

Offset Anvil for HH500

2012-01-1871

Published
09/10/2012

Carter Boad and Zory Taskar
Electroimpact Inc.

Copyright © 2012 SAE International

doi:10.4271/2012-01-1871

ABSTRACT

The handheld (HH) electromagnetic riveter (EMR) has proven to be an effective means of installing up to 7/16" diameter rivets in aircraft components. These devices are currently installing rivets on Boeing and Airbus planes all over the world. They are also very popular in China and Japan. However, there have always been difficulties with stringer access. A new version of light weight driver with interchangeable offset tooling was created to alleviate this problem. In addition, a disposable plastic wedge has been incorporated at the base of the offset ram to prevent stringer damage during the recoil.

INTRODUCTION

The handheld (HH) electromagnetic riveter (EMR), in its many forms, has proven to be a very useful tool to the aerospace manufacturing industry. Compared to traditional pneumatic riveting methods, the HH-EMR systems have demonstrated superior rivet installation quality and repeatability. They also boast reduced fatigue for the operators and are significantly quieter, both of which improve worker health and safety.

For nearly 25 years, Electroimpact has been developing and evolving the HH-EMR: First, a full range of tools for various fastener sizes was created and qualified for aerospace fastener installations. Then the weight of the tools was reduced to make them easier to operate. Next a spring-damper recoil system was incorporated to further improve ergonomics. Most recently, improvements have been made to the tooling to allow better access to under stringers with offset tooling, while reducing the probability of part damage through balanced ram design and a plastic wedge bumper.

The newest HH-EMR, the HH503, is now in the hands of its customer in the UK, replacing a much older system. It is used for both production rivets as well as panel repairs on the Single Aisle (SA) wing panel assembly line. The new system incorporates all the improvements made over the years as well as those detailed herein.

SYSTEM OVERVIEW

A typical HH-EMR system includes the following components: A pair of HH-EMR actuators (guns) and associated tooling, a pair of capacitor (cap) boxes, a controller, and for larger guns, a supporting gantry or jib cranes with tool balancers. See [figure 1](#).

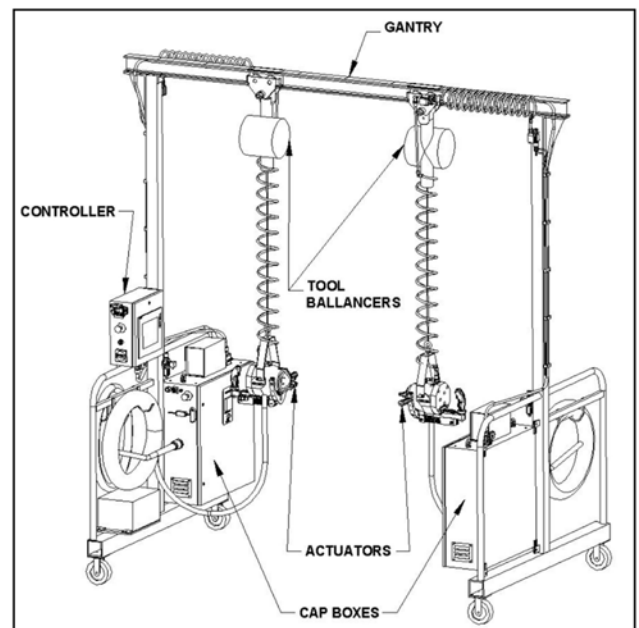


Figure 1. Overall HH-503 System

A pair of operators position the EMR actuators on opposing sides of a fastener. When the controller verifies that they are positioned correctly and the operator pulls the trigger, energy is synchronously released from the cap boxes into a coil inside each of the EMRs. This action forces a copper plate and driver/die assembly in each gun toward the fastener, forming the fastener in one controlled shot.

HH503 HH-EMR ACTUATOR

A typical EMR actuator consists of the following components: Front mass, back mass, coil/driver assembly, front tooling (offset ram, die), recoil mechanism, and handle. See [figure 2](#).

