy, and compliance with aerospace standards. Existing processes lacked precision, required manual data tracking, and separated installation from testing leading to inefficiencies and variability in quality. The requirements specified that the tool must be capable of installing grooved plain spherical bearings with a race hardness not exceeding Rockwell C38 and support staking and swaging methods. The tool was required to utilize a devise to apply precise staking pressure without contacting the ball-side of the groove, ensuring structural integrity during installation. Following installation, assemblies had to meet strict visual inspection criteria, such as gaps under 0.005 inches and no visible damage, while also withstanding proof-load forces based on groove type, ranging from 900 to 1,600 pounds force per inch of bearing diameter. These requirements defined the tool's mechanical capabilities, safety considerations, and performance benchmarks. To address these requirements, a modified HSP-30M Baileigh Hydraulic Press was selected and upgraded to include a digital pressure monitoring system, pressure transducer, and digital display. This setup allows real-time feedback, enabling operators to input die specifications and achieve precise staking pressures with improved accuracy and repeatability.

Background & Research

The initial steps of the project included extensive research into the current staking and swagging methods to familiarize ourselves with the current process and technology. The objective of our research is to determine the maximum deformation force that our design will need to be capable of. We will use this value to aid in the selection of the hydraulic press that will be used for our design. This involves exploring the relationships between the bearing OD, material hardness, and the deformation force required for installation. By understanding these relationships, we can develop tables to serve as a quick reference in the operation manual, ensuring installation's required deformation force installation's required deformation force operators have clear guidelines for expected force requirements.

In determining deformation force, we developed a set of tables based on estimated force values, which were calculated as a function of the bearing OD and a constant that is determined by the groove type. These tables will help establish the maximum load requirements of the press, which will be verified through a series of tests to ensure the selected press meets all operational demands.

Tensile Strength of 140,000 (HC 30)

	Pounds Force			Tons		
Bearing OD	Type A	Type B	Type C	Type A	Type B	Type C
0.5	3,850	6,000	8,850	1.9	3.0	4.4
1.0	7,700	12,000	17,700	3.9	6.0	8.9
1.5	11,550	18,000	26,550	5.8	9.0	13.3
2.0	15,400	24,000	35,400	7.7	12.0	17.7
2.5	19,250	30,000	44,250	9.6	15.0	22.1
3.0	23,100	36,000	53,100	11.6	18.0	26.6
3.5	26,950	42,000	61,950	13.5	21.0	31.0
3.75	28,875	45,000	66,375	14.4	22.5	33.2

Tensile Strength of 160,0000 (HC 38)

	Pounds Force			Tons		
Bearing OD	Type A	Type B	Type C	Type A	Type B	Type C
0.5	4,317	6,727	9,923	2.2	3.4	5.0
1.0	8,633	13,454	19,845	4.3	6.7	9.9
1.5	12,950	20,182	29,768	6.5	10.1	14.9
2.0	17,266	26,909	39,690	8.6	13.5	19.8
2.5	21,583	33,636	49,613	10.8	16.8	24.8
3.0	25,900	40,363	59,536	12.9	20.2	29.8
3.5	30,216	47,090	69,458	15.1	23.5	34.7
3.75	32,375	50,454	74,420	16.2	25.2	37.2

The Press

The HSP-30M Baileigh Hydraulic Press is a manually operated H-frame press designed for precision tasks and medium-duty applications, with a 30-ton capacity to handle loads for staking bearings, installing bushings, and bending metal components. Its adjustable work table accommodates various workpieces, and the manually-operated hydraulic pump provides precise control during pressing. The system includes real-time monitoring via a PLC and pressure transducer, ensuring accurate force readouts throughout the installation process. Compact and easy to use, the HSP-30M combines functionality and reliability, making it an ideal foundation for our prototype.

Programmable Logic Controller

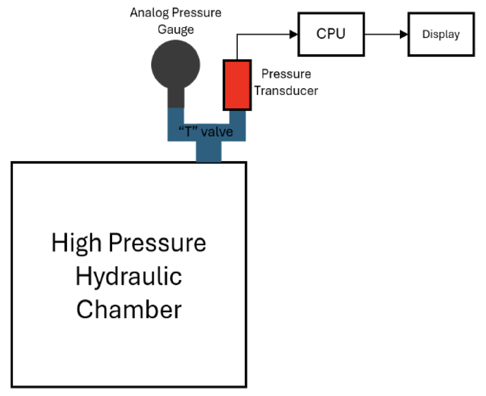
In industrial applications requiring sensor integration, a Programmable Logic Controller (PLC) like the Arduino Opta Lite offers significant advantages over traditional microcontrollers, such as the Arduino Uno. Our setup uses a 24V pressure transducer with a 0.1V–10V signal for hydraulic press monitoring, and the Opta Lite natively handles 0-10V signals, eliminating the need for voltage scaling and reducing signal inconsistencies. Its robust input protection and noise immunity are crucial in high-power environments, where electromagnetic interference (EMI) can distort sensor signals. With an input impedance of 8.9 kΩ and a high-resolution ADC, the Opta Lite provides more accurate measurements than a standard microcontroller. The PLC also supports Modbus-TCP for seamless HMI communication and has a compact, DIN rail-mountable design that offers protection against dust, vibration, and temperature fluctuations. Switching from the Arduino Uno to the Opta Lite significantly improved system stability, accuracy, and reliability, making it the optimal choice for interfacing with high-voltage sensors.

