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Basics of Production Engineering In Metalworking Milling Machines

Eng. Mohammad Hamad Alajmi*
*(THE PUPLIC AUTHORITY FOR APPLIED EDUCATION AND TRAINING, Kuwait)

I. INTRODUCTION

Metal cutting and all the different production machines has been designed to reduce the human effort, and to raise production efficiency and quality while reducing expenses.

Metal cutting machines are used such as lathes, milling machines, scrapers, drills, grinding machines, grooving machines for craft items with flat, conical, toothed or cylindrical surfaces, with required degree of roughness or smoothness, by removing layers of metal piece in form of Swarf, in order to get the required shape and measurement of the product.

High-precision is achieved while manufacturing craft items using metal cutting machines compared to the production of manual operation, so it is required in these machines to obtain the desired operations and speed movements, and each machine is included with equipment to install a number of pieces and craft items safely, and that the operating and control units are easy to use, and these machines should be manufactured with strength to be with well-established architecture and acceptable shape.

We will discuss in this effort: The Basics of Production Engineering in metalworking: (Milling machines).

II. METHODOLOGY

I will address in this effort Basics of Production Engineering in metalworking machines
- Formation by copying and drilling templates milling machine.

The horizontal milling machine is considered the simplest type of milling machines, and named horizontal relative to the horizontal spin column carrying the milling knife and parallel to the tray table.

Vertical milling machineis called with this name accordingto the vertical position of the cutter's column, Vertical milling machine is similar to horizontal milling machine in terms of form and basic movements of the knife and craft item, also differed from each other in the direction of the cutting tool positionand what follows these on milling and after work and experience using several types of minerals to produce different types of artifacts show us the quality of surfaces producing these artifacts.

Types of Milling Machines

Milling machines are machines that are used to smoothing the horizontal, vertical, oblique and curved surfaces of accurate craft items, as it is making grooves and opening of the teeth Straight, helical and conical teeth for gears with simple and fast way, through the leadership of the milling machines knives with circular motion on the craft items surfaces.

Milling machines are Similar to lathes in cutting movement or major circular motion, where the milling knivesperform the Circular movement in the milling machines, while the craft item does this movement in the lathe, and often the craft item does the feeding and approach movements during the different milling operations, as the tools perform these movementsduring the milling in the copier machines.

There are different types of milling machines, the most important are the following:
- horizontal milling machines.
- Vertical milling machines.
- Universal horizontal milling machines (gathering purposes).

arrangements to convert the rotation movement from horizontal to vertical.

As vertical milling machine is similar to automated drills in terms of the vertical position for the cutting tool and cutter's column feeding movement.

The vertical milling machine produces several crafts through the following movements:
- cutter's column head carrier movement to the top and to the bottom.
- Cutter's column head carrier movement to therequired angle.
- Table Movement (tray) up and down.
- Longitudinal feeding movement in both

directions.
- Transverse feeding movement in both directions.

WhileUniversal milling machines (gathering purposes) is similar to simple horizontal milling machine to a large extent, but the first distinct from the second in the possibility of conversion horizontal milling machine to vertical milling machine, in addition to the possibility of table movement (tray) in a circular motion in opposite directions to reach 45 degrees in each direction, so that feeding will be in oblique direction of the spindle, it is done through installing the tables on a circular base divided into grades for possible production of spiral grooves on the cylindrical operating pieces.

Universal milling machines (gathering purposes) in many industrial processes, including:
1. Settlement and formation of flat surfaces
2. Digging grooves.
3. Digging spiral grooves on the cylindrical operating pieces.
4.Do camshafts.
5.Production of gears teeth with straight and helical teeth.

Universal milling machines (gathering purposes) differs from other milling machines with the following advantages:
1.Tray presence between each of the plotter and the carriage, and thus the plotter can be installed with deviation from the main axis (at an angle with the cutter's column) to be able to operate snails.
2.The possibility of movement of the tray group-bearing the carriage and the plotter in all directions manually and mechanically.
3.Possibilityof converting to vertical milling machine by raising the horizontal axis and its accessories, and install a vertical milling machine unit that holds a vertical spindle.
4. Get more speed for each column of the overturn column and feeding group to suit the type of craft metal and cutter's diameter.

