Research and application of wireless network monitoring technology for operating parameters of nitrogen gas springs

The quality and efficiency of mold production heavily rely on the operating conditions of nitrogen gas springs. This paper presents an introduction to the operating principles and applications of nitrogen gas springs, highlighting the advantages of controllable nitrogen gas springs over conventional ones. Recognizing the significance and necessity of monitoring nitrogen gas springs, a monitoring system solution based on wireless data collectors and cloud servers is proposed. This system enables real-time monitoring of nitrogen gas spring pressure, anomaly detection through warning and alarm functions, and prevention of production defects by indicating machine stoppages. Additionally, the management software allows administrators to remotely monitor and manage nitrogen gas springs, visualize data, generate reports, and analyze historical data. The implementation of this system can enhance production quality and efficiency, reduce costs, and lay the groundwork for intelligent manufacturing. Suggestions for the further development of an intelligent control system are proposed to achieve correlation analysis and optimization control of mold forming parameters and processes. This research holds great significance for the management of nitrogen gas spring monitoring and the implementation of software functions, providing valuable insights for the development of new monitoring systems and intelligent manufacturing.

Keywords: Nitrogen gas springs; Monitoring system; Wireless network; Industry 4.0; Hot stamping.

1. Introduction

The use of high-strength steel hot stamping body parts and hot stamping production lines has become prevalent in the automotive component industry due to advancements in lightweight automobiles [1,2]. Nitrogen gas springs play a crucial role in hot stamping molds of varying complexities, providing auxiliary pressure and delayed ejection of hot blanks. The introduction of nitrogen gas springs in the market dates back to 1964. Over time, their performance has significantly improved with the development of new sealing methods for high-pressure gases in the early 1980s, leading to expanded applications such as car door and window operations, tilting of lifting and self-unloading heavy-duty truck boxes, and more [3]. This has led to specialized production, resulting in a wide range of nitrogen gas spring products with different specifications and varieties. Nitrogen gas springs have evolved from low-pressure, short lifespan single-plunger devices to series of gas springs with lifespans exceeding one million cycles and adjustable pressures [4]. Continuous advancements in sealing structures, materials, and the use of electrochemical processes to treat mating surfaces have further increased the lifespan and enhanced the performance of nitrogen gas springs [5]. They occupy less mold space and offer controllable pressure. For processes such as punching, deep drawing, bending, and forming,

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nitrogen gas springs with different performance characteristics can be selected to achieve optimal results according to process requirements. In the 1990s, nitrogen gas springs were included in the ISO world standard, and currently, nitrogen gas springs developed in China have found widespread applications in various industries, particularly in cold stamping and hot stamping molds for automotive components.

2. Operating Conditions of Nitrogen Gas Springs

Figure 1 illustrates the utilization of a nitrogen gas spring in metal forming molds, featuring a piston rod that can be locked at the bottom dead center (BDC). The return stroke of the piston rod is pneumatically controlled by the valve located in the spring base. The curve depicted in the figure demonstrates two distinct stages of a stretching mold in a stamping stroke process. These stages include the pressure stroke and the corresponding duration of the maximum pressure die, as well as the maximum stroke and the corresponding duration of the nitrogen gas spring.

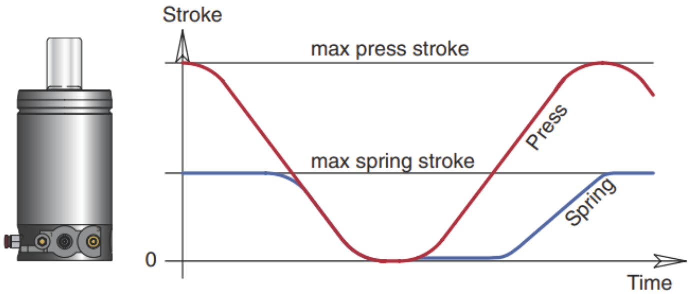


Figure 1. Nitrogen gas spring and the delay return application of stroke-pressure curve