Software Integration

The pressure transducer monitors the hydraulic press pressure, with a Programmable Logic Controller (PLC) used for data processing and a Nextion Human-Machine Interface (HMI) for visual display. The HMI communicates with the PLC via UART serial communication. Using the HMI's integrated software, we send and display the processed data directly. The PLC transmits this data to the HMI in a format that updates various display components, such as text fields and gauges, to show real-time pressure and force measurements. Our customized display options include:

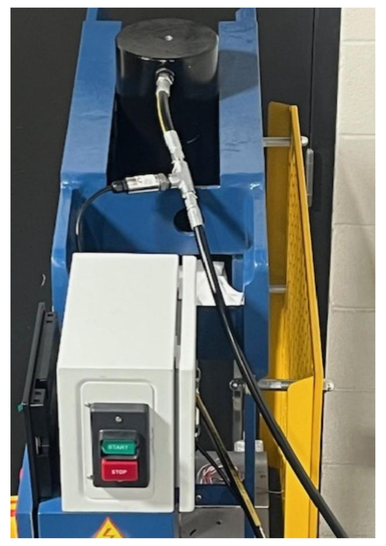
- **Maximum Force Value:** Calculated from the pressure transducer, representing the peak force detected during operation.
- **Pressure Display**: Shows the pressure originally displayed on the hydraulic press's analog gauge for reference.
- **Desired Force:** Indicates the target force needed for proper operation or specific tasks.
- **Estimated Installation Force:** Displays the force required during installation, aiding in the setup of the press.
- **Proof Load Testing Force:** Represents the force needed for proof load testing to ensure the press meets operational standards.

Data transmission between the PLC and HMI is managed through a well-defined protocol, ensuring system reliability and responsiveness. The integration of these components enables seamless monitoring and control of the hydraulic press, providing accurate, real-time data to operators for smooth system operation.



Modified Components

The final system includes several key upgraded components. At its core is the Arduino Opta Lite PLC, which replaced the Arduino Uno used during testing. The system uses the Omega PX309-10KG10V transducer for pressure sensing, connected directly to the hydraulic hose. Force values are displayed via a 7.0" Nextion touchscreen (model NX8048P070-011R-Y), embedded in a custom-cut steel enclosure mounted to the press. The enclosure itself is a VEVOR NEMA 4X-rated 10"x8"x6" junction box with a preinstalled mounting plate. Inside, a DIN rail-mounted Mean Well HDR-30-24 power supply delivers 24V at 1.5A to the entire system. Wiring runs from the original press electronics box to share power and organize signal routing. All components are mounted securely on DIN rails for safe and serviceable layout. The software features include real-time voltage-to-force conversion, rolling average filtering, interactive user input for bearing specs, and a live comparison between measured and recommended forces. Additionally, a 3-tooth scroll chuck is mounted on the bottom plate of the press, serving as the primary holding mechanism. This chuck is fitted flush with a spacer cylinder through its center hole, which redistributes the applied force evenly. To accommodate a range of bearing die sizes while addressing the limitation posed by the spacer cylinder, the scroll chuck is equipped with extended reach teeth.



Testing

Throughout this project, the group conducted many stages of testing needed to make key decisions about the project. Some of the key tests included:

- Compression force analysis tests to determine the compressional force needed to deform materials of varying hardnesses and to select a suitable press—either pressure-based or displacement-based. Our goal was to derive expressions for deformation force as a function of hardness and stress as a function of displacement (Young's Modulus for Compression). We accounted for force distribution in staking and swaging, tested materials up to Rockwell C-38, and designed for bearing diameters of 0.5 to 2 inches. If possible, we aimed to incorporate the staking/swaging tool.

- Using an Instron Compression tester and the swaging die provided by Aero, press on the test bearing until it is sufficiently deformed. The Instron will measure and record stress (force) and displacement(deformation). Use this data to deduce deformation stress vs hardness.

- Hydraulic hose testing to verify that the newly purchased hoses provided the same pressure as the original stock hoses. These new hoses were a critical part of our project, as they enabled the installation of a pressure transducer, allowing us to develop a feedback system. This system converted hydraulic pressure into a corresponding voltage, which was then displayed on the LCD screen, enhancing the monitoring and control of the press.

- Initial testing used a steel calibration block with a strain gauge and an Arduino Uno to validate the PX309 transducer's voltage output, revealing signal noise and limited resolution. After switching to the Arduino Opta, the system output became more stable, with live data matching analog gauge readings within a 10–15% error margin. Full system integration and testing under real load showed consistent, smooth live values on the LCD, confirming the system's readiness for staking and proof-load testing in a shop environment.

