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Pneumatic Rivet Gun Exchange Program on the C-17 Program
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History

Charles Brady King of Detroit invented the pneumatic hammer in 1890. In the late 1800’s and early 1900’s the rivet guns where were used in the rail road industry. The guns were used on small rivets on locomotives as well as swaging and sealing boiler tubes. The guns were also used for breaking old welds in thin steel.

The first successful all metal airplane was built in 1915 in Germany by Junkers. The first American metal airplane to be produced in large numbers was the Ford Tri-Motor. The planes were built from 1926 thru 1933. With the advent of the metal plane, rivets were used as the primary fastener to bond skins to primary structure.

Process Description

Riveting is a two person task. One person is typically inside the aircraft and the other outside. The workers switch between riveting and holding a bucking bar behind the rivet. Workers communicate verbally with or without radio head sets. Workers drive approximately 400-600 rivets per day.

The holes to be riveted are drilled out then reamed out to final hole size with a hand drill. The rivets are then placed in the open hole. The bucking bar is positioned behind the rivet by one worker and the rivet gun is held at the head of the rivet by the other worker. The rivet gun operator then squeezes the trigger in several short bursts to drive the rivet into place. The process then repeats.

Both the bucking bar and the rivet gun impart vibration to the hand that controls their placement. The rivet gun and bucking bar must be held firmly and steadily for extended periods of time over a work day, often while maintaining awkward body positions. The rivet gun and hand drill used are pneumatically powered.

Hundreds of holes may be drilled and reamed before rivets are driven. Wrist positioning for drilling is more likely to be neutral because the workers have different choices of drill motors to use. The motors are: pistol grip shaped, straight cylinder, or right angle drills. The rivet gun offers only a pistol grip and often required extended or flexed wrist positions.

There are four tasks associated with the drilling/riveting process. The tasks with the highest risk of injury are driving rivets and holding the rivet gun or bucking bar in place. Many times this process requires at least one of the two workers to maintain elbows above mid section, neck bent backwards and static shoulder positions.

Below is a sample of a task list with measurements taken from a study done at Little Rock Air Force Base.

Task	**Risk Factor/Body Part**	**Duration Average per Job/Total (per day)**
Ream/drill rivet hole	Hand force, awkward posture: hands, wrists, and shoulders	30sec/hole/1.5hrs/day
Pick up and place rivet in hole	Awkward posture: hands, wrists, shoulders, and neck	30sec/hole/1.5hrs/day
Place and hold rivet gun or bucking bar	Awkward posture (sustained): Hands, wrists and shoulders.	1min/rivet/3.5hrs/day
Drive rivet	Vibration, hand force, awkward posture: hands, wrists, and shoulders	1-5sec/rivet/3-6hrs/day
Total duration		2min/rivet/6.5hrs/day

The findings and checklist from the study are as follows:

<u>Upper Extremity</u>

Most of the work associated with riveting involves the upper extremities in static awkward positions, with forceful hand exertions.

One point was scored for squeezing hard with the hand in a power grip to maintain a steady rivet gun, bucking bar, or drill for more than two hours per day. Five points were scored on checklist A for awkward posture of the neck, shoulder, and bent wrist for more than two hours per day. One point was scored for contact stress associated with gripping metal handled tools (rivet gun, drill and/or bucking bar) for more than two hours per day or lying against rough edges and surfaces of the aircraft. Finally, a single point was scored for contact with a vibrating rivet gun or bucking bar even though the average time spent actually vibrating was less than two hours. This last point was assigned on professional judgment. The total task scored none points for upper extremity risks.

The force required to hold the bucking bar was measured in the shop. A piece of sheet metal was clamped in a vice (in a vertical position) at a work bench. A CSD 300 Chatillon, Dynamometer was positioned behind a three pound bucking bar while driving several rivets. An average force of 6.5 pounds and a peak force of 30 pounds was measured through the sheet metal.

Awkward posture is required for all the steps above either when riveting overhead or laying in a prone position on top of the aircraft. Elbows and shoulders are held high and in a static position, neck and wrists are often bent backwards, and forceful hand grip is required to control the rivet gun and the bucking bar even before the rivet is actually driven.

