ANALYSIS AND RECOVERY OF A COMPRESSED AIR RESERVOIR: PNEUMATIC AUTOMATION WORKBENCH

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Abstract
Air reservoirs are equipment highly used in pneumatic processes within engineering. Such equipment can often have discontinuities and defects that prevent them from operating efficiently. From the need to recover the potential of this machine, it is interesting to apply nondestructive tests that can monitor parts and control the quality of the equipment, through methods that provide important information about product defects, and present low operating costs and do not damage the machine. Thus, the objective of this work was to apply visual inspection, liquid penetrate inspection and ultrasonic testing in a compressed air reservoir of a didactic pneumatic bench, to detect discontinuities and, thus, try to eliminate them. Thus, after the equipment went through a sanding process, it was verified the presence of incrustations inside, through the use of the ECO-610 Endoscope and, through small holes, through the liquid penetrate inspection, which allowed the filling of such holes with application of filler metal by MAG welding method. As results, after the recovery, the reservoir passed again the nondestructive tests performed, showing no problems. Finally, a test with pressure above work was performed in which no failure occurred, which ensured the effectiveness of the process.
Keywords: Nondestructive testing, corrosion, preventive maintenance.

Resumo. Os reservatórios de ar são equipamentos muito utilizados em processos pneumáticos pela da engenharia. Esses equipamentos podem frequentemente apresentar descontinuidades e defeitos que os impedem de operar com eficiência. Pela necessidade de recuperar o potencial destas máquinas, é interessante a aplicação de ensaios não destrutivos que possam monitorar peças e controlar a qualidade do equipamento, por meio de métodos que forneçam informações importantes sobre defeitos do produto, e apresentem baixos custos operacionais e não danifiquem o equipamento. Assim, o objetivo deste trabalho foi aplicar inspeção visual, inspeção de penetração de líquido e ensaio ultrassônico em um reservatório de ar comprimido de uma bancada pneumática didática para detectar descontinuidades a fim de tentar eliminá-las. Dessa forma, após o processo de lixamento verificou-se, com o uso do Endoscópio ECO-610, a presença de incrustações em seu interior e, também, de pequenos furos pela inspeção de

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penetração do líquido que foram preenchidos com a aplicação de metal de adição pelo método de soldagem MAG. Como resultados, após a recuperação, o reservatório passou novamente por testes de desempenho não destrutivos, não apresentando problemas. Por fim, foi realizado um teste de pressão e não ocorreu nenhuma falha, garantindo a eficácia do processo.
Palavras-chave: Teste não destrutivo, corrosão, manutenção preventiva.

1 Introduction

According to Hellier (2003), nondestructive testing (NDT) is among the main tools for quality control and monitoring of materials and components, being widely used in industrial sectors, in order to contribute to the quality monitoring of goods and services cost reduction, preservation of life and environment, being a factor of competitiveness. Besides being a fundamental piece to guide studies whose main objective is to increase the reliability indices of industrial equipment (ANDREUCCI, 2008). Nondestructive testing includes methods that provide information about the degree of defects in a particular part or product, the technological characteristics of a material, or the follow-up of component, equipment, and structure degradation (CARTZ, 1995).

Advantages of this method can be pointed out the ease of application, the low cost associated, the possibility of performing tests with the equipment in operation, eliminating the need for interruptions of its operation and being nondestructive, do not present damage to the part. Constant monitoring of equipment is of great importance, as the preventive detection of problems allows the use of simpler and economical methods for its repair (SOUZA *et al.*, 2009; MESQUITA, 2012; LORENZI *et al.*, 2016). NDTs are widely used for fault analysis, seeking to identify hidden defects that may lead to the resolution of the identified problem, as presented by Barretto *et al.* (2012), in which the catastrophic failure of a flow control valve stem by ultrasonic testing (UT) and liquid penetrate inspection (LPI) was analyzed. Failure analysis is an important tool in the search for increased equipment reliability (AFFONSO, 2006).

The main nondestructive testing techniques include visual inspection (or visual testing, VT), LPI and UT. Visual testing is a simple technique to detect not only surface failure or structure distortion, but also the degree of finish and shape of a part. The result depends on the conditions of access to the place, the environment (lighting) and, mainly, the capacity and experience of the responsible person. LPI is based on the penetration of liquids into cracks and surface cracks of parts by capillary action, with the help of a developer it is possible to detect discontinuities not noticeable by visual inspection. In the ultrasonic testing, waves or ultrasonic impulses are used to detect surface or internal defects of materials, either by transparency (with constant ultrasonic vibrations) or by reflection (with ultrasonic pulses) (GARCIA; SPIM; SANTOS, 2010).

In the present work, the objective was to apply END (VT, LPI, UT) methods to check the defects and discontinuities present in a compressed air reservoir of a pneumatic automation workbench.

2 Development

The air reservoir used in this study was the pneumatic automation workbench located at the Federal Institute of Education, Science and Technology of Espirito Santo - IFES (Sao Mateus, Brazil), which presented defects that prevented its use, did not maintain the pressure to which it was submitted. Figure 1 illustrates this reservoir.

