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## ANALYSIS IMPROVES ERGONOMICS

*Executive Vice President*

*Ergonomics Technologies Corp.*

*Oyster Bay, NY*

*An ergonomic audit using real workers yields data that can be used to improve power tool and workplace ergonomics.*

THE APPLICATION OF ergonomic principles in the workplace has produced far-reaching benefits for workers, and is fueling a revolution in product design. Ergonomic principles are intended to protect the physical health of human operators, while ensuring optimum application of their strengths and capabilities. Companies are even requiring ergonomic guarantees from their vendors, and users are driving the designs of a new generation of products.

The applied science of ergonomics focuses on optimizing the design of equipment, tools and workplaces to ensure worker comfort and maximize productivity. In most cases, good ergonomic design is common sense. The principles of ergonomics extend beyond the tool to address the work methods, equipment layout and the physical fit of the job to the worker.

Ergonomics starts with the worker and attempts to design the process to meet the worker's strengths and limitations. The worker considerations include strength, size, endurance, range of joint motion, age, gender and physical condition in terms of health and fitness.

When the physical requirements of a job exceed the capabilities of the worker, the risk of developing a cumulative trauma disorder (CTD) increases. Workplace research has identified ergonomic risk factors that have been associated with the development of CTD. These are grouped into several categories such as force, posture and repetition of task.

Reductions in effort and improvements in comfort lead directly to increased productivity. From an ergonomic perspective, productivity is either doing more work with the same amount of effort, or doing the same amount of work with less effort. Either way, the performance of ergonomically designed tools is measurable.

### **Ergonomic Audits**

In-plant testing, conducted with real workers, is an effective method of determining how well power tools meet ergonomic objectives, and also yields information that can be used to improve both power tool and workplace ergonomics.

An ergonomic audit generally includes about 20 participants, selected to represent the diversity of the user population in terms of parameters such as physical size, strength, gender and experience. The audit is conducted with this group of operators applying the tools to realistic task simulations.

The tests focus on measuring the performance of the human as a result of the tool function. Some of the ergonomic performance goals for assembly tools include:

- Low torque reaction and impulse vibration.
- Use of neutral hand and wrist postures.
- Lowest possible muscle effort during use.
- Low peak pressures across the grip with a generally even pressure distribution.
- Operating temperature between 68 and 77 F for thermal comfort.
- Trigger pressure less than 22 psi.
- Correct tool balance for the application.

The tool does not exist in a vacuum. For a tool to be truly ergonomic it must be correctly matched to its application. Designing a tool for superior ergonomics includes anticipating the range of uses to which the tool will be put, and incorporating flexibility and adjustability to meet most requirements. Similarly, ergonomic installation of a tool will consider the subtleties in the mounting and adjustment to meet the expected range of user needs.

### **The Ergonomic Criteria**

Both objective data, based on measurements, and subjective data, based on opinion, are obtained as part of an ergonomic audit. Several of the objective criteria include:

**Muscle effort.** Electromyography (EMG) is used to measure muscle activity in much the same way that an electrocardiogram measures heart activity. Expressed as a percentage of the user's maximum effort, the EMG data can be used to determine the effort required to operate a tool, and to compare different tasks or different designs.

For work performed over an extended time in fixed postures (static work), it is generally recommended that the user not exert more than 15 to 20 percent of his or her maximum effort. For dynamic activities (involving physical movement), up to 30 percent of the user's maximum effort is considered acceptable. Muscle efforts significantly above these levels should be avoided to limit the potential for discomfort and fatigue.

The EMG data can also be used to determine the overall muscle work done by the user. For a given task, the less muscle work done, the better.

**Dynamic posture.** The body is strongest when the joints are in their neutral posture. Deviations from neutral position will greatly affect available strength. For example, flexing the wrist down 65 degrees will result in a 55 percent reduction in grip strength. Performed repetitively, such posture has been associated with an increased risk of CTD. Electrogoniometry is used to monitor the dynamic activity of the hand and arm during tool use.

**Vibration.** Tool vibration is one of the few ergonomic criteria regulated by U.S. and international standards. The acceptable duration of tool exposure is based on the magnitude and frequency of vibration entering the body. Factors dramatically affecting vibration include tool age, grip characteristics, operating temperature, bit types and application. Excessive exposure to vibration can produce debilitating and irreversible damage.

Accelerometers and frequency analyzers are used to record tool vibration. Some companies have incorporated vibration test systems in their tool cribs to ensure safe tool operation as part of a preventive maintenance effort.

**Grip temperature.** The thermal characteristics of a tool grip are critical to a successful ergonomic design. A cold grip can result in a constriction in blood flow to the capillaries of the fingers, and increase the risk of vibration disorders exponentially.

Ergonomically designed tools incorporate thermal isolation of the grip area. In general, a comfortable grip temperature range is between 68 and 77 F. Variations in the temperature of air supply and ambient environment should be considered when temperature testing pneumatic tools. The ability of the tool to maintain a constant grip temperature is an indication of its thermal isolation.

