lab to life

Unlocking Efficiency: Finding and Fixing Compressed Air Leaks in Industrial Machinery

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*The **AIR SAVE** project uses Industry 4.0 (integrating intelligent digital technologies into manufacturing processes) to analyse high-pressure air systems in manufacturing and identify faults where air could leak during an industrial process. But why should we care about air leaks in machinery? Air is a free and infinite resource, after all. **THINK** speaks to **Prof. Ing. Paul Refalo** (lead investigator) and **Prof. Ing. Emmanuel Francalanza** (co-investigator) to discover further.*

Compressed air systems are fundamental in industrial settings. High-pressure air systems are widely used in automated assembly and production processes, streamlining operations and increasing productivity. But it comes with a serious caveat. Machines powered by pressurised air are energy-intensive. In fact, compressed air ranks as the most intensive resource after electricity, fuels, and water.

Machines running on compressed air are usually in operation 24/7. With such a workload, they wear down quickly and are prone to faults. The most common deficiency is air leakage: when air escapes from the system. To counteract this, operators often increase the pressure to compensate for the loss; however, this is only a temporary and pricey solution. On the one hand, higher pressure means the machine will need more energy to operate, therefore more resources are needed. On the other hand, higher pressure will cause further issues in machinery that is calibrated to operate with a certain pressure – increasing pressure only creates more problems.

If leaks are so costly, why not just locate and fix them? 'As we're talking about air, leakages are invisible. In case of water or oil, a leak is immediately apparent. With air, machine operators don't have that luxury to easily locate the issue,' says Prof. Ing. Paul Refalo, lead investigator and Sustainable Engineering Expert at the Department of Industrial and Manufacturing Engineering, UM.

FINDING THE LEAK

Although we don't see the leak, the effects are immediately noticeable – you have a pressure drop. If the pressure drops, the actuator will take longer to operate, and the efficiency of the machine is marred. An actuator is a mechanical part that makes a specific physical movement in the automated manufacturing process. If the pressure drops, this movement takes longer, and the end product will take longer to produce – whether it's a plastic bottle, a soda can, or the doors of a car.

Considering this perspective, air leakage is detrimental. It wastes time and energy and leads to more rapid wear on a machine, which results in further faults – potentially even more leaks. It makes sense, then, to be more vigilant about leakages and invest effort in locating and fixing them.

However, 'finding a leak is cumbersome,' says Prof. Ing. Emmanuel Francalanza, Digital Manufacturing Expert at the Department of Industrial and Manufacturing Engineering. The machines are loud, so it's almost impossible to hear the hissing sound of a leak in a factory. Furthermore, we're talking about massive production halls with hundreds, if not thousands, of failure points. Technology present in the market uses microphones and noise analysis to find leaks, but this usually happens as part of an audit or annual shutdown, which is not prompt enough to deal with issues.

DEALING WITH THE LEAK

Currently, dealing with air leakages is problematic. However, the AIR SAVE project uses novel technologies and AI to monitor the parameters of high-pressure compressed air systems and compare these to a benchmark to find faults.

The preliminary research began around 2018, when the investigators started exploring how pneumatic systems consume and waste energy. Their enquiry into this issue grew into a collaboration because they wanted to understand how much energy and air these systems would consume.

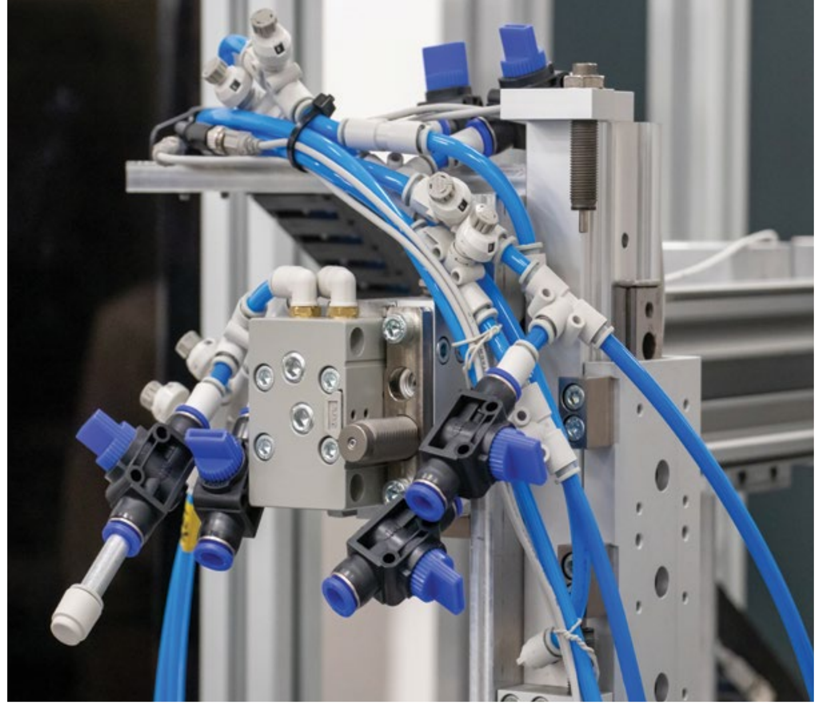
Two years passed, and when the project participants started understanding consumption better, they applied for research project funds in 2020. The AIR SAVE project's official kickoff took place in 2021, when the Malta Council for Science and Technology approved funding of the project.

