by Matej MIKLAVČIČ and Darko HOČEVAR | FerroECOBlast® | www.ferroecoblast.com

Robot-Controlled Shot Peening System for Landing Gear Overhaul

THE PROCESSING OF AIRCRAFT CHASSIS

The landing gear is the only aircraft system without built-in redundancy which means that 100% reliability of operation must be ensured for the pilot, crew and passengers. All the loads absorbed by the chassis during its life cycle should be taken into account, comprising tens of thousands of take-offs and landings, plus high mileage on the track.

Shot peening has always been one of the key processes in the production or overhaul of landing gear. The process is applied to the external and internal surfaces of the components. These are made of either high-strength steel (HSS) or modern aluminium and titanium alloys.

For the treatment of HSS components, steel-shot processing media is mainly used for achieving higher peening intensities. For the treatment of sensitive aluminium alloys, non-metallic media, such as glass or ceramic media, come into play at lower intensities.

Due to the complex geometry of the components and the technological requirements for various processing procedures, the integral solutions for the manipulation of nozzles and the regulation and control of the process prove highly complex.

The Ferročrtalič Company (FerroECOBlast®) has developed a robotic peening station featuring two connected chambers and two industrial robots. Thus, the full spectrum of shot peening treatment is covered. The peening station is designed in accordance with the requirements of SAE AMS 2432 concerning shot peening computerization as well as the strict instructions provided by the component manufacturers.

The process control is based on a complex technology, namely to achieve adequate productivity, efficiency and practical applicability of processed products, and all process parameters must be carefully regulated during the process itself.

The system is called ARSP+ARGB and is designed based on two robotic cells and intended for shot peening the outside and inside radii and surfaces of major aircraft landing gear components. As mentioned earlier, the constituent components made of different materials are of different sizes. The relevant shot peening requirements are beyond the capacity of any individual machining system. Consequently, the concept of two robotic cells associated with a conveyor line has been adopted. The intermediate conveyor line is intended for the manipulation of workpieces and connects the system as a whole.

The components are loaded onto the carrier rails by means of an integrated lift connecting the two cells. The workpieces are loaded onto one of the two trolleys featuring a synchronous servo rotary table, which enables the turning and precise positioning of the workpiece. Controlled by a robot controller, each synchronous drive of the rotary table acts as an additional (external) axis of the robot.

The ARGB cell is intended for shot peening at lower intensities within the Almen N range using a ceramic peening

Dual chamber shot peening system

medium. The medium collection and recirculation system is based on pneumatic transportation. The ARSP cell is for shot peening at higher intensities within the Almen A range using a steel medium. The Almen A intensities range requires a system that integrates the use of two different granulates in order to cover the whole spectrum. As a standard solution for steel granulates with a high specific gravity, a mechanical collection and transportation system is used.

With two separate cells featuring different processing media, the problem of covering the entire spectrum of treatment intensity has been solved. On the other hand, the challenge of the workpiece's complex geometry has been solved by the use of different processing nozzles and the appropriate technology to manipulate these. Used for the normal shot peening of external surfaces are traditional blasting nozzles fixed on a 6-axis robot manipulator.

The 6-axis nozzle manipulation system works in conjunction with a synchronous rotary table for workpiece manipulation. It provides a variety of mutual combinations of rectilinear and rotational movements.

It was necessary to solve the processing of small radii of internal diameters of 10 to 50mm and depths of up to 500mm. A special rotary lance featuring a small rotating nozzle has been developed for this application. The drive of the rotary nozzles is done by means of a small servo motor enabling a constant rotational speed and repeatable procedures. The above-described system has already been proven to be effective in the shot peening of internal diameters and grooves on LPT disks of jet engines. The rotary nozzle-featuring system is also fixed on a 6-axis robot offering all the manipulation options of conventional nozzles. The rotating and the conventional nozzles are interchangeable and fed by the same blast pressure generators.

Additional technological requirements for processing internal radii with diameters greater than 50mm and depths up to 1500mm require a different approach. For this purpose,

Transport trolley with synchronous turntable

an ITP (Internal Tube Peening) system featuring a long rotating machining arm with a nozzle at its end has been developed.

Two-axis linear movements are carried out in this case by a trolley moving along the conveyor line and the scissor type lifting mechanism.

Shot peening of aerospace components requires a continuous treatment without any interruptions. Any unplanned shutdown may result in a component not complying with the requirements and thus hazardous to operate. This is why the double pressure blast generator was adopted, enabling continuous processing by the simultaneous refilling with no noticeable air pressure fluctuations.