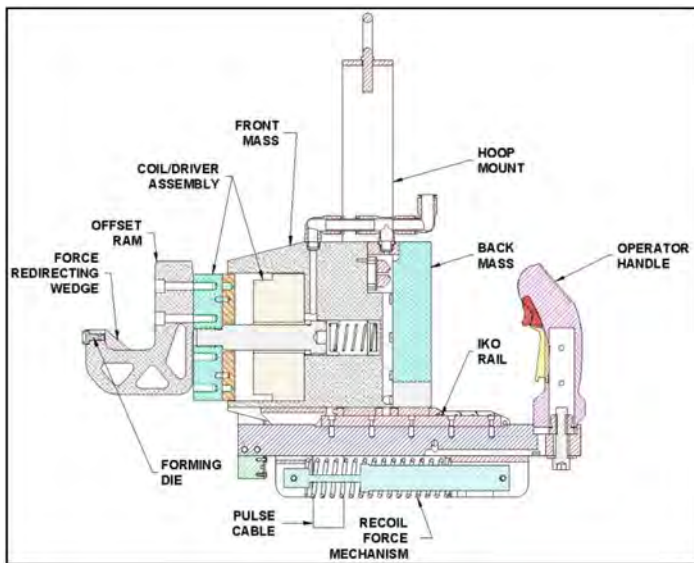


Figure 2. HH-503 Actuator Cutaway Diagram

Before the synchronized firing routine begins, the copper plate on the end of the driver has to be seated against the coil, and the forming die against the rivet. Then, when the trigger is pulled, energy (current) from the cap box travels through the pulse cable and is discharged through the coil. This creates Eddy-currents on the coil surface which excites the copper plate, forcing it towards the rivet. Based on the initial capacitor charge of the cap box, this system will provide repeatable output force, making it an ideal system for numerous manual rivet installations in the aviation industry.

The new system comes with interchangeable front-end tooling that bolts on the driver surface. Two sets are available for rivets on the stringer side: a long straight ram to clear the stringer and an offset ram for riveting a blind rivet under the stringer, each with a diameter specific rivet forming die. A shorter straight ram and die combination is used for the skin side of the rivet, so the operator can come as close to the panel as possible for best control. This tooling can be seen in [figure 3](#).

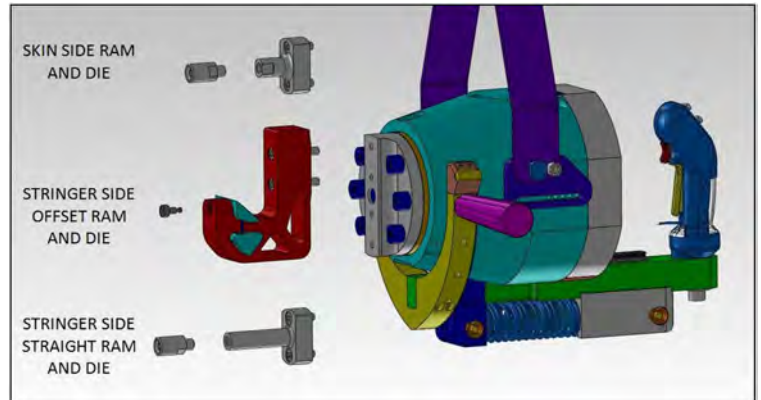


Figure 3. HH-503 Front Driver Tooling Options

ACCESS PROBLEM

The original HH503 works very well but is usually supplied with straight dies which require direct access to the fastener on both sides of the part. In this case, the customer needed a tool that had the ability to install fasteners using straight dies, but also a tool that is able to install fasteners under the crown (free flange) of a stringer. The obvious solution would be to use a U or J-shaped offset ram. See [figure 4](#).

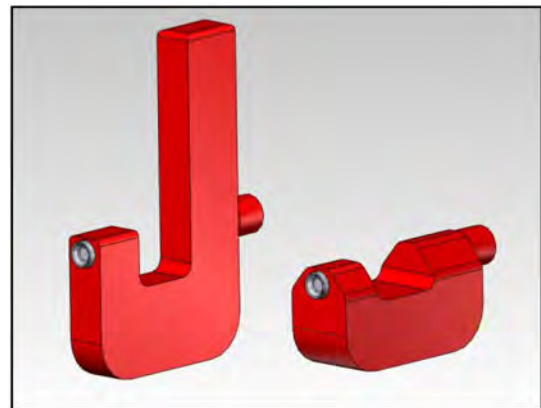


Figure 4. HH-503 Front Driver Tooling Options

We have used J-shaped offset rams on previous HH-EMRs and in fact, the system that this is replacing had a pair of offset rams just for this purpose. However, re-using the old rams presented a few issues. First, they used a different driver connection system which is incompatible with the new centerless-coil EMR design. Second, they were imbalanced and generate reaction forces perpendicular to the fastener centerline, making the gun difficult to control. Lastly, they offered no protection against contact with the aircraft parts. Most of the work presented here revolves around the last two problems.

Offset tooling has been used in aircraft assembly for decades. When coupled with an EMR however, the traditional J-shaped offset ram does exhibit some negative behaviors.

