HAND TOOL DESIGN

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Ergonomic Tools?

- It says that they are ergonomic, but are they and why?

Hand Tool Design Issues

- Hand tools are ubiquitous and integral to technological progress.
- Poor hand tool design results in:
  - Lost productivity (slower work, more errors)
  - More injuries (increased WRMSD risk)
  - More illness (increased long term illness e.g. vibration syndrome)
  - More accidents (9% of all disabling injuries related to poor hand tool design)
  - More costs (worker's compensation, litigation)

Biomechanical Considerations

- Hand grip strength depends on forearm muscles.
- Grip configuration determines strength requirements.
- Wrist posture affects strength and injury risks - straight wrist operation is always preferred.

Wrist Flexor Strain and Hand Posture

Wrist Deviation and Grip Strength

Tool Design: Shape

- Tool shape directly impacts hand tool performance.
- Tool should be shaped to avoid wrist deviation, allowing the hand and forearm to remain in alignment during forceful grip exertion.
- Typical design solutions involve:
  - Bent/curved handle designs
  - Pistol grip
  - Cylindrical grip

Ergonomic Design: Handles

- Handles can help to improve grip possibilities.
- Handles should be designed for bare or gloved hand operation.
- Handles should be located at or above the center of gravity of the load.
- Handles should be textured to reduce slippage, but should NOT be contoured.
- Handles should not be cold or hot, or sharp.
- Loads > 10lbs (~5 Kg) should have a handle.

- Bulky objects should have 2 handles.

Tissue Compression

- Poor handle design causes compression of nerves and blood vessels in the hand.

Ergonomic Design: Tool Shape

- Reshaping the tool can improve the functionality of the handle, as shown in this redesign soldering iron.

Ergonomic Design: Paint Scraper

- Conventional paint scraper handle design compresses the ulnar artery.
- Modified handle rests between thumb and index finger preventing pressure on sensitive regions of the hand (Tichaeur, 1967).

Hand Tools: Grip Design

- Grips should be contoured to the curve of the palm of the hand.
- Grips should not be ridged.
- Grip span should comfortably fit the palm of the hand (4”-5”).
- Grip handle length should fit the hand.
- Grips should be suitably padded.

Curved Handle Tool Design

Bent Pliers (Tichauer, 1978)

- Many wiring operation require gripping regular pliers with deviated wrist posture.

Bent Pliers

- 80 new employees studied for 12 weeks in 2 groups.
- <10% of those with bent handle pliers developed problems compared with > 60% of those with straight-handle pliers (Tichauer, 1978)

Bent Handle Scissors

- Bent handle scissor designs put the wrist in a better posture than conventional designs.

Hand Tools: Scissors Design

Poultry Knife Design (Armstrong, 1982)

- Cumulative trauma injury rate more than twice as high among poultry cutters as other workers.
- Ergonomic analysis revealed:
  - Frequent use of deviated wrist postures
  - Sustained grip force even when not cutting
  - Accidental hand/finger cuts
  - Wet, cold hands

Poultry Knife Design (Armstrong, 1982)

- Bent handle for straight wrist
- Strap to allow hand relaxation

- Curved blade for straight hand cutting.

Ergonomic Knives

- Bent handles for straight wrist cutting.
- Choice of angles for different cut strokes.

Ergonomic Knives

- Some knife designs use a sawing action and a straight wrist can be maintained when the handle curves upwards.

Ergonomic Knives etc.

- Ergonomic design principles can be used for a variety of hand tools.

Ergonomic Design: Hammers

Ergonomic Design: Canoe/Kayak Paddles

- The bent-handle paddle design allows for:
  - Better wrist and upper body posture during paddle use.
  - More stroke power.
  - More comfortable paddle use.
  - Less fatigue.

Ergonomic Design: Grip span

- Grip spans that are too small or large reduce grip strength and stability.
- Grip span depends upon gender and anthropometric dimensions.
- 2.5”-3.5” is optimal.

Ergonomic Design: Ice Cream Scoop

- Poor design:
  - Wide grip span
  - Short neck
  - Short handle

Ergonomic Design: Pneumatic Tools

- Thumb switch controls can cause overextension of the thumb.
- Finger-strip controls share the load between the fingers, and allow the thumb to be used in a power grip for tool stability.
- Tool diameter must fit the hand.

Ergonomic Design: Power Tools

- Tool design should facilitate the effective use of a power grip.
- Tool weight should not place the center of gravity too far away from the handle.
- Longer handles (>4”) are better.

Ergonomic Design:

Posture and Adjustable handles

- Workers should avoid bent wrist postures where possible.

- Some tools have adjustable grips to allow a worker to maintain good wrist posture.

Ergonomic Design: Pens/Pencils

- Many different pen/pencil designs, but the principles of optimal grip span and wrist posture still apply.
- Pens/pencils should:
  - Not be too thin or too thick
  - Have a padded, shaped grip
  - Not be too heavy
  - Be well balanced
  - Have easy flow nib/point

Ergonomic Instruments

- Musical instruments can be ergonomically designed.

Ergonomic Design: Handedness

- Depending on the definition of handedness, 10-30% of people are left-handed.
- On average, left handed people live 9 years less and are 5 times more likely to die of accident-related injuries than right handed people.
- Many products are designed for right handed people, but an increasing number of left hand designs are becoming available.

