THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATION COUNCIL

DIPLOMA IN SECONDARY EDUCATION EXAMINATION

789 METAL WORKING AND MECHANICAL PRACTICE

(SUPPLEMENTARY)

Time: 3 Hours. **ANSWERS** **Year: 2020**

Instructions

1. This paper consists of **eight (8)** questions.

2. Answer **any five (5)** questions.

4. Cellular phones are **not** allowed inside the examination room.

5. Write your **Examination Number** on every page of your answer booklet

1. (a) Briefly explain the purpose of the electrode holder used in electric arc welding.

The electrode holder is a device used to hold the electrode firmly during the process of arc welding. Its main purpose is to conduct electric current from the welding cable to the electrode, allowing the arc to be struck between the electrode and the workpiece.

The holder also provides insulation for the welder's hand from the live current, thus ensuring safety during operation. Additionally, it allows easy changing of electrodes when they are consumed, saving time and improving efficiency in welding tasks.

(b) Give six functions of the electrode coating.

The first function of the electrode coating is to stabilize the electric arc by controlling the ionization process, which helps in maintaining a smooth and steady arc during welding.

The second function is to provide a shielding gas that protects the molten weld pool from atmospheric contamination such as oxygen and nitrogen. This prevents oxidation and porosity in the weld.

The third function is to form a slag layer on the weld bead. The slag covers the hot metal and allows it to cool slowly, preventing oxidation and improving the mechanical properties of the weld.

Fourthly, the coating supplies alloying elements to the weld pool, enhancing the strength, ductility, and corrosion resistance of the weld joint.

Fifthly, the electrode coating helps in deoxidizing the weld area by including chemicals that react with oxides, keeping the weld metal clean and sound.

Lastly, it improves the appearance of the finished weld bead by ensuring proper flow and formation of the molten metal during solidification.

(c) Draw neat sketches to show the following effects of an electric current in arc welding:

(i) Too low electric current
(ii) Too high electric current
(iii) Correct electric current

When the electric current is **too low**, the arc becomes unstable and flickers. The electrode tends to stick to the workpiece, and the weld bead appears narrow and poorly fused.

When the current is **too high**, excessive heat is generated, causing the electrode to melt too fast and producing spatter. The weld bead becomes wide, with undercut edges, and there is risk of burning through thin materials.

When the **correct current** is used, the arc is stable and produces a smooth, uniform weld bead with proper penetration and good surface appearance.

2. (a) Explain the application of the following bench work tools:

(i) Draw files

Draw files are used in bench work to produce a smooth and fine surface finish on metal after general filing. The file is drawn across the workpiece sideways rather than pushed forward. This technique removes small irregularities and scratches, giving the metal a polished appearance and preparing it for fitting or finishing operations.

(ii) Precision files

Precision files are small, fine-toothed files used to finish intricate work requiring high accuracy, such as in instrument making or fitting small machine parts. They are designed to remove very little material while ensuring tight dimensional control. These files help achieve smooth surfaces in delicate components where large files would be too aggressive.

(iii) Scrapers

Scrapers are used to remove very thin layers of metal from a surface to produce a true and flat finish. They are often used after filing or machining to achieve precise fits between mating parts. Scraping ensures close contact between surfaces, which is essential in machine assembly, such as fitting bearings and slideways.

(iv) Center punch

A center punch is used to make small conical indentations on a workpiece surface before drilling. The punch mark guides the drill bit and prevents it from wandering. It also helps ensure accurate hole positioning according to the marking-out layout.

(v) Divider

A divider is a marking-out tool used to scribe circles or arcs on metal surfaces. It can also be used to

transfer measurements from a drawing to the workpiece. Dividers are essential in layout work where precise distances and circular patterns are needed.

(b) Give the meaning of the letter and numbers in the expression M4 × 0.7.

The letter "M" indicates that the thread is a metric thread, which means it is measured in millimeters. The number "4" represents the nominal diameter of the screw or bolt, which in this case is 4 mm. The number "0.7" represents the pitch, or the distance between two adjacent threads, which is 0.7 mm. Therefore, M4 × 0.7 refers to a metric screw thread with a 4 mm diameter and a 0.7 mm thread pitch.

(c) How acid method helps to remove a broken piece of tap in a metal?

The acid method involves using a chemical solution, often nitric acid or alum, to dissolve the broken high-speed steel tap embedded in the metal workpiece. The acid selectively dissolves the tap without attacking the base metal. This process is particularly useful when mechanical extraction is not possible due to the tap's tight fit. The dissolved material is then flushed out, leaving the original threads intact and ready for reuse.

(d) Briefly explain how a tap extractor is used.