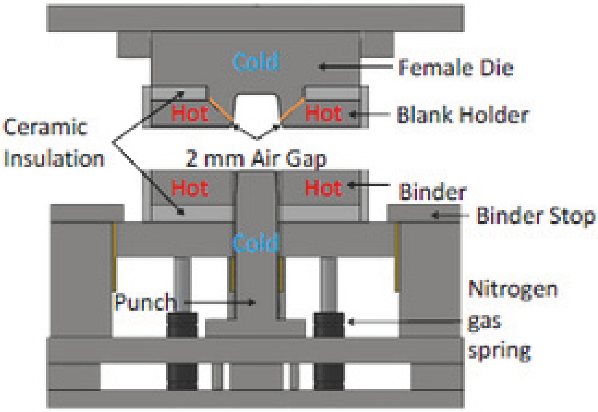


Figure 2 shows a hot stamping experimental mold with two nitrogen gas springs [6].

In the context of hot stamping forming molds, the incorporation of nitrogen gas springs facilitates the contact between the mold and the blank during the closing process and enables the control of applied pressure. Additionally, the optimization of the process flow can be achieved by regulating the delay time of the nitrogen gas springs, as depicted in Figure 2.

Controllable nitrogen gas springs differ from ordinary ones in that their piston rod can be locked in the bottom position, and the delay return time of the piston rod can be controlled either through compressed air or electrical signals. This feature allows controllable nitrogen gas springs to provide adjustable pressure for material feeding, thereby preventing deformations or other defects that may arise from cylinder ejection after component forming. However, it is important to note that there are limitations to the beat that controllable nitrogen gas springs can achieve. Continuous operation under overload beats without proper attention or prior calculation can lead to damage to the controllable nitrogen gas springs, thus affecting the quality of components. Controllable nitrogen gas springs also have maximum heat factor limits, regardless of whether external cooling devices are present or not [7].

In stamping molds, numerous positions are pressurized by nitrogen gas springs. Some positions can be assessed by manually inspecting external pressure gauge readings to determine the pressure status of the nitrogen gas springs. However, for certain positions, detection of air leaks in the nitrogen gas springs can only be accomplished through manual tapping based on experience. This becomes particularly relevant when air leaks in nitrogen gas springs cannot be promptly detected during production. Failure to address these air leaks in a timely manner can result in mold damage, material wastage, high costs associated with personnel inspection and maintenance, risks to personal safety, and missed inspections. Moreover, temporary inflation or replacement of nitrogen gas springs can lead to production delays and reduced efficiency.

To mitigate these issues, it is essential to monitor the pressure status of nitrogen gas springs in real-time during mold production and storage. In the event of abnormalities, timely alarms or chain machine stoppages should be initiated. If the pressure data of nitrogen gas springs can be sent on demand during their application, it would enable preventive maintenance, thereby establishing the foundation for intelligent production manufacturing.

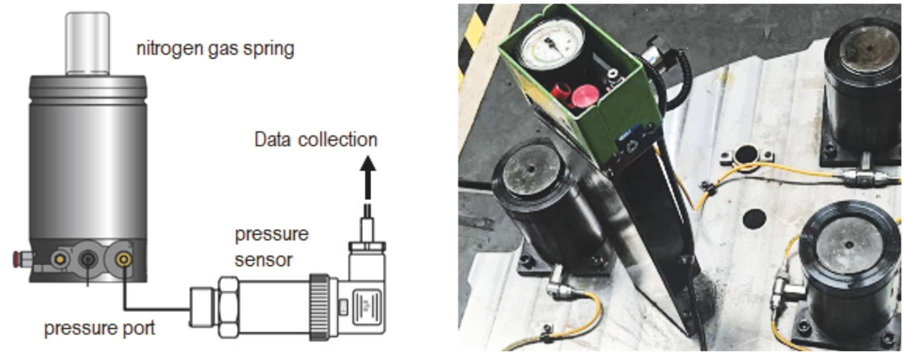
3. Monitoring of Operating Conditions of Nitrogen Gas Springs