Basic movements done with Universal milling machines (gathering purposes):
1.circular motion of the knife installed horizontally.
2.Circular motion of the knife installed vertically.
3. Longitudinal feeding movement in two directions (right and left) on the main axis or at a certain angle.
4.Transverse feeding movement in two directions.
5.Feeding movement of the tray to the top and to the bottom.

Milling and configuration machine is used by copying and drilling templates in the production of crafts with complex surfaces.

Motion passed on number of different pieces with milling and configuration machine by copying and drilling templates by mechanical or hydraulic or electromechanical ways.

The principle of milling and formation by copying is through controlling the movement rates of many cutting tools, by composition templates that are designed specifically for this purpose, so this type of machine is fast, efficient and high precision.
Cutting tools (milling knives) in milling and configuration machines by copying to feeding movement in different directions as follows:
- Longitudinal feeding movement in two directions.
- Transverse feeding movement in two directions.
- The depth of cutting movement in two directions.

Milling process

Milling is the process intended to remove metal part of the craft item in the form of swarf by milling knife with a multi-tooth circular section, each of the teeth represents simple cutting toolwithone edge.

Due to the multiplicity of teeth means the multiplicity of cutting edges in the milling cutter, so you can remove a large size of the metal parts in the form of swarf in a single operation. The milling knives are made of high speed steel, where it has enough durability to do different metal processing as long as possible without the need for sharpening, and their efficiency depends on the cutting edge angles, like the other cutting tools. Milling knives moves with circular motion during the various cutting operations where cutting edges Permeateinto the metal piece to be regularly cut, these edgesdiverge from each other in equal spaces so that the space between each edge and end-axis exactly equal to the one who followed, in order to equal the depth of cutting in front of each edge.

Number of cutting edges vary depending on diameters of each of them: In the case of cutting edges converge from each other, the small distances between them cause the accumulation of the swarf which weakens its durability. Experiments was made on a large number of knives used in the milling operations of different pieces through the comparison between number of teeth (the number of cutting edges) and found that knives that have less teeth have the most quality in the operation.

Running surfaces milling operations metal cutting operations summarized generally in removing excess layersfrom the craft on the form

of swarf, to get a specific with the required shape, measurements and the degree of softness.Operating machines that do cutting operations are Lathe, scrapers, Drill, milling machines, and others, different cutting operations are done on these machines using a number of different cutting tools, turning tools, milling knives and drills.

The process of turning is the foundation for all metal cutting operations, and the turning tool serves as the basis for all cutting tools.

To implement the various cutting operations on a lathe or on milling machine it is necessary to have two basic movements:

1.the basic movement (the movement of cutting).
2. Feeding movement.

The basic movement (cutting movement) in the process of turning is the rotational motion of the operating pieces, whereas the basic movement (cutting movement) in the milling process is the rotational motion of the cutting tools and the cutting speed is usually determined by the basic movement speed.

The feeding movement in the turning process is the transition movement of the turning tool in the longitudinal and transverse direction, while feeding movement be in the milling process is the transition movement of the craft item in three directions (longitudinal and transverse and vertical), and through cutting operations on a lathe or ona milling machine, it produces various artifacts with the required engineering forms by the penetration of the cutting edge of the tool and separation of layers of the metal.

Operating flat horizontal surfaces

The flat horizontal surfaces is operated by using cylindrical cutting tools, and there are different types of cylindrical cutting tools including:

- Cylindrical milling knife with straight teeth.
- Cylindrical milling knife with left spiral teeth.
- Cylindrical milling knife with right spiral teeth.
- Cylindrical milling knife with roughspiral teeth.
- Cylindrical milling knife periphery with spiral teeth.

One of the disadvantages of right spiralor left spiral knives is a side pressure on the craft during the cutting.

Therefore we prefer to use the double spiral knives with right and left together, and in this case the side pressure is vanished, since the side pressure resulting from one contradictory to theside pressure from the other.

Flat surfaces milling operations can be divided using horizontal milling machines or universal milling machines to the following:

- Peripheral milling to the bottom.
- Peripheral milling to the top.

The method of peripheral milling to the down is characterized by the following factors:

- Low corrosion of the surface of the back cutting edgetothetooth.
- Low temperatures resulting from cutting forces.
- Reducing the generating edge and increase the cutting machine's life.
- To get surfaces that are good in operations.
- Consumption less possible power in the milling process.