During the fastener forming process, the forces involved deform the ram, curling the end of the ram up and back toward the driver. The deformation along the axis of the EMR and fastener is acceptable, and just plays into the stiffness of the ram. But the deformation and force perpendicular to that axis have a couple of negative effects. On our full-sized Low Voltage Electromagnetic (LVER) riveting machines, some of the force is transferred to the fastener, evidenced by shifted or “smeared” rivet tails. The rest of the force is transferred to the driver and driver bearing, causing them to wear prematurely. When used with a HH-EMR, since there is no multi-ton machine to support the driver, that perpendicular force is transferred to the operator, as a torque applied to the wrist.

Protecting the aircraft parts being assembled from damage by the tooling is just as important as the fastener installation itself. The torque reaction described above can force the operator to rotate the tool into the part during the recoil event. Since the tooling must sometimes operate under a stringer, often with very limited clearance, contact with the part is inevitable. This contact must be able to take place without marking or damaging the aircraft components.

SOLUTION ANALYSIS

The goal of this project was to design a ram which does not create external perpendicular forces during or after rivet forming and to protect the surrounding parts from contact with the ram. The customer for this system had three main fastener access groups: Under-stringer, or “offset” fasteners, straight fastener with limited access close to the part, and basically unlimited access fasteners. In order to use the same HH-EMR for all three scenarios, and to facilitate tool changes with a minimum of steps involved, we designed three different rams. The aforementioned J-shaped offset ram for under stringer access. A long straight ram for straight fasteners with limited access, and a short straight ram for all other fasteners. We arrived at a universal mounting scheme where each ram can be interchangeably bolted to the front of the EMR, depending on where on the panel the customer is installing fasteners. This simple, self-aligning, attachment method uses counter-bored tooling and socket head cap screws which can be removed and replaced with common hex-keys.

The most critical ram design is the offset ram. First, the customer's specific needs were considered and a basic “first draft” ram was designed which could physically fit in the workspace available, and sized to withstand the forming forces involved using historical data. Since the attachment method had been sorted first, we were immediately able to model the ram and apply loads and constraints using ANSYS finite element analysis (FEA) software to gain a basic understanding of the stresses and deflections. See [figure 5](#).

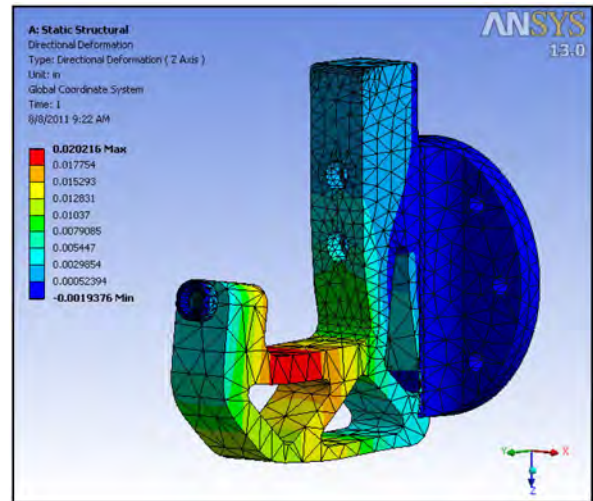


Figure 5. Offset Ram Finite Element Analysis

We have learned through experience that through careful removal of material in specific places through the ram's profile, we can affect the movement at the toe of ram where the die is located. This results in a truss-shaped ram. Next we embarked on a series of iteration cycles changing the profile and recording deflection and stress.

Working within the physical constraints of the material (heat treated S-7 tool steel) we were able to design a ram with total non-axial deflection of less than 0.001” at the center of the rivet die. This minimal deflection correlates to minimal perpendicular reaction forces as well so the operator is saved from having to resist torque imparted to the HH-EMR's handle. It also helps keep the recoil motion linear so that the ram does not deflect up or down into a stringer or other aircraft component.

Even though the recoil would now be controlled and along the axis of the fastener, we still needed to protect for unavoidable contact with the underside of the stringer. Many of our LVER machines use a Delrin or polyurethane “bumper” on the back of the ram's toe for this exact purpose, so we began to adapt that design to the HH-EMR's ram. Rather than a flat faced bumper which abruptly arrests the recoil stroke when contacting the stringer, we investigated an angular, wedge shaped bumper. This design allows the recoil energy to be shared by deformation of the bumper and gentle redirection of the recoiling tool away from the stringer.

A few different geometries of the wedge were evaluated. Trying to balance stringer access, part protection, and operator comfort, we found that the 40-deg wedge worked best. We also learned that by making the wedge slightly taller than the top of the ram toe, we were able to offer additional part protection without any negative consequences.