**Torque reaction.** The torque reaction of an assembly tool during shut-off is a primary concern of users of these tools. A variety of tools set to the same torque shut-off level will translate this impulse vibration to the user differently. Determining the reaction to the user requires measurement of the impulse vibration at the user's hand and arm.

The subjective data are typically collected from a group of experienced users who are asked to assess criteria such as balance, hand and finger comfort, ease of control, trigger response, fit to hand and even color, appearance and surface texture. Users are asked to give their opinions on a numeric rating scale.

The objective and subjective data are typically combined to develop an ergonomic index that represents an overall assessment of the tools that are the subjects of the ergonomic audit. The ergonomic index, normalized to a five-point scale, is useful in evaluating tools and in designing both tools and workplaces.

## Looking Ahead

The sense of urgency surrounding power tool ergonomics is clear. An aging U.S. workforce, productivity imperatives and multitasking, and the high costs of workers compensation claims and lost-time incidents all emphasize the need to continually improve ergonomics. But those responsible for implementing positive change need a rational basis for decision making, and this is where a systematic, objective method for measuring ergonomic factors can provide validation and value. In this manner, those specifying tools can uncover the difference between cosmetics and substance, based on designs that truly reflect human capabilities and limitations.

Although the perfectly ergonomic tool does not yet exist, advances in technology and techniques for monitoring human response are driving us closer to the ideal solution. As users continue to gain knowledge in this area, and as tool designers continue listening to customers, we can continue to expect to see major improvements in the design of industrial tools. M

The author would like to thank Ingersoll-Rand for its cooperation. The illustrations and data presented in this article were compiled during an ergonomic audit conducted with various models of Ingersoll-Rand power tools.

The contour of the egg-shaped grip on this tool minimizes contact pressure concentrations on the hand and fingers. An ergonomic audit verified that the grip reduces torque reaction and improves user comfort.

### **Audit the Workplace, Too**

A quick ergonomic audit of the operator's workplace often reveals the need for improvements. Here's a list of suggested questions for conducting the workplace audit.

- Can multiple lifting of the same object or heavy lifting be made easier by installing an articulating arm or lift assist?
- Do any locations exist where the arm or body rests on an edge causing contact stress?
- Can work done in fixed positions be changed so that the static posture is not required?
- Can jobs where elbows are raised above shoulder height or out to the side of the body be improved by repositioning parts or using different tooling?
- Can any slippery floors be improved with antiskid paint, floor mats or similar devices?
- Can the need for awkward postures such as stooping or twisting be eliminated through redesign, new tools or different work techniques?
- Can any poor environmental conditions, such as heat, humidity, cold or poor lighting, be identified and improved?
- Can excessive vibration exposures, typically more than 4 hours of total run-time of the tool or equipment, be identified and eliminated?
- Can any items or parts not within easy reach be stored within easy reach?
- Can tools or equipment be identified that cause incorrect working conditions or are inappropriate for the task?
- Can heavy items on low shelves be located in the middle of the shelf?
- Can any pinch grips, that is, lifting objects with fingertips, be eliminated by modifying the work practice or with an assist device?
- Can part presentation be improved to reduce walking and reduce handling effort?
- Are there hand-pounding tasks that can be eliminated through the use of a mallet?
- Can part fit be improved to reduce the force required to do the job?

### **Ergonomic Facts**

- The Egyptian physician Imhotep is credited with the earliest known report of work-induced back pain cases, circa 3,000 to 2,500 BC. He provided medical care to the workers who built the great pyramids.
- The study of human beings and their tools in this century emerged around the time of World War I, in an attempt to improve the fit of soldiers into armored personnel carriers.
- Writers cramp was attributed to the introduction of the steel pen around 1820. In 1875, the disorder was termed Telegraphers Cramp. It wasn't until the 1970s that these injuries were described as cumulative trauma disorders.
- The strongest handgrip is a power grip, in which our fingers and thumb are wrapped around an object.
- A pinch grip generates only 25 percent of the strength of a power grip.
- Bending the hand down 65 degrees results in a 55 percent loss of available grip strength.
- In the back, the nucleus of the spinal disc is approximately 70 percent water, but gets dryer with age.
- A safe limit of spinal disc compressive force is 700 pounds. However, a person can generate up to twice his or her body weight in spinal disc compressive force by just sitting down.
- When we wake up we are typically 1/4 to 1/2 inch taller than when we went to sleep, because our spinal discs absorb water and thicken when we are lying down.
- Lifting, while twisting, can increase the potential for spinal disc injury by six times.
- A majority of lifting injuries occur when lifting an object from the floor.
- As we all know, our bodies change with age. Beginning at age 35, we begin to lose strength in our muscles. Typically, beyond age 65 hand strength is reduced from 16 to 40 percent, arm strength by 50 percent, and leg strength by 50 percent.
- Employees are getting older. The average employee in U.S. auto manufacturing was close to 50 years old in 1995.

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