Automatic Tool Change System for Stringer Side Rivet and Bolt Anvils on a D-Frame or C-Frame Fuselage Fastening Machine

2017-01-2080
Published 09/19/2017

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CITATION: Merluzzi, J. and Bahr , I., "Automatic Tool Change System for Stringer Side Rivet and Bolt Anvils on a D-Frame or C-Frame Fuselage Fastening Machine," SAE Technical Paper 2017-01-2080, 2017, doi:10.4271/2017-01-2080.

Abstract

Manually changing stringer-side tooling on an automatic fastening machine is time consuming and can be susceptible to human error. Stringer-side tools can also be physically difficult to manage because of their weight, negatively impacting the experience and safety of the machine operator. A solution to these problems has recently been developed by Electroimpact for use with its new Fuselage Skin Splice Fastening Machine. The Automatic Tool Changer makes use of a mechanically passive gripper system capable of securely holding and maneuvering twelve tools weighing 40 pounds each inside of a space-saving enclosure. The Automatic Tool Changer is mounted directly to the stringer side fastening head, meaning the machine is capable of changing tools relatively quickly while maintaining its position on the aircraft panel with no machine operator involvement. Additionally, since the tools are all contained within an interlocked enclosure, this system reduces the required frequency of tool recalibration which also saves time and increases productivity. Other features of this system include machine crash protection, tool interface automatic blow off, and tool RFID.

Introduction

The Automatic Tool Changer (ATC) has been successfully integrated into Electroimpact's latest D-Frame fastening machine *(see Figures 1, 2, 3)*. This system would be an appropriate addition for any vertically oriented fastening machine (including C-Frame machines) where production rate is critical. The ATC system has three practical advantages: reduced potential for human error, increased operational safety, and increased machine productivity. These benefits will be demonstrated in the following sections.

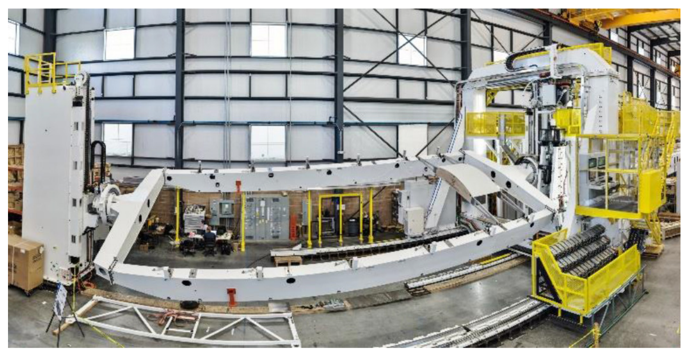

Figure 1. Electroimpact Skin Splice Riveter.

Figure 2. Mounting the ATC directly to the lower fastening head allows the machine to maintain position during tool change.

Figure 3. ATC and lower fastening head below test panel

Mechanical Design Features

Grippers

The ATC employs tool grippers and interfaces developed and cycle tested by Electroimpact *(see Figure 4)*. The gripper finger design uses only mechanical spring force to grip a tool and does not require any electrical or pneumatic input. The grippers are capable of securely holding, manipulating, and precisely positioning an object weighing over 40lbs with an eccentric center of mass. Tools can be installed in the grippers and removed by hand with relative ease.

Figure 4. ATC grippers and tool interface

Carousel

A servo-driven, crescent shaped carousel is used to rotate the tools to the correct position *(see Figure 5)*. The carousel is mounted on a pneumatically actuated sled, which allows for the ATC to be in a compact orientation during normal machine operation. The crescent shape enables the carousel to be positioned as close as possible to the fastening head in the compact orientation. During a tool change routine, the carousel expands and rotates the anvils to the desired position *(See Figure 6)*.

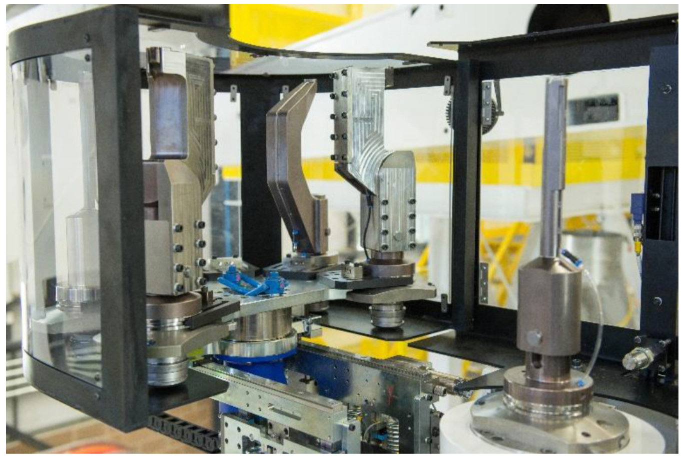

Figure 5. Crescent shaped carousel and fastening head (carousel shown in expanded position)

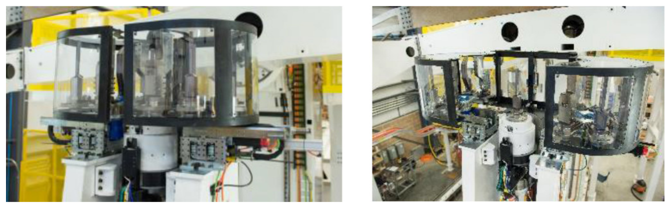

Figure 6. ATC compact vs. expanded orientation.