The bumper is disposable and is attached to the ram using two small SHCSs anchored in a second block which is nested in the front of the ram. Even though it is specifically designed as a perishable part of the tooling, the bumper did not show any signs of wear after more than fifty fastener installations during initial testing. See [figure 6](#).

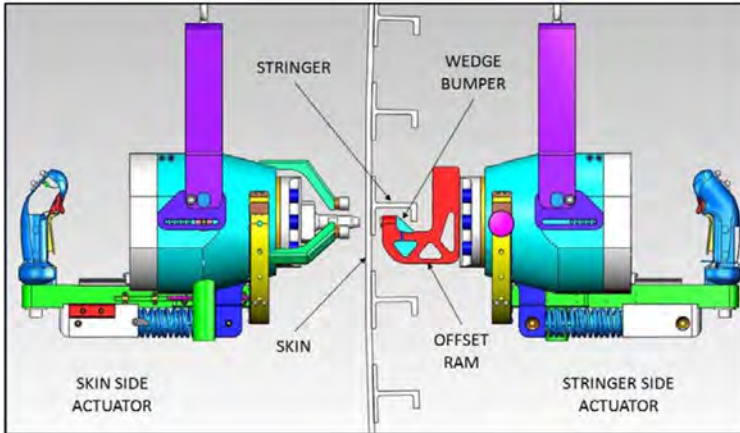


Figure 6. Offset Ram and Bumper

SUMMARY/CONCLUSIONS

Electroimpact has designed, tested, and delivered a new HH-EMR system that allows its users better fastener access, reduced operator discomfort, and enhanced part protection. Fastener access has been improved by the use of interchangeable tooling specifically designed for working in different areas of the wing. Operator discomfort and fatigue has been reduced by combining a spring/damper system, ergonomic handle placement, and a new offset ram design with no perpendicular deflection during use. And finally, even in the tight confines that the new ram is required to work in, the aircraft parts are protected through the use of a disposable plastic wedge, eliminating potentially costly metal on metal contact.

REFERENCES

- Hartmann, J., "Development of the Handheld Low Voltage Electromagnetic Riveter," SAE Technical Paper [902048](#), 1990, doi:[10.4271/902048](#).
- Hartmann, J., Brown, T., Pinkerton, B., and Nixon, K., "Integration and Qualification of the HH500 Hand Operated

Electromagnetic Riveting System on the 747 Section 11," SAE Technical Paper [931760](#), 1993, doi:[10.4271/931760](#).

DeVlieg, R., "Lightweight Handheld EMR with Spring-Damper Handle," SAE Technical Paper [2000-01-3013](#), 2000, doi:[10.4271/2000-01-3013](#).

Perley, W. and Zieve, P., "Lightweight HH503 Handheld Riveter," SAE Technical Paper [2002-01-2631](#), 2002, doi:[10.4271/2002-01-2631](#).

Taskar, Z., Tocco, B, Uetake, I. "Compact HH-553 Handheld Riveter", 08 FAS 0014, SAE Aerofast Conference, 2008.

Huffer, B., "HH54 Rugged and Reliable Handheld EMR," SAE Technical Paper [2009-01-3267](#), 2009, doi:[10.4271/2009-01-3267](#).

CONTACT INFORMATION

Carter Boad is a Mechanical Engineer and Project Manager, and Zory Taskar is a Mechanical Engineer specializing in hand held riveters at Electroimpact Inc.

Carter Boad
Electroimpact, Inc.
carterb@electroimpact.com

Zory Taskar
Electroimpact, Inc.
zoryt@electroimpact.com

DEFINITIONS/ABBREVIATIONS

- HH** - Hand Held
EMR - Electromagnetic Riveter
Actuator - EMR "gun"
LVER - Low Voltage Electromagnetic Riveter
FEA - Finite Element Analysis
SHCS - Socket Head Cap Screw

The Engineering Meetings Board has approved this paper for publication. It has successfully completed SAE's peer review process under the supervision of the session organizer. This process requires a minimum of three (3) reviews by industry experts.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

ISSN 0148-7191

Positions and opinions advanced in this paper are those of the author(s) and not necessarily those of SAE. The author is solely responsible for the content of the paper.

SAE Customer Service:
 Tel: 877-606-7323 (inside USA and Canada)
 Tel: 724-776-4970 (outside USA)
 Fax: 724-776-0790
 Email: CustomerService@sae.org
SAE Web Address: <http://www.sae.org>
Printed in USA