



Hand tool design

- Physiological factors of concerns in hand tool design – static muscle load, awkward posture, design of tools, activation force, handedness, tissue pressure, pinch points, vibration, special purpose vs. general purpose tools
- Types of Grips
- Design of grips

Physiological factors - 1. static muscle load resulting in muscle fatigue and soreness

Tools for grinding, polishing which are held in hand for extended period

The gravitational force due to weight of the tool itself and/or operational force give rise to static loading in hand, arm, back.

Trigger force that needs to be maintained by fingers can also give rise to static loading and fatigue in weak finger muscles.



Physiological factors - 2. Awkward joint positions- back, neck and arm

In non-neutral posture, a joint is comparatively weak. Hence, in terms of percent of MVC, muscle fatigue ensues quicker for the same external force.

Back/neck/shoulder – during bent posture, moment arm of the upper body segments increases, causing increase in static load levels of the low back and neck muscles – back pain, neck pain.

Arm – Extended elbow with forceful movement, tennis elbow. Keep elbow at about 90°.

Arm abduction or elevation of elbow causes static load due to weight of the arms – give rise to static loading in shoulder/neck muscles.



Physiological factors - 2. Awkward joint angles in hand, wrist, fingers

Bent wrist, high activation force- carpal tunnel syndrome – bend the tool, tilt the workplace to correct the situation.

Straight and bend handle drilling machines, bent handle pliers, bent handle scissors designed to promote better wrist postures.



Physiological factors - Muscle load in hand, wrist, fingers

Heavy gripping/activation force can also cause forearm muscles to fatigue – reduce gripping force by designing better handles, better activating switch.

Design grip for both hands, such that they can alternate.

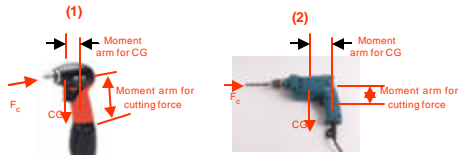
10% of the population is left handed, and non preferred hand has lower MVC



Physiological factors- static muscle load in forearm muscles

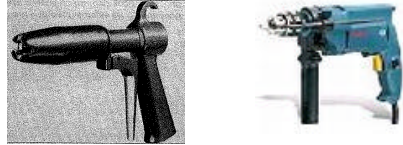
For heavy tools held in hand, keep the CG of tool close to the handle, this will reduce the holding torque on wrist.

For same weight and cutting force, which of the two hand drills will produce less torque on the wrist: (i) When held in hand? (ii) When drilling?



Physiological factors- static muscle load in forearm muscles

If the trigger needs to be held, reduce activation force to reduce forces on fingers, or provide a power grip switch or a bar – instead of a single finger switch.



Spring loaded return for a two handled tool, eg. pliers – finger extensor muscles are weak

Physiological factors- static muscle load in forearm muscles

Use larger muscle group



Physiological factors- 3. Pressure on Tissue

- (a) Palm – when handle ends within the palm, it may press the area where blood vessels and nerves are passing through and can cause swelling – (i) extend the handle, (ii) increase the contact area to reduce the pressure.
- (b) Finger – high pressure due to gripping force, weight of the tool, trigger activation or holing – reduce gripping force, reduce activation force, increase the area of contact reduce the pressure.
- (c) Pinch Points – especially important where large force is developed. Provide adequate clearance between handles to prevent pinching.



Physiological factors- 4. Vibration & Noise

Pneumatic chipping hammers, pavement breakers are noisy (>75 dB) and vibrate at 60-90 Hz.

Any rotary tool or pneumatic impact tools produce vibration. Maintenance is important.

Vibratory energy (frequency, amplitude and use time) is correlated to circulatory problems (white fingers).

Tightly gripping requirement transmits the vibration. Frequency 20-200 hz is most critical for hand arm vibration syndrome.

Frequency <50 Hz put greater load on elbow and shoulder, >100 for hand and fingers.

Physiological factors- 4. Vibration & Noise

Design objectives

- Use a process with zero or low operator vibration
- Use equipment with low levels of vibration
- Use equipment with vibration-isolated handles
- Avoid resonance frequencies
- Furnish vibration-isolating gloves.
- Encourage to follow VS-reducing practices.