As peripheral milling to the bottom method is preferred when milling surfaces that are installed good and tight on the machine table, and this method is only used on rigid milling machines, but if the part to do the milling on is molten or knocked it should not use a method of milling to down because the knife's tooth begin to penetrate in metal hard crust, which affects the speed of corrosion and damage.

Linking crafts on milling machines

Small craft items is linked in of the machine's accessories, and the large-sized artifacts are linked directly on the milling table, using different linking aid, it is natural that the linking screws heads suit the table's streams that is shapedonthe form of 'T'.

The most widespread milling machines accessories:

- Fixed **binding**.
- Binding with tray included.
- General binding (Universal purposes).

While linking operatingimportantcraftsyou have follow the following:

Disassemble binding screws to allow a simple clearanceof the movement between the machine table and binding stream.

- Linking one of the two screws by hand and connect the other screw by the key so that it can control the movement of binding the circular motion.
- The accurate movement of binding by the suitable knock on one of the sides of the binding using a hammer made of plastic, and the installation is done using the appropriate means and equipment.
- Linking the binding screws well using a wrench.
- The accurate installation of the binding is done using the following:

1. The dial gage with a magnetic baseis installed on the millingfurnishing.

2. Set craft through the Sensor of the dial gage, the movement of the table on the lateral surface of the piece to operate, and knocking on the binding sides using suitable plastic hammer.
3. Install a good binding screwswith the required position.

pieces and calculations of milling elements
Milling process from terms of cutting, required precision and the quality of the surface depends on the right choice of the cutting speed, the amount of feeding and depth of cutting, and the right choice depends on technical expertise who does the milling process.

It is known to all technicians working on various production machines, that the greater the cutting speed the more heat generated due to friction force, As a result the temperature of the knife's teeth rises, and when reaching a certain temperature the cutting edges lose their hardness, and thus the knife losesit's ability to continue the cutting process.

The milling technician in order to be able to operate all the crafts with the right way to get the best possible results (in terms of operating and maintaining turning tools) it must identify the correlation of cutting elements (cutting width, cutting depth, cutting speed, the headquarters of feeding) to each other, and they are as follows:
- Cutting width:

The thickness of a metal layer that the milling knife removes from the surface of the operating craft item in one way of millimeters.
- Cutting depth:
It the thickness of a metal layer that the milling knife removes from the surface of the operating craft item in one way of millimeters, usually the cutting depth is equal to the thickness of the layer to be removed, if this layer was big it can be removed in several runs as follows:

1. roughingstage:
thickness of the removed metal is large, we use milling knives with great pitches for this purpose, and usually ranges of cutting depth in the rough milling between 3-8 mm.

3. **smoothing stage (finishing):**
4. The thickness of the removed metal in this case is small, we use milling knives with small steps, and usually ranges of cutting depth in soft milling between 0.5 -1.5 mm.

The cutting depth can be found from the following relationship:

A = L1-L2

whereas :
A: depth pieces.
L1: Craft height before the milling process.
L2: Craft height after the milling

Process.
Cutting speed:
It is the speed at which the milling knife moves circular motion, any peripheral speed on its axis, and it's unit is measured with: the meter / min. The choice of the number of turns per minute also depends on the cutting speed and the diameter of the cutter, and cutting speed can found by the following relationship:
P = n / d / n ÷ 1000 (m / min)
N = 1000 ÷ P (n * d) (revolution / min)

Whereas:
P: cutting speed.
D: diameter of the milling knife.
N: number of milling knife's revolutions per minute.
And it can be divided on 1000 to convert from meter to a millimeter.

Cutting speed is based on several factors:
1. The type of metal used in milling knife.
2. The type of metal used in craft item
3. The diameter of the milling knife
4. The number of milling knife's teeth.
5. The amount of feeding.
6. Cutting depth.
7. The grade of surfaces quality (roughing - smoothing).
8. The use of a cooling liquid or without it.
9. Power and efficiency of the machine.

In practice usually the speed used during milling operations, about half the speed used during turning operations, and cutting speed in milling operations must change inversely in relation to the hardness of material to do the milling operations on, whenever the milling operations are done on more hardness part whenever the milling knife rotation speed decreased and the cutting speed must not increase of any milling process more than the typical rates for the following reasons:
- To avoid breaking the milling knife or loss the hardness of the cutting edges through high temperatures that lead to rapid corrosion and damage.
- To avoid damages to the milling machines.