Quick fixes

Several quick fixes were identified for this process (note the following were true for Boeing too). They include:

- The use of anti-vibration gloves. The gloves have a dampening material in the palm to distribute and dissipate contact stress with the bucking bar and/or the rivet gun. Gloves without fingertips are most useful (these type are used at Boeing)
- Cover handles of drills, rivet guns, and bucking bars with padded grip material. (only the bucking bars have padded grip material at Boeing)
- Either of the fixes will reduce the score by one point for contact stress and one point for dampening vibration to a total Upper Extremity Risk Score of six.

Back and Lower Extremity

Back and lower extremity risks were all associated with awkward postures. One point was scored for backward bending of the torso when working in a prone position on top of the aircraft (rivet gun operator). A second point was scored for standing stationary on a ladder for more than four hours. This task did not seem extremely risky for the back or lower extremities as witnessed. Different riveting locations on the aircraft will alter this score, but are unlikely to result in a total score higher than 5 points for the entire day.

Quick fixes

There were no quick fixes identified at the Air Force Base, however, special dollies were designed to work under the aircraft. The backs of the dollies were adjustable and could be adjusted anywhere from 0 degrees to 45 degrees to alleviate pressure on the lower back and offer support to the lower torso.

Manual Handling

Any manual handling that might occur such as: lifting the bucking bar or rivet gun is normally less than 10 pounds and is considered safe lifting. No score was added to the checklist for manual handling.

Rivet Gun Design

The same basic design of rivet guns have been used since the advent of metal airplane construction as well as other applications in where riveting is used. The three main manufactures of rivet guns used in the aerospace industry have been Rockwell ™, Ingersoll-Rand ™, and Cleco ™. The air hammers are constructed of aluminum and weigh approximately 20 oz; the guns are balanced heavy on the “nose” end of the gun, are loud and have a high rate of vibration.

(Typical rivet gun/air hammer)

Presently, the company is in the process of distributing new design rivet guns to the employees. This section will discuss design and application features of the new tools being handed out to the employees.

(*New design rivet gun/air hammer)*

The C-17 program has an ergonomic center to provide Ergonomic services for all of its employees.

Ergonomic Center Mission

"Providing a safe and efficient work environment is one of the site's primary goals and the Ergonomic Center of Excellence is designed to enhance this philosophy. The center was created to assist and educate the employees of the C-17 program as to the value of applying ergonomic principles and equipment in their daily work. The Center is for every employee so we encourage you to use it to help make your work safer, more enjoyable, and more efficient."

The Center's Charter is as follows: "The Ergonomic office provides qualified resources to conduct ergonomic activity designed to reduce injuries and enhance performance throughout IDS Long Beach"

Strategy

"The Ergonomic Center will leverage the strength of the C-17 Employee Involvement strategy to facilitate a heightened awareness of the benefits of considering ergonomic solutions on a daily basis. As we engage the workforce, we will use Lean Manufacturing Accelerated Workshop techniques to conduct Ergonomic focused events to assist the identification of ergonomic improvement opportunities. In addition, the Center will draw on the expertise of our Technology capabilities utilizing our partnership with California State University, Long Beach to provide advanced ergonomic tool solutions."

Center Capabilities

- Ergonomic awareness training
- Lean/Ergonomic Accelerated Improvement workshops
- Human factor modeling and simulations
- Ergonomic job evaluations
- Development of ergonomic standards
- Health and safety job evaluations
- Enterprise Ergonomic solutions

We have contracted with the Atlas Copco company to partner in ergonomic studies on the tools being used on the C-17 program. The following are attributes that were studied as well as benefits of the new designs:

The basic ergonomic principle when designing a hand held power tool is that operation should be easy and involve no risk of damage to the health of the operator or the immediate environment. Poorly designed tools pose several potential risks.

Incorrect types of handles chosen in relation to the workstation and/or task to be performed can lead to awkward working postures and reduced operator capacity in terms of muscle fatigue.

The physical characteristics of the operator might not be fully considered. Thus, the size or shape of the hand tool may cause excessive local pressures to be applied to the blood vessels and nerves of the hand, resulting in musculoskeletal symptoms.

Advantages of powerful hand tools in several industrial situations may be a disadvantage for the operator. The reactive force or torque generated by powerful tools can be beyond the limit an operator can withstand without sustaining physiological injury.

Holding heavy tools subjects the upper extremities to continuous load and applies static load to certain musculoskeletal structures. The vibrations caused by conventional rivet guns can be very uncomfortable to the operator and cause damage to the neuro-vascular system of the hand. Some of the conditions that can occur are white finger syndrome and carpal tunnel syndrome.

