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HH54 Rugged and Reliable Handheld EMR

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ABSTRACT

The previous generation of handheld electromagnetic riveters (HHEMRs) Model HH53, designed and manufactured by Electroimpact, Inc., provided operators with a means of forming rivets and swaging collars onto bolts in a repeatable, single shot process with active recoil damping to reduce operator fatigue. In use the guns were sometimes dropped from an elevated operator platform and sustained considerable damage to both the gun and the power pulse cable attached to it. This was due to the lack of pulse cable/EMR attachments for support on the platform and the use of medium strength plastic body parts. The stiff attachment of the pulse cable contributed to cable breakage as well. The diameter of the gun also limited fastener access along upstanding stringer legs.

The next generation HH54 EMR design incorporates an internal recoil damper of the same design used in our full scale wing machine EMRs, a very flexible coaxial pulse cable attachment, and a new coil design which supports the driver bearing- eliminating the front driver bearing plate, all housed in a reduced diameter high strength glass/epoxy reinforced shell for durability. Additionally, the pulse cable assembly has been repackaged to remove tension loads from the pulse cable components and apply them to a load bearing outer strap member.

INTRODUCTION

Handheld electromagnetic riveters (HHEMR) have been designed and used in production environments to provide a simple, rapid, and high quality means of installing fasteners in airframe structures. Additionally, computer control of the EMR process provides high repeatability and a quieter work environment for the operator versus the use of pneumatic hammer riveting equipment.

Light weight HHEMRs capable of forming up to 3/16" diameter rivets have evolved recently to include spring-damper recoil systems to lessen the impact force transmitted to the operator. The object of the HH54 project is to streamline and simplify the spring-damper recoil system while reducing the overall diameter for increased fastener access using high strength materials for a more rugged and reliable handheld EMR.

HH54 EMR SYSTEM

MECHANICAL DESIGN – The HH54 actuator with the spring-damper system is similar in size and shape to a conventional pneumatic riveting gun. The mass of the actuator is 3.6kg (8 lbs).

Figure 1. HH54 Gun Assembly.

A basic analysis of the actuator function shows that the kinetic energy imparted to the driver (the ram/die that forms the rivet) is proportional to the ratio of the masses of the body and the driver (see Figure 3, Appendix). Efficient driver design is critical to ensuring a high output force while minimizing recoil.
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The HH54 driver was designed to have minimum mass, yet provide proper rivet formation. Because the HH54 is designed to form rivets up to ∅3/16", the required forming force can exceed 36 kN (8,000 lbs.). This must be resolved into a driver assembly, which has a mass of 0.28 kg (10 ounces including the rivet die). The HH54 driver is made from heat treated tool steel with a copper drive plate surrounded by glass fiber composite pieces for electrical isolation and is positioned normal and concentric to the coil face with an alloy shoulder bolt, which in turn is supported by a tool steel cylindrical bearing potted into the coil assembly. The benefit of this design is to eliminate the external driver bearing and associated structure that supports it at the rivet forming end of the gun, reducing the overall length and diameter and increasing access to fasteners located near obstructions. Another benefit is the ability to achieve optimum normality between the copper drive plate and the coil through a direct coupling path.

The rivet forming die is also made from hardened tool steel to inhibit cup wear. Retention of the die in the driver has been improved with a heavier threaded connection than previous light weight HHEMR models for increased durability.

Unlike previous models, the copper drive plate is held in constant contact with the coil by a spring behind the driver shoulder bolt. This new feature aids the operator in positioning the flat forming dies over the head of the rivet. Previously, the flat dies had a tendency to slip off of the rivet head as the "pop-out" spring acted to push the driver away from the coil. In the event of a dry fire, the shoulder bolt absorbs the energy imparted to the driver and, as verified through testing at full voltage, retains the driver and prevents it from separating from the gun. Repeated dry fires result in driver bearing deformation and bearing displacement within the coil assembly increasing the gap between the coil and copper plate, resulting in inoperability after a few shots.

Recoil System - With the spring-damper system, the actuator can be broken down into three major sub-assemblies; the coil/driver, the recoil mass/spring-damper, and the body/handle assembly. The system efficiency is increased by concentrating the majority of the guns mass in the recoiling component which consists of the coil, the recoil mass, the recoil return spring and the damper. The mass of the recoiling components is 2.4 kg (5.3 lbs).