A tap extractor is a specialized tool designed to remove broken taps from threaded holes. It consists of several small fingers or prongs that fit into the flutes of the broken tap. Once inserted, the extractor is turned anticlockwise using a wrench, applying even pressure to unscrew the tap without damaging the existing threads. Tap extractors allow safe and efficient removal of taps that cannot be extracted manually.

(e) Give two purposes of broaching in the workshop.

The first purpose of broaching is to produce accurate and smooth internal or external shapes, such as keyways, splines, or holes, in a single operation. Broaching provides high precision and excellent surface finish.

The second purpose is to achieve uniformity and repeatability in production. Since broaching removes material using a series of cutting teeth of increasing size, it ensures consistency across multiple workpieces, making it ideal for mass production.

3. (a) With the aid of sketches, differentiate parallel shank from taper shank of a twist drill.

A **parallel shank drill** has a uniform cylindrical shank with the same diameter throughout. It is usually held in a drill chuck. This type of shank is used for light-duty work and small drills.

A **taper shank drill**, on the other hand, has a conical shape that fits directly into the machine spindle or an adapter socket. It provides a self-holding fit, allowing better torque transmission and alignment. This type is commonly used in heavy-duty drilling operations.

(b) How are conical or tapered heads of bolts and screws fitted correctly with the surface of the metal?

Conical or tapered heads of bolts and screws are fitted correctly by countersinking the hole in the metal surface. Countersinking creates a conical recess that matches the angle of the bolt or screw head, allowing it to sit flush with or below the surface. This method improves appearance, prevents projection of the screw head, and ensures even pressure distribution when tightening.

(c) Explain the following terms as applied in hole making:

(i) Reaming

Reaming is a finishing process used to slightly enlarge and smooth a drilled hole to an exact diameter with a high-quality surface finish. It removes only a small amount of material, ensuring accurate hole alignment and size.

(ii) Fluted reamer

A fluted reamer has spiral or straight grooves along its body that help in cutting and removing chips during reaming. The flutes provide space for chip removal and also help distribute cutting fluid to the cutting edges.

(iii) Hand reamer

A hand reamer is designed to be rotated manually using a wrench. It has a long lead taper at the front for easy alignment in the hole. Hand reamers are used where precise control is needed to avoid oversizing the hole.

(iv) Expanding reamer

An expanding reamer is adjustable in diameter and is used when slightly larger hole sizes are

needed. The blades can be expanded to achieve a precise fit, making it useful for repairing or resizing existing holes.

(d) With the aid of a sketch, explain the techniques of sharpening a reamer.

A reamer is sharpened by grinding its cutting edges carefully without altering the original geometry. Only the face or rake surface of each tooth is ground to restore sharpness. The back taper and margin must not be touched, as altering them can affect the reamer's accuracy. The process requires the use of a precision grinding machine to maintain correct angles.

(e) What are the three important points to follow in the procedure of hand reaming?

First, ensure the hole is correctly drilled slightly smaller than the desired final size to allow minimal material removal.

Second, insert the reamer carefully and keep it perfectly aligned with the hole axis to avoid tapering.

Third, rotate the reamer smoothly in one direction (usually clockwise) with steady pressure, avoiding backward turns to prevent edge damage and maintain accuracy.

4. (a) (i) Explain the term brazing as used in metal joining.

Brazing is a metal joining process in which two or more metal parts are bonded together by melting and flowing a filler metal into the joint, without melting the base metals. The filler metal used has a lower melting point than the parent metals. This process produces strong, leak-proof joints and is widely used in pipe fittings, HVAC, and tool repair.

(ii) How does the technique used in brazing assist the flow of flux and molten filler metal?
In brazing, proper heating ensures capillary action occurs, allowing the molten filler to flow into the narrow gaps between the metal surfaces. The flux cleans the surfaces by removing oxides, improving the wetting action and promoting uniform spreading of the molten filler for a sound joint.

(iii) Why is it necessary to wear goggles during brazing?
Wearing goggles protects the welder's eyes from intense light, ultraviolet rays, and hot metal

splashes produced during brazing. It also shields the eyes from harmful fumes and prevents accidents caused by flying particles.

(b) Suggest precautions that should be observed to avoid danger of explosions in brazing tanks containing flammable materials.

The tanks should be properly ventilated to prevent accumulation of flammable gases. Any nearby flames or sparks must be eliminated before heating. Equipment should be inspected regularly for leaks, and appropriate safety valves must be used. Operators must also wear flame-resistant clothing and follow correct procedures for lighting and shutting off torches.

(c) (i) What does it mean by angle of contact (θ) as used in braze welding?

The angle of contact (θ) refers to the angle formed between the molten filler metal and the surface of the base metal. It indicates how well the filler metal wets the surface. A small angle of contact shows good wetting and results in a strong joint, while a large angle indicates poor wetting.