Figure 1 - Compressed air reservoir

Source: Authors, 2019

The first step of the work was to perform the VT. By attempting to use the equipment, it was found that the defect was in the lower part of the reservoir, showing leakage. To remove the paint layer from the equipment, the analyzed region was sanded with silicon carbide sandpaper (80, 100, 200, 400 mesh size). Two forms of sanding were performed, manually and with the aid of an automatic sander. After removal of the paint layer, no visually perceptible defects were identified. Figure 2 illustrates the bottom of the reservoir after this design step.

Figure 2 - Reservoir after bottom sanding

Source: Authors, 2019

Thereafter, the reservoir wall thickness was measured by ultrasonic testing, according to Abendi PR-036 standard, in which it is possible to discover the existence of some internal crack. The equipment used was the Karl Beutch ultrasonic, Figure 3, with an accuracy of 0.01 mm.

Figure 3 - Ultrasonic equipment used

Source: Authors, 2019

By measuring the reservoir thickness by the ultrasonic testing, some discontinuities were detected localized along the surface, leading to the idea that some pits could be formed. According to Nunes (2007) the formation of electrochemical corrosion presents the main characteristic of interaction of metallic material with an electrolyte (in this case the aqueous medium located by the endoscope), where from these interactions occurred the formation of corrosion cells that led to deterioration of material. This type of corrosion is a process that occurs very often in nature, also manifesting in equipment in various production systems, especially when they do not have proper maintenance or non-compliance with regulatory requirements (CARVALHO *et al.*, 2016; SILVA, 2017). With the help of an ECO-610 endoscope, Figure 4, it was possible to analyze the inner part of the reservoir to check for defects.

Figure 4 - ECO-610 endoscope

Source: Authors, 2019

According to the images obtained, Figure 5, it was observed the presence of incrustations present inside the reservoir, especially in the lower part, where visual inspection was performed. These fouling were possibly caused by the accumulation of contaminant residues that entered the system, such as dirt, lubricants and water.

Figure 5 - Images obtained by the endoscope

Source: Authors, 2019

The liquid penetrate inspection (LPI), Type II - Technique A, was performed according to Abendi PR-001 standard. First, the surface was cleaned with a wire brush, then according to Figures 6 and 7, the E-59 remover was used to remove any substance still on the surface. With the surface clean and dry, LP SKL-WP was applied leaving the surface resting for 30 minutes as recommended by the manufacturer. After standing time, the test surface was washed with running water, dried and the developer SKD-S2 applied.

Figure 6 - Products used: remover, liquid penetrant and developer

Source: Authors, 2019

Figure 7 - Application of the remover and liquid penetrant, respectively

Source: Authors, 2019

After a few minutes of developer application, Figure 8, holes were detected. These were marked and drilled with the aid of a drill.

Figure 8 - Reservoir bottom after developer application and drilling

Source: Authors, 2019

Then, the reservoir was sent to the welding laboratory of the Federal Institute of Education, Science and Technology of Espirito Santo - IFES (Sao Mateus, Brazil), in which the holes were filled with filler metal filler. The welding process used was the MAG (Metal Active Gas), Figure 9, applying as parameters a voltage of 19.6 V, a speed of 82 IPM and a copper-coated steel electrode.

Figure 9 - MAG welding equipment and reservoir after welding

Source: Authors, 2019

Again, the reservoir has returned to the sanding step to improve surface finish. Then, the LPI was performed again so that it could analyze the quality of the solder performed. As shown in Figure 10, the assay revealed some pores in the filler regions of the weld. These pores must have been caused by insufficient gas addition at the time of welding, causing the filler metal to react with ambient air.

Figure 10 - Revelation in the weld region through the LPI

Source: Authors, 2019

Due to the formation of these pores, the reservoir returned to the drilling and welding steps again. After undergoing the LPI and UT, the recovery process was continued, finally performing another cleaning and then painting the reservoir, finished as shown in Figure 11.

Figure 11 - Reservoir after cleaning and painting

Source: Authors, 2019

Upon completion of the recovery process, the reservoir returned to the pneumatic bench and was tested with pressure above working pressure and operated without leakage. Thus, he began to perform his duties regularly, demonstrating the effectiveness of the work developed.

3 Conclusion

When performing the reservoir recovery process, discontinuities were detected by the ultrasonic testing, previously identified with LPI, which was some localized points of corrosion, characterized by its geometry as pitting corrosion. This defect may have occurred due to the presence of scale (formed by water and impurities) that were located at the bottom of the reservoir, as shown by the endoscope.

As the reservoir worked at room temperature and without aggressive fluid, it was evaluated that the deterioration of the reservoir was due to the formation of electrochemical corrosion. As improvement measures for the equipment, preventive maintenance may be performed on the bench, especially in the filtration and trap areas to prevent contaminants from entering and effective output if needed, performing ultrasonic inspections to check for changes in the thickness of the reservoir.

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