The principle of the mold's nitrogen gas spring monitoring system is illustrated in Figure 4. In this system, a data collector is capable of connecting multiple pressure sensors of nitrogen gas springs within the same set of molds. The monitoring system's operating principle is depicted in Figure 5. Distinct monitoring and alarm methods are employed depending on whether the mold is in an online production state or an offline non-working state.***During Online Production of Molds***

During online production, when the wireless data collector obtains the pressure value from the pressure sensor and detects that it falls below the predefined lower limit, a wireless network message warning notification can be sent to the cloud server. Simultaneously, the yellow light of the tri-color light illuminates to emit a beep warning. If the air leakage persists and the pressure value falls below the specified lower limit, an alarm notification is triggered through the cloud server. Additionally, a high- or low-level signal is outputted to the press control system, signaling an immediate press stoppage to prevent the occurrence of quality defects. In this case, the red light of the tri-color light illuminates to emit a beep alarm.

3.2. *During Offline Maintenance or Storage of Molds*

During offline maintenance or storage of molds, each data collector, in addition to connecting pressure sensors, is also connected to pressure gauges equipped with limit position control outputs on the same mold. The monitoring system remains in standby mode with backup batteries. When the wireless data collector obtains the pressure value from the pressure sensor and detects that it falls below the predefined lower limit, a warning notification is sent through the cloud server. Simultaneously, the yellow light of the tri-color light illuminates to emit a beep warning. If the air leakage persists and the pressure value falls below the specified lower limit, another alarm notification is triggered through the cloud server. Furthermore, the red light of the tri-color light illuminates to emit a beep alarm. This approach significantly reduces the costs associated with personnel inspection and mitigates the risks of missed inspections resulting from manual inspections. Ultimately, it enables preventive maintenance and reduces the scrap rate.



a) b)

Figure 3. Connection of nitrogen gas springs and sensors: a) schematic diagram of sensor connection; b) photo of sensor connection

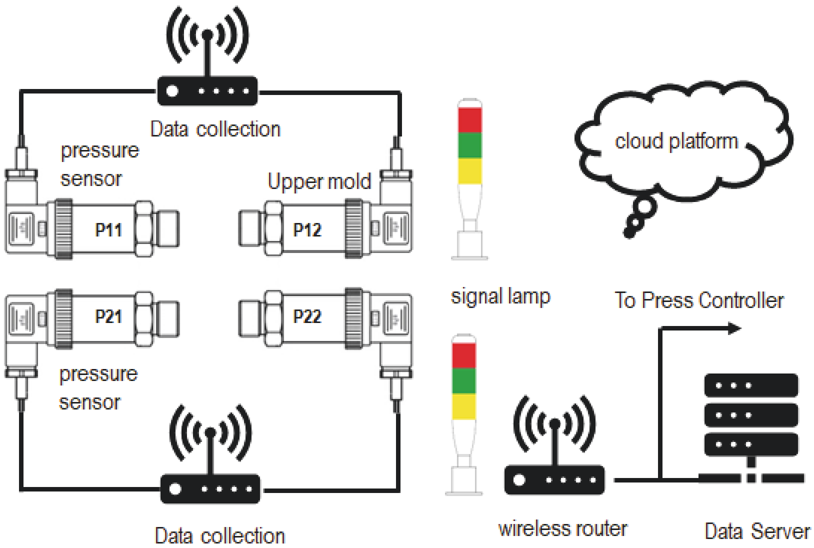


Figure 4. Principle of the monitoring system

4. Management and Software of the Monitoring System

The nitrogen gas spring monitoring system incorporates software applications that provide comprehensive management functions. This system enables real-time monitoring and recording of pressure, temperature, and position parameters of nitrogen gas springs. It also offers alarm and fault diagnosis capabilities. The software facilitates the visualization of monitoring data, supports report generation, and enables historical data analysis. Administrators can remotely monitor the status of springs, promptly detect issues, and implement corresponding maintenance measures to enhance work efficiency and safety. Furthermore, the monitoring software provides lifespan prediction and aids in the development of maintenance plans for springs, thereby reducing maintenance and replacement costs and improving resource utilization. Accurate data recording and analysis enable administrators to optimize the usage and management processes of nitrogen gas springs, thereby enhancing work efficiency and production quality. This system plays a crucial role in improving the operational management level of enterprises, ensuring employee safety, and enhancing competitiveness.