Handle Design

The handle of the hand tool is the part that has most direct contact with the hand of the operator. The handle design directly affects the usability and comfort level of the tool during operation. From an ergonomic point of view, the goal is to design a handle which will allow the operator to apply maximum force and grip. Good handle design provides natural working postures and eliminates harmful local stresses on the operator's hands.

Working postures are an important guide in selecting tool handles. Special consideration should be given to the hands, shoulder, and upper arms. The hand and forearm should always be aligned when force is being applied. If the tool shape causes extreme hand postures, the operator will often compensate by raising an arm or elevating the shoulder.

The torque exerted on the shoulder is governed by the angle of elevation of the upper arm. Therefore the angle should be limited to less than 20 degrees when the tool is in continuous operation to minimize stress on the shoulder muscles.

When choosing the tool handle and planning the workstation, it is always the goal to achieve a work posture with a straight wrist. Several tendons and the median nerve pass through a narrow tunnel (carpal tunnel) in the wrist. Extreme hand positions compress the nerve and tendons resulting in Carpal Tunnel Syndrome.

The pistol handle (for a rivet gun) is often designed with an angle of 70 degrees in relation to the longitudinal axis of the tool. The pistol design is also preferred for tasks requiring both power and precision. The pressure contact area of the handle should be the fat pads of the hand. Excessive pressure on the fingers may damage the neurovascular bundles on either side of the fingers, making them susceptible to trauma. The center of the palm is not designed to withstand direct forces. This is due to the existence of sensitive anatomical structures such as the median nerve, arteries, and synovium for the finger flexor tendons.

Fingers differ in strength. The middle finger is the strongest and the little finger the weakest. The force generating capacity of the index, middle, ring, and little fingers is on average about 21%, 34%, 27%, and 18% respectively. Therefore trigger design and location should use the stronger fingers to the full advantage.

The length of the handle plays a role in the design of the tool. Studies of the breadth of male and female hands indicate that the palmer force-bearing area should be at least 90mm long to ensure the palmer forces are supported by the muscles on each side of the palm. The general recommendation for the handle length of tools where appreciable forces are being applied is 100-130 mm.

The handle diameter is the main factor influencing the operator's capacity to generate force. For power grips the recommended optimal diameter is 38 mm for men and 34 mm for women. An acceptable range would be from 30-45 mm. (For information: precision grip recommended diameter is 12 mm with an acceptable range from 8-16 mm.)

The contact surface between the handle and the hand must not be too small, because it could cause pain. The rule of thumb is that the pressure on the skin surface should not exceed 20 N/cm^2.

Riveting Hammer Model RRH 06

The above picture is the new riveting hammer that is being introduced into the workforce on the C-17 program.

The RRH 06 has been designed with an active vibration dampening system. The system is capable of adapting to changes in feed forces, while retaining good vibration control properties. The tool is mainly being used by male employees. The dampening system starts attenuating vibration at a feed force of 50 N and can withstand a feed force of 250 N before bottoming out. The bucking bar which is a partner to this unit has a built in vibration isolation spring. The spring is designed to give a force of 100 N at the foot of the rivet. A trained operator applies a force of 125N during the riveting process.

Vibration (taken from brochure)

"The machine has been designed with an active vibration control system in the form of an isolation system utilizing an air spring and the mass of the handle. The air pressure in the air spring increases as higher feed force is applied. Thus, the very soft spring can transfer high feed forces without any significant increase in stiffness. This gives the isolation system a natural frequency well below the blow frequency it is designed to attenuate."

Initial Findings

The initial distribution of the new rivet guns was approximately a month ago, and the initial response has been tremendous. The employees have mentioned that the job is much more comfortable and their hands don't hurt nearly as much as they did prior to using the new rivet hammers. The employees can go longer and work faster with the new tools.

The distribution plant wide of the new rivet hammers should be completed by March 2006.

Conclusion

With the distribution of the new rivet guns, Employees will be much more comfortable and definitely much happier. In the departments where the new tools have been distributed employees rave about how well balanced the rivet guns are and the comfort in holding the tools as well as the significant decrease in vibration during the riveting process.

Hopefully the long term benefits will include a significant decrease in Carpal Tunnel Syndrome as well as white finger syndrome. Employees will feel much less fatigue and be more efficient on the job. It's good to see the company care for the employees for once as much of the workforce has really felt very much neglected during the past few years.

With the tool improvements, it's a win-win situation for both employee and company. Employees are happy and healthier and the company has a more productive and healthy worker.

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