Upon firing on a fastener the coil, recoil mass, and damper move away from the panel compressing the damper rod and recoil spring against the handle assembly. The damper is the same robust design used in full scale EMR machines but with a shorter, 1" stroke. At rest, the damper is in the extended position and configured to dampen motion under extension only, hence only the forward, return motion of the recoil mass under recoil spring force is damped as the damper rod is extended and the recoil mass/ coil-driver returns to its rest position. The damping of the recoiling components on the return stroke has been shown to be critical in eliminating operator discomfort due to system recoil.

The entire recoiling section is housed within a 2.5" diameter glass fiber composite shell (body) which allows the operator to grasp and position the HH54 on the fastener without exposure to any internal moving parts. This arrangement makes for a very streamlined and rugged riveting system. The body is fastened to the aluminum handle support bracket which features an off-the –shelf industrial trigger control unit with LED indicators to alert the operator that the system is "Fully Charged" and other "Trigger Ready". The handle support bracket is also outfitted with an eye nut that the pulse cable webbing support strap is attached to to transfer the load of the pulse cable assembly to the handle as opposed to the power pulse cable where it enters the gun as in previous models.

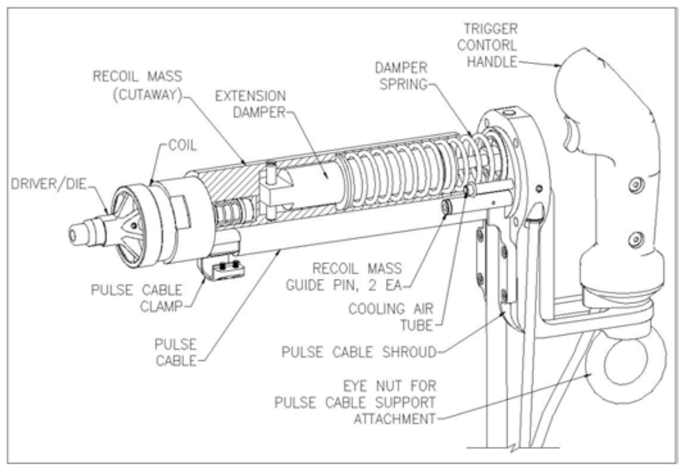

Figure 2. HH54 cutaway view of damping components.

The power pulse cable mates with the coil leads with a glass fiber lined clamp and runs along the recoil mass to the rear of the gun where it turns 90 degrees and exits out the bottom of the actuator within a cable shroud, free to deflect and move with the recoil mass without a strain relief. In previous models, the stiff junction at the strain relief caused pulse cable fatigue and breakage.

The pulse cable assembly consists of the power pulse cable, the control cable, the EMR coil cooling air line, and a ground conductor. These components are bundled together with a spiral wrap of 1" polypropylene webbing terminated with threaded quick links that attach to eye nuts on the actuator end and on the control box end. The webbing provides support for the pulse cable assembly and transfers tension loads across the pulse cable to the actuator and control box, eliminating the stresses on the individual components which have caused failure on previous designs.

The eye nut on the gun also provides a convenient location to attach a shoulder harness so the HH54 can hang at the operator's side when not in use. This feature helps eliminate the incidence of dropping since a convenient location to place the gun in the work area is not always at hand.

ELECTRICAL DESIGN – The electrical and control design of the HH54 is identical to previous models. In short, the HH54 utilizes the 1000 volt limit charging/ discharging system rather than the conventional 500 volt system for a small, powerful package with minimum recoil. Output force is dependent on capacitor voltage so the required force to upset a particular diameter and length of rivet is set by selecting the proper voltage setting on the controller. Since the coil acts as a resistor, filtered cooling air is fed through radially drilled holes in the coil to dissipate the heat generated in the coil during the discharge cycle.

Communication with the HH54 EMR system is accomplished through a touch pad/LCD interface located on the system control box. Information such as voltage levels, delay values, etc. are displayed on the LCD, as well as any error messages that may occur. Operators use the touch pad interface to perform all parameter entry for forming and/or driving different fasteners. Further tailoring of the rivet formation is achieved by setting a delay between the firing of the actuators (3). Since the EMR pulse takes less than a millisecond to complete, the delay value is entered in the microsecond range. A unique set of voltage and delay settings exists for each fastener diameter, material, fastener type, length, etc. These values are obtained experimentally. Once these values are determined, they are stored in the controller under a user-defined name (e.g. grip, diameter, MS14186E6, etc).