(d) Explain the importance of the following gears in soldering:

(i) Soldering gun

A soldering gun provides the heat necessary to melt the solder, allowing it to flow into the joint. It is quick-heating and suitable for heavy soldering work.

(ii) Flux

Flux cleans the metal surfaces by removing oxides, ensuring the solder adheres properly. It also prevents further oxidation during heating.

(iii) Filler rods

Filler rods supply the molten metal that forms the joint. They provide the bonding material between the two pieces being soldered, ensuring a strong, leak-proof connection.

5. (a) Describe the following metal cutting tools:

(i) Files

Files are hand tools made of hardened steel with numerous small teeth used to remove small amounts of metal for shaping or finishing surfaces.

(ii) Grinder

A grinder is a power tool that uses an abrasive wheel to grind, sharpen, or polish metal surfaces. It removes material quickly and shapes hard metals efficiently.

(iii) Chisels

Chisels are cutting tools with a sharp edge used to cut, chip, or shape metal by striking them with a hammer. They are used for cutting rivets, splitting nuts, or removing waste metal.

(iv) Reamers

Reamers are finishing tools used to enlarge drilled holes slightly and achieve a smooth, accurate diameter. They provide precision fitting in engineering assembly work.

6. (a) (i) Briefly explain two categories of metal testing methods.

The first category of metal testing is **destructive testing**. This method involves subjecting the metal sample to forces or conditions that cause it to fail or deform permanently. The purpose of this test is to determine the metal's strength, toughness, and ductility. Examples include tensile tests, impact tests, and hardness tests. Although the specimen is destroyed, the data obtained helps engineers design safer and more reliable products.

The second category is **non-destructive testing (NDT)**. In this method, the metal is tested without causing any damage or permanent change. It is used to detect internal flaws, cracks, or discontinuities that might affect performance. Common NDT techniques include ultrasonic testing, magnetic particle inspection, and radiographic testing. This method is useful in maintenance and quality control where the metal component must remain intact.

6. (a) (ii) For each of sheet metal, drawn wire, engine block, and rubber parts identify one essential property that enables it to be produced.

Sheet metal requires **ductility**. Ductility allows the metal to be stretched or bent into thin sheets without cracking. This property makes forming and shaping operations like rolling and pressing possible.

Drawn wire needs **malleability**. Malleability enables the metal to withstand compressive forces as it is pulled through dies to form wires of smaller diameter. Without this property, the wire would snap during drawing.

An engine block requires **compressive strength**. This property allows it to resist the high pressures and forces produced during combustion without deforming. A metal with high compressive strength, like cast iron, ensures durability and performance.

Rubber parts require **elasticity**. Elasticity allows them to return to their original shape after being stretched or compressed. This is essential for seals, gaskets, and vibration-damping components.

6. (b) (i) Elaborate the four applications of annealing in mechanical component production.

Annealing is applied to **relieve internal stresses** in metals after cold working processes like bending or rolling. These stresses, if not removed, can cause warping or cracking during later use.

It is also used to **improve ductility**. After hardening or working, metals become brittle. Annealing restores their ability to deform without breaking, which is important for further shaping.

Another application is to **refine the grain structure**. During annealing, the metal is heated and cooled under controlled conditions, allowing new, uniform grains to form. This improves mechanical properties and appearance.

Finally, annealing is used to **soften metals** for machining or forming. Softer metals are easier to cut and shape, reducing tool wear and production costs.

6. (b) (ii) Account for the hot piercing as applied in manufacturing of mechanical components.

Hot piercing is a process of forming holes in metal while it is at a high temperature. The heated metal becomes soft and plastic, allowing a pointed mandrel or punch to pierce through it easily. This method is commonly used in producing seamless tubes and hollow shafts. The main advantage is that it prevents cracking and ensures smooth internal surfaces because the metal flows around the punch rather than tearing apart.

6. (c) Explain the purposes of the following processes as used in sheet metal works:

(i) Planishing:

Planishing is used to smooth and refine the surface of sheet metal after shaping. It involves light hammering or pressing using a smooth-faced hammer and a planishing stake. This process removes minor dents and irregularities, producing a polished finish suitable for aesthetic and functional purposes.

(ii) Hollowing or blocking:

Hollowing or blocking involves shaping a flat metal sheet into a hollow form using hammers and stakes. It is used in producing curved or concave components such as bowls and lamp shades. The process allows metalworkers to gradually stretch and form metal into complex shapes without cracking.

7. (a) (i) Briefly describe three types of calipers used in the workshop.

The **inside caliper** is used to measure the internal diameter of holes or cavities. The legs of the caliper are inserted inside the workpiece, adjusted until they touch the walls, and then measured using a ruler.