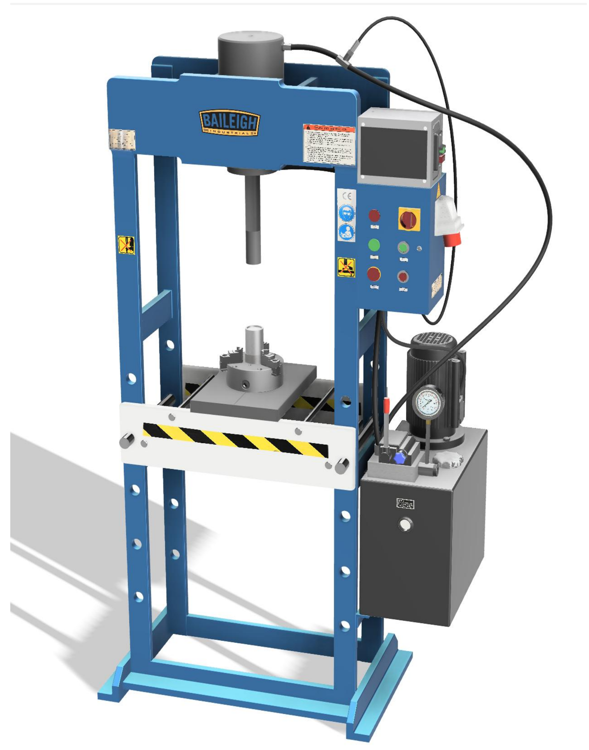
Final Design

Through comprehensive testing and research, the team verified the force requirements for bearing installation and selected components capable of meeting stringent tolerance and performance needs. Key mechanical alterations to the original press include the addition of a removable three-point chuck device mounted on the central assembly plate, allowing for easy installation of varying bearing sizes up to 3 inches in diameter. The original hoses were replaced with a new set modified to mount a pressure transducer for accurate pressure readouts during installation. A PLC display was added to show real-time pressure and target pressures. These integrated updates ensure the tool meets proof-load and staking/swaging requirements while remaining adaptable, user-friendly, and compliant with industry standards for both compression staking and swaging methods.

The HSP-30M Baileigh Hydraulic Press, a manually operated, medium-duty H-frame press, was chosen as the foundation for the system. With a 30-ton capacity, it is well-suited for tasks like bearing staking, bushing installation, and metal component bending. Its heavy-duty steel frame provides stability and durability under full load, ensuring reliable performance during repetitive use. The adjustable work table allows for height adjustments to accommodate different workpieces, while the manually operated hydraulic pump ensures precise control. The integration of the PLC and pressure transducer allows for real-time hydraulic pressure monitoring, ensuring consistent and accurate force during bearing installation. Compact and easy to operate, the HSP-30M serves as an ideal starting point for the project's prototype.

The system software was developed using the Arduino Opta Lite, an industrial-grade PLC. Initial testing with an Arduino Uno confirmed the functionality of the PX309 pressure transducer. After validating the sensor, the system transitioned to the Opta Lite, offering superior voltage handling, stability, and DIN rail compatibility. The software, written in the Arduino IDE, processes analog voltage from the Omega PX309-10KG10V pressure transducer, converting it into pressure and force values. A rolling average algorithm smooths voltage spikes and sensor noise for stable, accurate readings. These values are displayed in real-time on a Nextion 7.0" touchscreen LCD, where the operator can input bearing specifications, view force outputs, and monitor live data to ensure compliance with aerospace tolerances. The system is housed in a VEVOR NEMA 4X-rated steel enclosure, and power is supplied via a Mean Well HDR-30-24 24V power supply. This integration modernizes the hydraulic press, enhancing live monitoring, guided testing, and overall consistency while maintaining ease of use in industrial environments.

Additional components, such as proof load supports, were designed to support the housings during the proof-load test. These components allow for unit testing after each installation, ensuring consistent quality. The set of supports will be stored in a bin with cutouts for each specific size, streamlining operations. This solution provides Aero Components with a durable, adaptable, and digitally enhanced system that ensures consistent quality in bearing installations.



Conclusion

This project successfully addressed the need for an integrated bearing installation, staking, and proof-load testing system capable of meeting aerospace standards for efficiency, precision, and repeatability. By upgrading a modified HSP-30M Baileigh Hydraulic Press with a digital pressure monitoring system, pressure transducer, and real-time feedback capabilities, we have created a system that ensures precise staking pressures and consistent quality control. The software developed for the Arduino Opta Lite PLC integrates seamlessly with the hardware, providing live monitoring, stable force outputs, and easy operator control through a user-friendly touchscreen interface. The inclusion of a custom jaw to hold various cups and dies further enhances the system's versatility, allowing it to support a wide range of bearing installations. Ultimately, this project modernizes the bearing installation process, improving both operational efficiency and compliance with stringent aerospace tolerances, while maintaining the simplicity and durability necessary for industrial environments.