As the three-year project is nearing completion, the team is happy with the progress achieved. They've collected an immense amount of data that is being used to train AI and optimise AIR SAVE. 'As we're hitting the goals we had set, we're also seeing further questions arising that will help us improve our system in the future,' Refalo says.

AIR SAVE has led to an Industrial Internet of Things solution that integrates hardware and software solutions. Its software communicates with smart sensors installed in industrial equipment. These sensors can be fitted when machinery is built or retrofitted to already operating machinery. Furthermore, AIR SAVE's software can collect information from sensors already installed in machinery for other purposes.

'AIR SAVE collects and analyses data in real time,' Francalanza says. 'In the framework of this project, we've analysed the data to identify what the best parameters to use for machine learning are, and we've developed the machine learning algorithms to identify and characterise the faults industrial machinery may exhibit,' he adds.

This high-tech solution notifies the company where faults in the production line are located and quantifies the costs and CO_2 production so plant owners can make educated decisions on dealing with air leaks. Based on the big data the project has been collecting, the project team has also improved the solution to not only monitor and locate issues but also control the systems for more efficiency.



The AIR SAVE system at work
Photos by James Moffett

Ideally, once faults have been identified, one expects that they are simply removed. If there's a clogged filter creating a pressure drop, for example, ideally, it is cleaned or changed. If there is a leak, it should be fixed. While this approach sounds like common sense, due to the cumbersome nature of locating air leaks, the industry simply does not approach leaks in this manner.

Many times, the industry just lives with leaks. The AIR SAVE team is well aware of this approach and is here to offer a solution. AIR SAVE aspires to become a control system for uninterrupted operations, helping plant operators maintain productivity while reducing the effects of faults, leaks, and pressure drops.

The system, therefore, provides information on which pressures and flow rates to increase or reduce to maintain productivity with a smaller impact on energy consumption and lower levels of generated CO_2. Thanks to its optimisation techniques, AIR SAVE offers tangible solutions to industrial issues. It uses multi-criteria decision-making techniques rooted in AI, such as heuristics algorithms, genetic algorithms, and particle swarm optimisation to come up with the best solutions for problems caused by air leakage.

The investigators apply a hands-on approach to the oft-discussed gap between academia and the business world. To bridge this gap, AIR SAVE works together with industrial players. Coming from the industrial and manufacturing engineering department, by default, the research that the team carries out and the problems that they solve are industry-oriented.

However, to translate research into practical solutions, AIR SAVE collaborates with AIM Enterprises Ltd., which brings the understanding of real problems from the industry into academic research. Business representatives and researchers work together to solve real, existing issues in the market.

The project also has an Industrial Advisory Board, with representatives from ST Microelectronics, Methode Electronics, and Toly Products Limited – three of the main manufacturing companies in Malta. This holistic collaboration allows the project team to break the glass ceiling of the laboratory and extend their solutions to the industry.

INDUSTRIAL COMPLEXITY

As with any project, AIR SAVE has seen ample challenges. 'One of the main challenges was the learning curve. As with any project, it takes time to build momentum, the know-how, and the knowledge necessary to understand the problem better. As we're venturing outside the lab walls, we've had to understand the requirements and issues of collecting data in industrial operations,' Francalanza says.

Another challenge has been complexity. 'Compressed air systems can be very complex. To prepare for this, we constructed a system in our laboratory that's as close to an industrial setting as possible for experimenting with our approach,' Refalo says. Typically, research in this area is carried out on systems made up of two or three actuators. The greater the number, the more complicated such a system becomes. Therefore, AIR SAVE constructed a system with eight actuators to make it complex before going into industry and testing the system in real environments.

Now that the project is wrapping up, AIR SAVE's next step is entering the market. The inventors have filed an initial patent application in the United Kingdom and are currently looking for potential investors and interested parties willing to work with them and their industrial partner to implement this solution in the industry.

The AIR SAVE consortium, comprising the UM and AIM Enterprises, is funded by the 'R&I Fusion - Technology Development Programme' of the Malta Council for Science and Technology (R&I-2020-008T). The project is led by Prof. Ing. Paul Refalo from the Department of Industrial and Manufacturing Engineering at UM, in collaboration with Prof. Ing. Emmanuel Francalanza from the same department, and Dr Peter Xuereb from the Faculty of Information and Communication Technology. The research team includes two Research Support Officers and Ph.D. students, Massimo Borg and Jasmine Mallia, along with Jurgen Aquilina, a Master by Research student.

The AIR SAVE team from left to right: Jasmine Mallia, Prof. Ing. Emmanuel Francalanza, Massimo Borg, Prof. Ing. Paul Refalo, Dr Peter Xuereb and Jurgen Aquilina
Photo by James Moffett