Riveting - Riveting with the HH54 EMR system is a two person process. One operator is responsible for the front side (head side) fastening and the other operator replaces the conventional bucking bar on the back side (tail side). For the system to work, both actuators must be fired at the same instant, or delayed slightly using the delay parameter as mentioned above. The timing of the discharge is not controlled by the operators, but by the system computer. In order for the actuators to fire, both triggers need to be pulled in a specific order. Basically, the team establishes a "master" and "slave". The system will discharge only when the master holds down his/her trigger, followed by the slave pulling his/her's. The triggering system can be set to either 1-2, 2-1, or 1-1 with 1 being the head side, and 2 the tail side. Once the correct sequence has been established, the computer signals both actuators to fire (3).

In many cases, visual obstructions exist between operators, making communication of ready/not ready status difficult. The HH54 actuators have been fitted with two LEDs to convey two critical messages. A green "Fully Charged" indicator is illuminated when the capacitor bank for the corresponding actuator is fully charged, and a second, yellow LED illuminates on the slave actuator indicating the master is "ready to fire".

CONCLUSION

The latest enhancements provided by the HH54 Lightweight Electromagnetic Riveting System take the proven advantages of the hand held EMR process to the next level of comfort, repeatability, and rugged dependability desired by aerospace assembly crews. With its reduced diameter, robust recoil spring/damper system, internal driver bearing/coil assembly, reinforced pulse cable design, and ease of use, the new HH54 Handheld EMR offers unique solutions for structural fastening in the Aerospace industry.

REFERENCES

1. Hartmann, J., "Development of the Handheld Low Voltage Electromagnetic Riveter", SAE Aerofast Conference, Long Beach, October 1990.

2. Hartmann, J., Brown, T., "Integration and Qualification of the HH500 Hand Operated Electromagnetic Riveting System on the 747 Section 11", SAE Aerofast Conference, Wichita, September, 1993.

3. Zieve, P., Durack, L., Huffer, B., Brown, T., "Advanced EMR Technology", SAE Aerofast Conference, Bellevue, October, 1992.

4.DeVlieg, R., "Lightweight Handheld EMR with Spring-Damper Handle", SAE Aerofast Conference, New Orleans, September, 2000.

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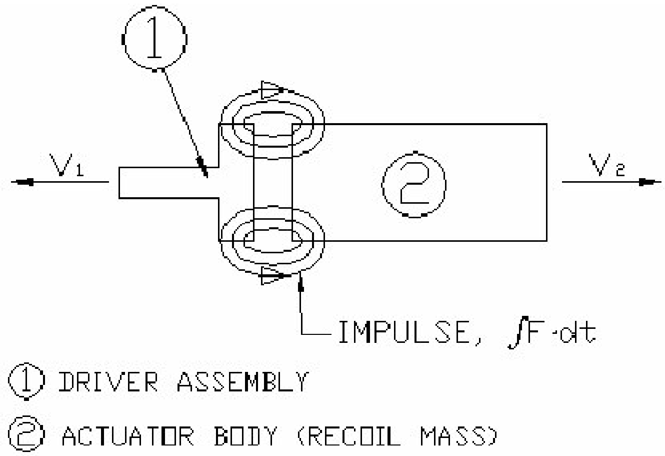
DEFINITIONS, ACRONYMS, ABBREVIATIONS

HH: Handheld (EMR)

EMR: Electromagnetic Riveter

LCD: Liquid Crystal Display

APPENDIX



$m_1 \cdot v_1 = m_2 \cdot v_2$ (Conservation of Momentum)

$$KE_1 = \frac{1}{2} \cdot m_1 \cdot (v_1)^2 = \frac{(m_1 \cdot v_1)^2}{2 \cdot m_1} \quad \text{or} \quad (m_1 \cdot v_1)^2 = 2 \cdot m_1 \cdot KE_1$$

$$KE_2 = \frac{1}{2} \cdot m_2 \cdot (v_2)^2 = \frac{(m_2 \cdot v_2)^2}{2 \cdot m_2} \quad \text{or} \quad (m_2 \cdot v_2)^2 = 2 \cdot m_2 \cdot KE_2$$

but $m_1 \cdot v_1 = m_2 \cdot v_2$ so $m_1 \cdot KE_1 = m_2 \cdot KE_2$

$$\text{or} \quad \boxed{\frac{KE_1}{KE_2} = \frac{m_2}{m_1}}$$

Figure 3. Simple model of EMR function.