4.1. *Data Visualization*

Data visualization within the monitoring management software system involves presenting the system's data in the form of charts, graphs, and other visual representations. This approach allows users to intuitively comprehend the operational status and data of the system. Through data visualization, users can easily identify and analyze patterns, trends, and anomalies in the data, enabling them to take timely actions based on their findings.

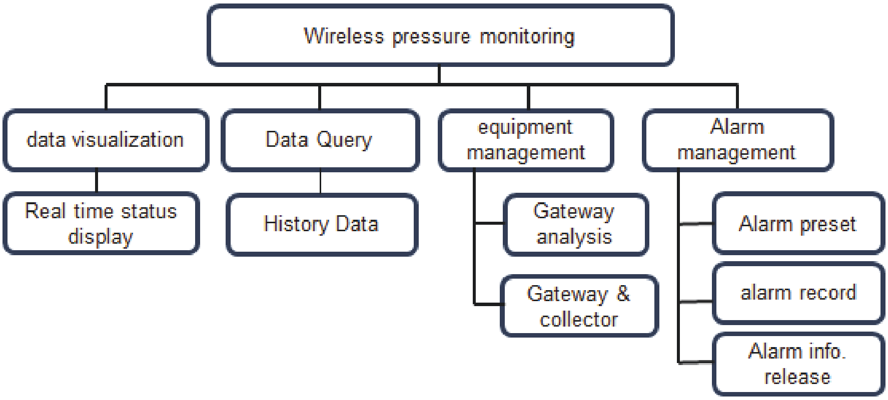


Figure 5. Functional diagram of the monitoring system management software

The software enables the unified and intuitive display of information and data on the user terminal, allowing operators to quickly and efficiently grasp the overall status of the wireless pressure system and the specific status of each node. The interface displays different colors based on the actual statuses, providing visual cues to operators. Different screens, such as standby and online work screens, can be distinguished based on the usage status of the on-site mold, enhancing monitoring efficiency.

4.2. *Data Query*

The software functions consist of real-time monitoring, data query, device management, alarm management, and system settings, with sub-functions tailored to specific monitoring application requirements.

4.3. *3Device Management*

Operators in the production control center can efficiently and conveniently manage devices related to the wireless pressure monitoring system through the user terminal on the web page. This includes device viewing, addition and deletion, device parameter viewing and setting, device association binding and unbinding, maintenance and fault information, and modification of alarm thresholds.

4.4. *Alarm and Emergency Control Management*

By continuously monitoring and analyzing the pressure of molds in real-time, the system triggers alarms when the pressure exceeds the predefined threshold. Emergency control measures are then implemented to ensure the safe operation of the mold and production quality. Once an alarm is triggered, the system issues warning lights and messages to management personnel based on the alarm level through the network. Management and operators are required to promptly initiate emergency control measures, such as stopping the press and mold operation, troubleshooting, and adjusting mold parameters, to ensure the safe operation and production quality of the mold. After troubleshooting, manual operation is required to clear the alarm status.

5. Conclusion

By monitoring the operating conditions of nitrogen gas springs, the issues of mold damage and material waste can be addressed, resulting in reduced costs associated with personnel inspection and maintenance, as well as minimized loss of production efficiency. The application of wireless network monitoring technology for the operating parameters of nitrogen gas springs enables timely problem detection, improves production efficiency, reduces costs, and facilitates intelligent production manufacturing. This technology has been successfully implemented in the automotive industry for cold stamping and hot stamping molds for automotive components and holds potential for application in other industrial fields. Building upon the mold's nitrogen gas spring monitoring system, further development of an intelligent control system based on the principles of Industry 4.0 can be explored. This would involve correlation analysis of auxiliary parameters and forming processes of molds, enabling precise control and process adjustment to detect and address quality defects.

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