Vertical Compliance

The assembly is mounted on vertical linear bearings and rests on preloaded springs *(See Figure 7)*. This allows for compliance in the vertical direction in the case where the fastening head crashes into the ATC during a tool change routine. If this happens, a proximity sensor is triggered and the machine stops before damage occurs.

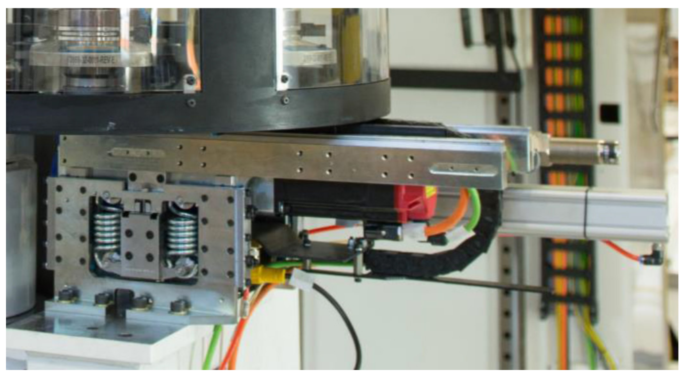

Figure 7. Preloaded springs allowing for vertical compliance

Other Features

Other system features include a pneumatically actuated machine/tool interface which holds tools securely and precisely. An air nozzle clears the machine/tool interface of swarf during tool changes to ensure tools are seated correctly. Additionally, each tool has a unique RFID chip which is detected by this interface *(see Figure 8)*.

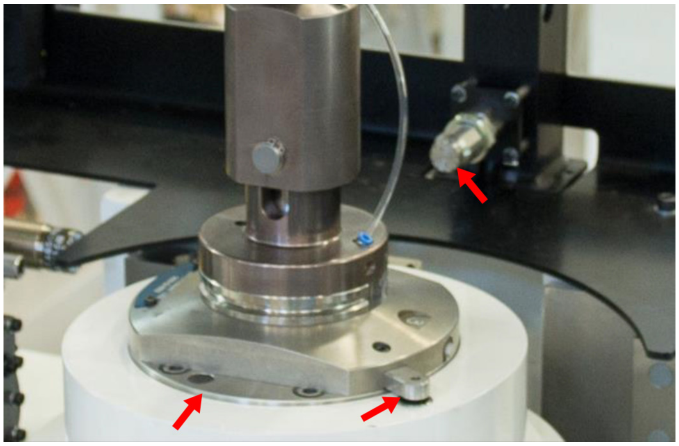

Figure 8. Left to right: Machine interface, tool RFID chip, and air nozzle

System Advantages

Safety

The ATC system requires no physical involvement of the machine operator. This means that the operator is not required to handle potentially heavy tools and is not required to put themselves in compromising situations to install and remove those tools. However, mounting the tool change system directly on the machine requires measures to ensure that the tools cannot fall out and cause damage or injury. To prevent the tools from falling out of the ATC, the carousels are enclosed on all sides in both the expanded and compact orientation *(See Figure 8)*. The safety enclosure has maintenance access doors which are interlocked with safety switches. The switches prevent all motion when the doors are open, reducing the risk of injury of maintenance personnel.

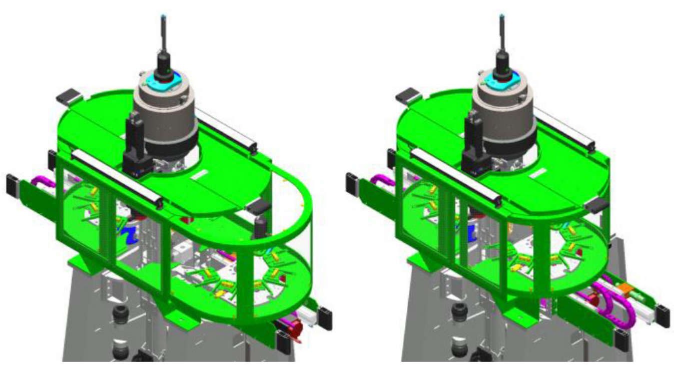

Figure 8. ATC enclosure (depicted here in green), fully encapsulates anvils.

Human Error Reduction

Manual tool changes present various ways that human error may be introduced into the tool change procedure. The automatic tool change system reduces the potential for tool misalignment (i.e. due to debris on the machine/tool interface) and damage (due to tools being installed harshly or being dropped). Additionally, the RFID chip in the tool base provides a guarantee that the correct tool was installed. Overall, the potential for tool misalignment, installing the wrong tool, and damaged tools/interfaces are all reduced by removing operator involvement from the tool change procedure.