THE ROLE OF ROBOTIC MANIPULATOR

At FerroECOBlast, special attention is paid to industrial robots manufactured by ABB, whose features and functionality respond to all requirements such as SAE AMS 2432. Before the introduction of robots and CNC multi-axis manipulators, the process used to be solely based on "hard automation", mostly based on a single-axis processing nozzle manipulation.

The robotic manipulation of processing nozzles enables manufacturers to deal with shot peening processes with absolutely predictable machining cycle times, results and costs per cycle. By positioning repeatability at ±0.04mm and the resolution of individual axles between 0.001° and 0.005°, a robot can easily follow the outer contours of any large and complex piece with only a single nozzle and one program, and it can position a small rotating nozzle in the required technological openings with a second program.

By using the ABB RobotStudio simulation package, the robotic shot peening manipulator can be programmed off-line with no direct connection to robot. Then the program can be uploaded into the robot controller. However, most operators and programmers prefer to supervise the actual position of the nozzle relative to the workpiece. This is why most of the software is developed by the way of storing the positions of the robot along the desired path of movement using the manual control panel. By using it, the programmer can adjust the distance between the nozzle and the workpiece, the angle of attack as well as its speed, and can also adjust both the position and the speed of the rotary table. The software code is stored in the robot controller located outside the cell. Subsequently, any processing programs can be recalled by manually entering the serial number of the workpiece in the control computer or by simply scanning a product bar code.

Due to the aggressiveness of the robot manipulator's working environment, all the moving parts, both inside and outside the processing cell, must be well-protected against abrasive impacts specific to shot peening. The ABB robots of the IRB-series feature an improved level of IP protection (version FoundryPlus 2) and additionally protected by

Robotic manipulator featuring the rotary nozzle system

customized polypropylene protection they provide a perfect solution. Therefore, they comply with all the requirements for work in the abrasive environment characteristic of shot peening cells.

As well as being suitable for shot peening, durable and reliable, the robots must also be highly precise, repeatable and easy to program. A robot must offer a wide application range and provide sufficient freedom of movement to follow the contour of the entire workpiece. This especially applies for jet engines, where the requirements for processing large external and small inner radii are highly demanding. On the other hand, most of the work pieces rotate or move in front of the machining nozzles and therefore, their manipulation must occur at high speeds. Normally, linear speeds of 4 to 5m/min and rotations at approx. 720°/min are sufficient.

CLOSED-LOOP CONTROLS OF PROCESSING PARAMETERS

Not only have the robotic manipulators provided a superior method of manipulation processing nozzles, they have also proved crucial in improving the overall peening process. Using the incremental encoders on the servo drives of all the robot axis make a closed-loop feedback connection possible. Thus, the robot controller can be constantly supervised.

Closed-loop control of compressed air dosage and the mass flow rate of the peening medium have also contributed to the high reliability of the shot peening system. This is now able to operate from cycle to cycle without any supervision.

Currently, various technological solutions for the regulation of these process variables are available on the market. As an standard option ferrite media mass flow closed-loop control is commonly installed. This type of regulation is performed directly by means of the MagnaValve® magnetic valves.

The MagnaValve® is a normally closed valve regulating the flow of steel granulates for air shot peening systems. Its built-in sensor measures the mass flow through the magnetic valve. Together with a separate controller, it provides accurate and repeatable process mass flow.

Similar closed-loop systems, consisting of a proportional valve, i.e., a regulator and the control valve, are used for accurate and repeatable control of air pressure.

For technically complex aerospace components, shot peening procedures dictate specific requirements typical for a difficult-to-manage machining process. Given those requirements, the only logical and acceptable solution is following the procedure using robotic technology for manipulating the processing nozzles and cutting-edge systems for the closed-loop control of medium mass flow and working air pressure.

The entire processing cycle is supported by steel shot medium recovery and a management system comprising cleaning, volume-classifying and the automatic filling of cylinders. Modern systems are designed to allow operation with two or more different types of processing media.

Modern PLC-controllers with purpose-built software packages are used for control of the whole machining process. These are supported by the SCADA process visualization system on an industrial PC computer. The design of the modern SCADA systems allows for various functionalities, such as:

- process visualization
- real-time monitoring of parameters
- parametric programming and program recalling
- recording the history and printing messages
- flexibility of servicing manipulations and simulations of operation

Among these, we also find the SAE AMS 2432 standard requirements relating to the storage and archiving of process parameters, as well as their subsequent processing.

Conclusion

The shot peening systems described in this article provide exceptional quality from fully controlled and repeatable processes used for the treatment of complex components installed in military and commercial aircraft. Robotic shot peening systems contribute significantly to overall air traffic safety.

With the aerospace industries' increasing efforts to prolong the service life of their products, we are faced with more stringent and more precise requirements for shot peening. Our robotic shot peening system is a new tool used to optimize and extend the service life of components.