

Automated Coaxial Squeeze Riveter

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ABSTRACT

Electroimpact has developed a new automated squeeze riveting process. This process utilizes an innovative coaxial riveting head design in which the drill spindle and rivet driver share a common servo axis, with a simple toggle mechanism to switch which tool is active. This system has been optimized for the installation of headed solid rivets which can be automatically installed without the need for additional process tools beyond the drill and driver. By optimizing for the requirements of these rivets, Electroimpact has been able to eliminate much of the complexity typically seen on automated fastening equipment, resulting in an unprecedentedly simple and cost-effective design.

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INTRODUCTION

An effort has been underway at Electroimpact to develop a new automated squeeze riveting process which enables the installation of several types of rivet which are not well suited for installation using the EMR technology [1] that Electroimpact has traditionally relied upon. The process is accomplished using a new coaxial riveting head design which is designed to be as simple as possible to minimize costs while achieving an exceptionally fast rate of fastener installation and meeting the quality requirements of aerospace manufacturers.

The coaxial riveting head is ideally suited for installing flush head rivets (e.g. NAS1097, MS20426) and universal head rivets (e.g. MS20470). It is limited to fasteners with a manufactured head that do not require the head to be shaved (milled off) after bucking.

SYSTEM OVERVIEW

The riveting machine consists of two riveting heads mounted to a supporting "U-frame" structure. Riveting is accomplished along a horizontal axis with the workpiece held in a predominantly vertical orientation. Compared to vertical-axis riveting, this approach provides better accessibility to the heads for manual tool change and maintenance. Additionally, by holding the panel vertically, any chips that are not collected by the vacuum system will tend to fall away rather than lingering on the workpiece surface.



Figure 1. Automated squeeze riveting machine utilizing the coaxial head design

The system is controlled by a Fanuc 31i CNC and its servo axes are powered by Fanuc Alpha motors. Secondary feedback is provided by Heidenhain LC493F encoders which utilize the Fanuc serial interface.

COAXIAL (OUTER) RIVETING HEAD

Spindle Housing and Floating Headstone

The spindle housing (Fig. 3) forms the main structure of the coaxial end effector. It is a machined out of a solid block of aluminum using a 5-axis CNC milling machine. The

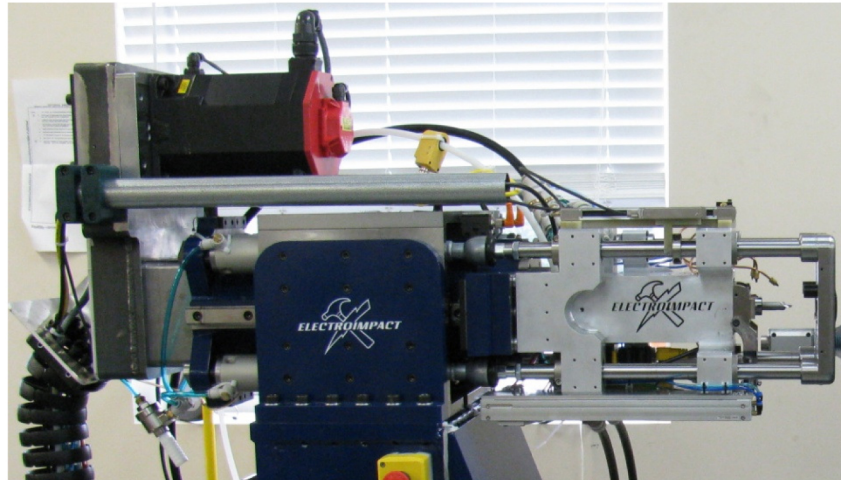


Figure 2. Coaxial riveting head

critical final machining steps are all performed in one setup to produce an end product that conforms to the tight tolerances required. The central feature of the housing is the bore into which the spindle is fitted. The housing is also equipped with a multitude of other machined features for mounting the various subassemblies that make up the end effector.