Error Detection

The ATC has been instrumented with sensors to ensure that the entire device is functioning as intended. This includes sensors to determine that the correct gripper is empty before dropping off a tool, and also that the desired tool is present in the ATC before attempting to execute the pickup routine. If an error is detected at any time during the operation of the ATC a descriptive error message is displayed to the operator detailing which component is the likely problem and potential ways to easily remedy the situation. This allows the operator to attempt to recover the error before involving the maintenance team which leads to reduced machine downtime and in turn higher production rates.

Productivity

Lower Tool Calibration

In addition to their primary function as a safety interlock, the switches on the enclosure doors also signal that upon opening the doors, lower tool calibration must be performed before running a fastening cycle due to the now unknown status of the tools loaded into the ATC. If the doors have not been opened, calibration status is saved for all tools stored in the ATC. This allows for time-consuming calibration procedures to be ommitted when tools are changed automatically.

Time Savings

An automatic tool change sequence using the ATC is completed in approximately thirty seconds. A manual tool change would require moving the machine to a position where the operator can access the lower tool interface. Additionally the operator would be required to pick and drop off the tools manually. This process could take up to 10 minutes of down time. In this way, the ATC allows for an increased percentage of machine time to be spent on fastening operations.

Tool Change Sequence

The tool change sequence is outlined here. Refer to Appendix A.

1. Fastening head is at panel position, ATC is in compact orientation
2. Fastening head retracts to tool change position
3. Appropriate carousel translates to allow for rotation
4. Carousel rotates to the correct gripper position for pickup
5. Carousel translates to engage gripper
6. Fastening head anvil interface unlocks and fastening head retracts to free tool from interface
7. Carousel translates to allow for rotation
8. Carousel rotates to new tool position
9. Carousel translates to position tool over fastening head
10. Fastening head extends to engage tool and locks onto tool
11. Carousel translates to allow for rotation
12. Carousel rotates to compact position
13. Carousel translates back to compact orientation
14. Fastening head extends to panel position

Summary/Conclusions

The Automatic Tool Change system presented here has be shown to increase machine productivity through time savings and reduced tool calibration requirements. It has also been demonstrated to improve operational safety and reduce the potential for human error by removing operator involvement from tool change routines. As tested and designed, it is compatible with any vertically oriented fastening machine.

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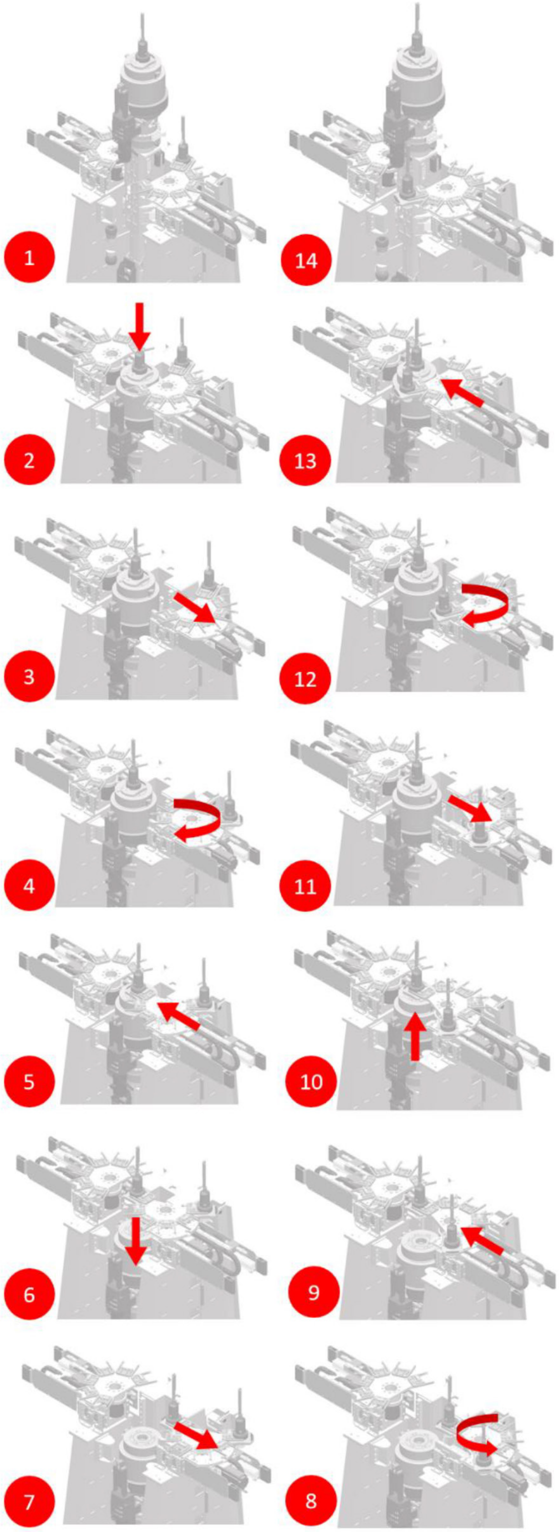
APPENDIX

APPENDIX A: TOOL CHANGE SEQUENCE



ISSN 0148-7191

http://papers.sae.org/2017-01-2080