The **outside caliper** measures the external diameter or thickness of objects like rods and pipes. The legs are adjusted to fit around the outer surface, and the distance is read with a scale.

The **odd-leg caliper**, also known as a hermaphrodite caliper, is used to scribe parallel lines along the edge of a workpiece. One leg has a pointed tip for marking, while the other has a curved foot for reference.

7. (a) (ii) There are eight divisions of 1mm and one subdivision of 0.5mm visible on the main scale. The 15th division of the thimble also coincides in the datum line. Find the reading of the micrometer.

Main scale reading = 8 × 1 mm = 8 mm

Thimble reading = 15 × 0.01 mm = 0.15 mm

Total reading = 8 + 0.15 = **8.15 mm**

Hence, the reading of the micrometer is **8.15 mm**.

7. (b) Explain the five basic precautions to be observed by anyone who uses a vernier caliper.

The first precaution is to **ensure the surfaces of the object and caliper are clean**. Dirt or oil can affect the accuracy of measurements by creating a gap between the jaws and the workpiece.

The second precaution is to **avoid overtightening the jaws**. Excessive force may damage both the caliper and the workpiece or distort the reading.

Thirdly, **the vernier caliper should always be zero-checked before use**. This ensures that the reading starts accurately from zero, preventing systematic errors.

Fourthly, **readings should always be taken at eye level**. Viewing the scale at an angle causes parallax error, leading to inaccurate results.

Finally, **the instrument should be handled carefully and stored properly**. Rough handling can damage the fine scales and affect long-term accuracy.

7. (c) (i) Differentiate between measurement and gauging.

Measurement is the process of determining the exact numerical value of a dimension using an instrument like a ruler or micrometer. It provides quantitative information about the size of an object.

Gauging, on the other hand, determines whether a dimension falls within allowable limits. It is a comparison process that uses gauges such as plug or ring gauges, giving a “go” or “no-go” result without an exact reading.

7. (c) (ii) Give the important characteristics for surface of gauges that are used in workshop.

Gauges should have **high wear resistance**, since they are frequently used against metal surfaces. This ensures long service life and consistent accuracy.

They must also possess **high dimensional stability**, meaning their size should not change significantly due to temperature or humidity variations.

Additionally, gauges should have **a smooth and polished surface finish** to prevent scratching the workpiece and to ensure precise contact points.

Lastly, they should be **hardened and corrosion-resistant**, ensuring accuracy and durability under workshop conditions.

8. (a) Briefly explain the processes of cutting external threads by using the following:

(i) Hand tools:
In hand threading, a die and die stock are used. The die is placed on the end of the rod and turned manually to cut threads as it advances. Lubrication is applied to reduce friction and produce smooth threads.

(ii) Lathe machine:
On a lathe, the workpiece rotates while a single-point threading tool moves longitudinally along the work. The movement of the tool is synchronized with spindle rotation using change gears to maintain correct pitch.

8. (b) Give the meaning of the following terms in relation to thread cutting:

(i) A flank:
A flank is the surface of a thread between the crest and the root. It forms one side of the thread angle and plays a role in the strength and fit of the thread.

(ii) Depth of thread:
This is the distance measured between the crest and root of a thread, perpendicular to the axis. It determines how tightly two threaded parts engage.

(iii) The number of threads:
This refers to how many threads exist per unit length, often measured in threads per inch (TPI). A higher TPI indicates finer threads.

(iv) Lead:

Lead is the distance a screw advances in one full revolution. For a single-start thread, lead equals the pitch; for multi-start threads, it is a multiple of the pitch.

8. (c) (i) Calculate the helix angle of thread with a lead of 5mm if screw diameter is 50mm. Take $\pi = 3.142$.

Formula:

$\tan(\theta) = \text{Lead} / (\pi \times D)$

$\tan(\theta) = 5 / (3.142 \times 50)$

$\tan(\theta) = 5 / 157.1 = 0.0318$

$\theta = \tan^{-1}(0.0318) =$ **1.82°**

Hence, the helix angle is approximately **1.82 degrees**.

8. (c) (ii) Outline six methods that are used to measure threads in the workshop.

The **pitch gauge** is used to check the pitch of threads by matching the teeth of the gauge with the threads of the screw.

The **optical projector** magnifies the thread profile to allow precise measurement of thread angles and dimensions.

The **microscope method** uses a toolmaker's microscope to accurately measure the pitch, angle, and depth of the threads.

The **three-wire method** involves placing three small wires in the threads and using a micrometer to measure the effective diameter.

The **thread micrometer** is a specialized micrometer with conical and V-anvils designed to measure the pitch diameter directly.

Finally, **CMM (Coordinate Measuring Machine)** can also be used for very precise measurement of threads by scanning their geometry digitally.