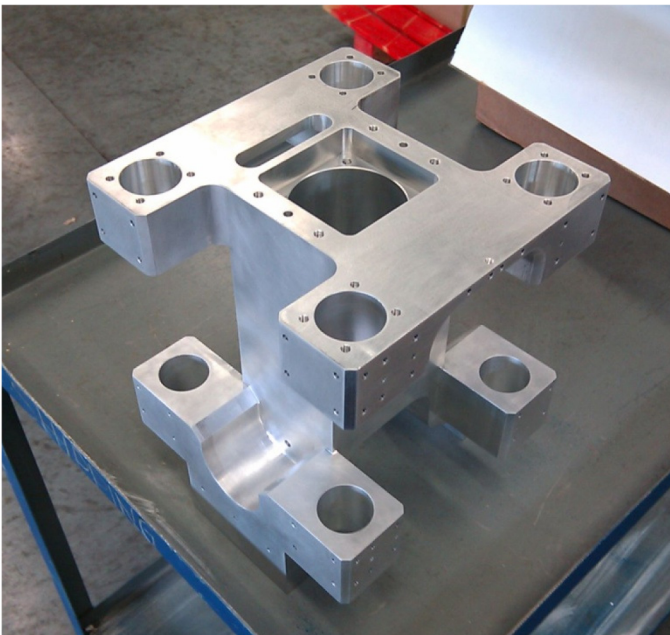


Figure 3. Spindle housing

The spindle housing is box-shaped and features four pairs of concentric bores, parallel to the spindle axis, located at the corners of the “box.” These bores are fitted with linear ball bushings and support a set of four shafts. The shafts are connected at the rear to pneumatic cylinders and at the front to the headstone (clamp plate). Together, the air cylinders, shafts, and headstone comprise the floating headstone assembly (Fig. 4).

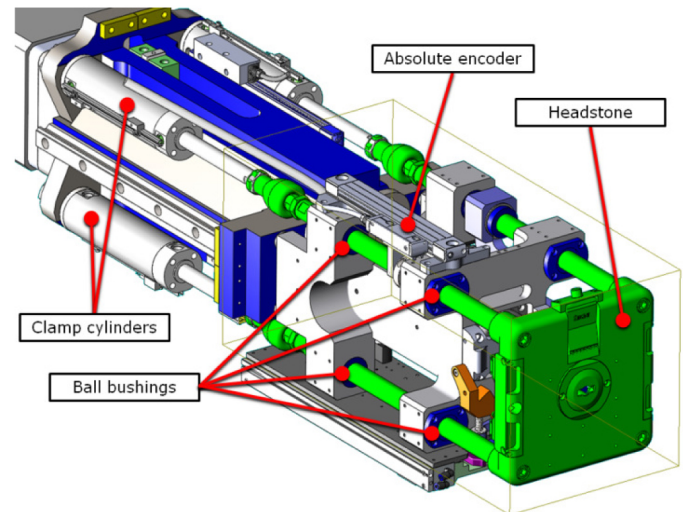


Figure 4. Floating headstone assembly

Mounted to one of the shafts is the read head of a Heidenhain absolute linear encoder. The body of the encoder is mounted to the spindle housing. As the floating headstone moves relative to the spindle housing, the encoder provides displacement feedback to the CNC.

The headstone is fitted with a set of four laser distance sensors used for normality correction as well as measurement of the distance between the contacting surface of the headstone and the part surface. This is a configuration which Electroimpact has successfully implemented on several recent automated fastening machines.

On many riveting machines, the outer (upper) clamp assembly is mounted directly to the supporting machine structure (typically a C-frame) and cannot be moved in the Z axis, thus creating a fixed working plane and requiring that the surface of the workpiece be brought to that plane before each cycle. On the coaxial head, the headstone is mounted to the outer head and moves along with it. This means that it is

possible to clamp up and install a rivet at any point along the Z axis within a certain range. For some applications, this may eliminate the need for an independent Z axis on the part positioner.

Flip-up Rivet Buck Mechanism

The driver assembly consists of a wishbone-shaped body made of tool steel fitted with an anvil and a pair of rivet-gripping fingers. The driver pivots on the pressure pad assembly, which is a plate made of tool steel that is fixed to the front of the spindle housing. The driver is actuated between two positions: a flipped-down “feed” position and an upright “drive” position. In the “feed” position, the driver points downward, with the fingers positioned in front of the rivet injector, and the drill bit is fully exposed so that drilling can take place. In the “drive” position, the driver surrounds the drill bit and brings the anvil and rivet into alignment with the freshly-drilled hole.