Maintain equipment, minimize handgrip force, rest the tool on a support, reduce continuous exposure, keep hand warm and dry.

Special-purpose vs. general purpose tools

An SP tool Performs better for tasks that are repeated many times/week, quality of task is improved, usually more costly, needs variety of tools in the inventory.

A general purpose tool can do variety of tasks, cost is low, but quality, speed etc are compromised.

A mechanic wants a special wire-stripping tool (\$35); it will be used once per day. It will save about 30 seconds per use. Should it be purchased?

Whether a tool is expensive depends on a detailed analysis, not just capital cost. Benefits include savings beyond just labor savings (capability, quality, etc.)

Types of Grips – Power grip



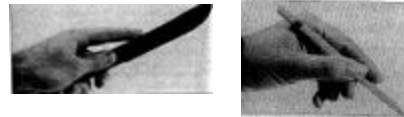
- Fingers are closed with the thumb and the tool handle perpendicular to the forearm axis. Provides maximum gripping force.
- Direction of force:
 - Parallel to forearm – balance is important
 - At an angle to forearm – wrist deviation should be minimized, bent hammer handles.
- Force generates a torque about forearm

Types of Grips – Semi-power Grip



- Fingers act as a group but thumb position changes.
 - Oblique grip: thumb aligned along tool axis, improves precision.
 - Pinch grip: held between thumb and other fingers, more stress on finger muscles
 - Hook grip: fingers wrap around tool, thumb is passive

Types of Grips – Precision Grips



- Has about 20% strength of a power grip.
- Internal precision grip (e.g. table knife)
- External precision grip (e.g. pencil)
- Forearm may need to be supported.

Make the Grip the Proper Thickness, Length and Shape

- Hand Sizes
 - Are larger with gloves, may reduce torque
 - Tend to be larger for men than for women



Make the Grip the Proper Thickness, Length and Shape

Grip Diameter

- For power grip, 35 mm to 45 mm is optimal.
- For power grip thumb must close other fingers. Custom fit size is 10 mm less than grip circumference
- For precision grip, use 9.5 mm to 12.7 mm.



Make the Grip the Proper Thickness, Length and Shape

Grip Length

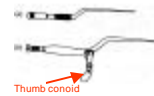
- For power grip, all fingers must make contact – wide enough, consider glove
- For internal precision grip, tool must extend past palm but not as far as wrist. Tissue pressure on palmer side may be an issue.
- For external precision grip, shaft must be supported, long enough – try to write with a small IKEA pencils



Make the Grip the Proper Thickness, Length and Shape

Grip Shape: Section Perpendicular to Grip Axis –

- If rotation is not a problem, cylindrical shape is most forgiving, because no sharp edges.
- To prevent rotation and slippage use noncircular cross-section, e.g. elliptical, oval as seen in the hammer handles. This will reduce gripping force.
- Non circular sections such as square, will increase contact pressure
- For positive prevention of rotation provide thumb conoid.



Make the Grip the Proper Thickness, Length and Shape

- Grip Shape: Section Along Tool Grip Axis
- Varying diameter keeps tool from moving forward and backward in hand and allows force exerted along tool axis to be greater.
- Can act as a shield in the front to prevent injury for accidental slippage
- Avoid finger grooves along the length of the handle – do not increase contact area but increase pressure point for hand sizes for which it is not designed.
- A pommel can increase the force when the tool is pulled toward the body.



Make the Grip the Proper Thickness, Length and Shape

Other geometric and material characteristics:

- Larger handle diameter increases work torque thus smaller gripping force is required – a smaller screw driver may not need to have proportionally smaller handle diameter.
- Rubberized material to increase coefficient of friction – less gripping force to produce torque
- Avoid ridges along the handle length – increases localized tissue pressure or contact stress



Make the Grip the Proper Thickness, Length and Shape

- Make the Grip Surface Smooth, Compressible, and Nonconductive
 - Smoothness reduces pressure points.
 - Compressibility increases contact area and thus minimizes pressure on the hand tissue
 - Non-conductivity reduces heat and cold problems and risk of electric shock.