Ergonomic Design: Different abilities

- Hand tool use can become more difficult with many ageing disorders, such as arthritis.
- Numerous “add-ons” are available to help people with restricted dexterity to perform commonplace manual tasks.

Vibrating Hand Tools

- Many types of hand tools vibrate.
- Vibrations can be:
  - Intentional – integral to the function of the tool
  - Incidental – a by product of tool operation
- Prolonged use of vibrating tool can cause vascular damage to the upper limbs.

Examples: Vibrating Hand Tools

Vibration Effects

- Vibrations are mechanical oscillations of the body or body segment
- 5 quantities are important:
  - Point of application (e.g. hand, arm, feet, buttocks)
  - Frequency (Hz)
  - Acceleration (m/s^2) – usual measure of vibration load
  - Duration
  - Individual frequency and resonance

Resonant Frequencies

- Everything has it's own natural frequency. The closer a vibration is to this the greater it's amplitude. For the human body:
  - 3-4 Hz: strong resonance in cervical vertebrae
  - 4 Hz: peak resonance for lumbar vertebrae
  - 5 Hz: shoulder girdle (very strong resonance up to double normal amplitude)
  - 20-30 Hz: resonance between head and shoulders
  - 60-90 Hz: eyeballs
  - 100-200 Hz: lower jaw

Direction of vibration

- Vertical (up/down)
- Horizontal (forwards/backwards)
- Lateral (side-to-side)

Vertical Vibrations

- Vibrations between 2.5-5Hz induce strong resonance in neck and lumbar vertebrae
- Vibrations between 4-6Hz induce strong resonance in trunk, shoulders and neck
- Vibrations between 20-30Hz induce strong resonance in head and shoulders

Vibrating Hand Tools

Vibration Effects

- Physiological effects – vibration initiates protective muscle reflexes (extended muscles shorten), which increases heart and respiration rate, and energy consumption
- Visual effects – visual acuity decreases and images are blurred and unsteady
- Skill – less able to perform skilled movements
- Information processing – less able to process information
- Speech – difficult to talk
- Driving – at 2-16Hz driving performance is impaired and errors increase

Vibration as a Nuisance

- 4-8 Hz – greatest subjective sensitivity
- 10 m/s^2 (1g) – 'very severe intensity'
- 15 m/s^2 (1.5g) – dangerous and intolerable

Vibration Health Effects

- 0.2-0.7 Hz – motion sickness, nausea vomiting (max at 0.3 Hz)
- 1-4 Hz – interference with breathing
- 4-10 Hz – pains in chest, abdomen, rattling of jaws, muscular discomfort
- 8-12 Hz – backache

- 10-20 Hz – muscle tension, headaches, eyestrain, pains in throat, intestines, bladder, speech disturbances
- <40 Hz (e.g. pneumatic hammer) causes degenerative damage to bones, joints, and hand/arm tendons
- 40-300 Hz (e.g. power tools) – damage blood vessels and nerves in hands.

Hand-Arm Vibration Syndrome (HAVS)

- Vibration-induced white finger (VWF) is the most common condition among the operators of hand-held vibrating tools. Vibration can cause changes in tendons, muscles, bones and joints, and can affect the nervous system. Collectively, these effects are known as Hand-Arm Vibration Syndrome (HAVS). The symptoms of VWF are aggravated when the hands are exposed to cold.
- Attacks of whitening (blanching) of one or more fingers when exposed to cold
- Tingling and loss of sensation in the fingers
- Loss of light touch
- Pain and cold sensations between periodic white finger attacks
- Loss of grip strength
- Bone cysts in fingers and wrists

Vibration White Finger

- Stage 0 – No symptoms
  - OT - Intermittent tingling
  - ON - Intermittent numbness
  - OTN - Tingling and numbness
- Stage 1 - Blanching of one or more fingertips with or without tingling and numbness.
- Stage 2 - Blanching of one or more fingers with numbness, usually during winter only. Slight interference with home and social activities; no interference with work.
- Stage 3 -Extensive blanching with frequent episodes during both summer and winter. Definite interference with work, home and social activities; restricted hobbies.
- Stage 4 - Extensive blanching of most fingers; frequent episodes during summer and winter; finger ulceration, gangrene. Occupation change required to avoid further vibration exposure.

VWF Prevalence

- 50 percent of 146 tree fellers examined in British Columbia had Raynaud's phenomenon; it affected 75 percent of workers with over 20 years of experience.
- 45 percent of 58 rock drillers had attacks of white finger; 25 percent of workers with less than five years of experience, but 80 percent of those with over 16 years experience were affected.

VWF Latency

Vibration Limits

- <2Hz – accelerations of 3-4 g are intolerable
- 4-14 Hz – accelerations of 1.2-3.2 g are intolerable
- >14 Hz – accelerations of 5-9 g are intolerable
- ISO has established vibration limits based on:
  - Criterion of comfort (divide acceleration by 3.15)
  - Criterion of maintenance of efficiency
  - Criterion of safety (multiply acceleration by 3.15)

ISO 2631 Vibration Limits

- 0.3-0.45 m/s^2 for 8 hrs day for tractors, heavy vehicles, construction machinery (mostly 2-5 Hz vibrations)
- Dampen hand-tool vibrations

Reducing Vibration Injuries

- Anti-vibration gloves – absorb vibration energy, can get some impairment of dexterity.
- Tool re-design – e.g. 'Gentle Jack' jackhammer:
  - 50% fewer parts than a conventional jackhammer
  - 50% less noise
  - 99% less vibration