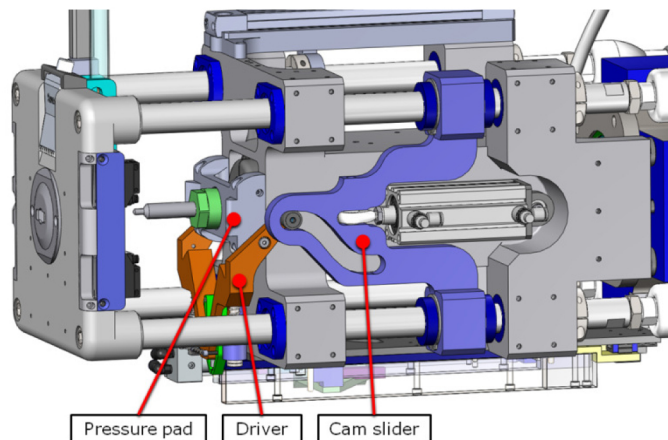


Figure 5. Pressure pad, driver, and cam slider (Driver in “feed” position)

The actuation between “feed” and “drive” is achieved via the cam slider assembly, which is a plate with a curved cam path that slides on two of the headstone shafts, powered by a small pneumatic cylinder. The curved shape of the cam path allows for some control of the acceleration and deceleration of the driver as it flips from position to position without the need of more complex and expensive methods of actuation such as a servomotor.

When the driver is in the “drive” position, it interfaces with the pressure pad at two locations (Figs. 6 and 7). The contact points on the pressure pad are concave, while the mating parts of the driver are convex. A curved Hertzian-contact interface was selected rather than a flat-to-flat interface to allow some compliance and avoid edge loading. Both parts are machined to very tight tolerances to ensure that they fit together properly, with wire EDM used to cut the critical curved interface features on both parts. Visual inspection of the first driver and pressure pad after installing several thousand rivets reveals a single linear mark on each of the pressure pad’s “cup” faces where the Hertzian contact

pressure reaches its maximum. The contact points are designed to be 100 mm apart, which was confirmed by measuring the separation between the marks on the worn-in pressure pad with a caliper.

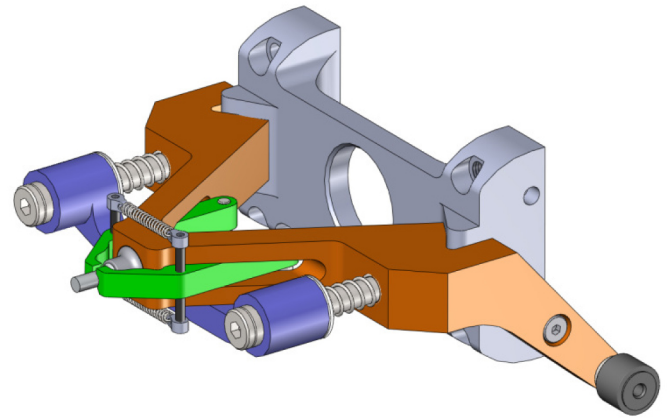


Figure 6. Driver and pressure pad, ready to insert rivet (“drive” position)

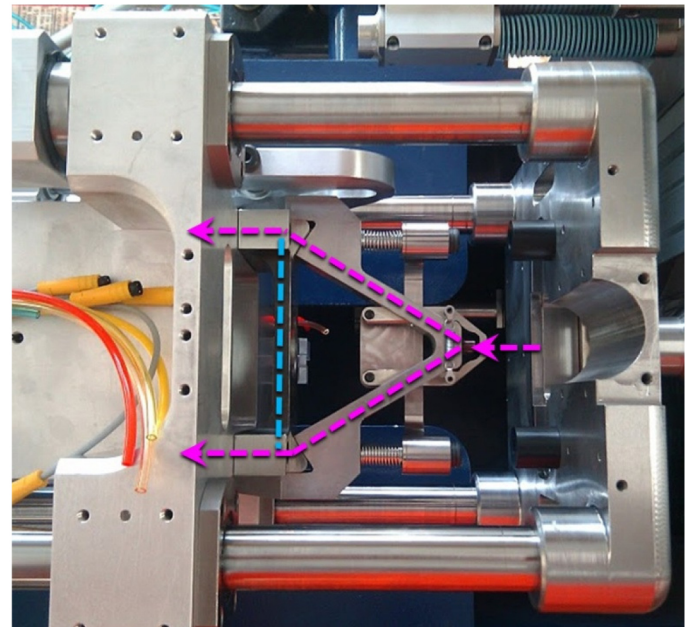


Figure 7. Driver and pressure pad, showing areas of compressive (magenta) and tensile stress (blue) during rivet upset

The primary function of the pressure pad is to turn a spreading force into a predominantly compressive force (Fig. 7). The driver and pressure pad together form a highly stable triangle structure, with the middle portion of the pressure pad taking a tensile load. This reduces the severity of the stress concentrations induced in the spindle housing and allows for the use of aluminum for the housing’s construction, saving a