- To avoid moving the craft item between the jaws of the binding machine or any oscillation during milling operations, thus a lack of the quality of running surfaces.

Division heads

The division heads is considered the most important part in milling machine accessories, where you can install the crafts and moving it on its axis, and can be divided into any number of equal sections, and through the use of their own drilled disks.

This will lead to the expansion of the work to produce the required crafts to do the milling on according to the required section.

There are different designs of the division heads, each of which differs from the other, but practically all of them are united in the purpose designed for, which is the exact division.
- Handle.
- Direct division head.
- Division head protection cover from the swarf.
- Body of the division head.
- Chuck with a finger.
- Division headcentre.
- Moving head centre.
- The moving head.
- Installation nail.
- Controlhandle of the longitudinal movement of the moving head centre.

Division ways

Craft items that are required to be divided differs from each other depending on the partition type:
- Direct division.
- Indirect division.
- Discriminating division.
- Differential division.
- Spiral milling.

used division heads are different for each of them, here different ways of division:

Direct division:

while doing many of milling operations using the direct division, the more productive and economical heads are those heads that are helping to implement the direct division only, note that in the case of direct division no longer the infinite worm and worm gear are not engaged in the division head.

Craft item that needed to be divided is installedbetween the centre of the division head and centre of the moving head, and is used to divide the interchangeable disk often contains 12 or 24 hole or stream, where it is installed on the axis of the division to the left side of the division head, note

There are different designs of the division heads, each of which differs from the other, but practically all of them are united in the purpose designed for, which is divided into the following types:
1. Direct division head.
2. Simple division head.
3. The collective purposes division head (general division
head).
4. The optical division head.

There are also other hydraulic division heads works with compressed oils, pneumatic works with compressed air and electrical works with electricity.

Direct division heads consists of the following parts:
- Turning off arm.
- Direct division head nut install.

that there are interchangeable division heads contain:

16-24-36-42-60 hole or stream.

In the case of a division head contains 12 hole or stream, the following divisions can be obtained: 2-3-4-6-12 portion equal.

The purpose of the use of direct divisiondisks, is to divide the requiredcrafts by dividing the disk holes to any number of equal sections without remainder.

In direct Partition:

Simple division head in used in the indirect division, where the division head spindleaxisturns around through infinite worm and worm gear, and the proportion of transmission in the gears group equals 1:40.

Divisionis calculatedthrough fixed division disks, through partitioning attachment connected to divisionhead spindlethrough worm engagement. Simple division head from the inside contains infinite worm with one interlocked door with worm gear contains 40 teeth, this means that when the worm rotates one revolution through the partitioning attachment, the gear worm moves just one tooth, means it movescircular motion by 1/40 of the revolution, as well as moving the craft with circular motion by 1/40 of its surroundings, it means angle of 360/40 = 9 degrees, and thus can cut serrated gear contain 40 teeth.

This means that when the craft rotates one revolution, it must rotate the division attachment that is directly related to the worm with full 40 laps.

When the craftturns over of half revolution (180 degree), it must complete 20 laps, and so on. Thus, you can calculate the number of cycles of the division attachment through the following relationship:

Number of division attachmentcycles = number of gear teeth ÷ (number of sections required * Number of worm gates).
Or: **N = G ÷ T**

whereas:
N: Number of division attachment cycles.
G: The number of worm gear teeth (usually 40 teeth).
T: number of divisions required.

Discriminating Partition

Discriminating division is expanding in the division method, where access to a wide range of indirect divisions.The craft is divided this way if you cannot use the simple indirect division method is, in the absence of drilled division circles which are appropriate to divide the craft.

The formerdivision head is used in (direct and indirect divisions) in discriminating division by adding gears group to change it, so that the partition disk is free in movement, which means not installing disk partition.With management of division attachmentdivision head spindleaxisrotates, which manage the worm and gear worm, it's end is connected to the end of the craft, and the other end of the column, riding gear that spins and engage with gears group, rotational motion is transmitted to the spindle then to the two canonicalgears for rotating the spindle which haspartitioning disk installed on, thereby rotating partitioning disk.

Spinning motionof partitioning disk may be in the same direction or reverse of division attachment, depending on the system of gears engagement (clutch), and if theintermediate gear is changed with gears group, partitioning disk is rotated to the right in the same direction of the division attachment.

Spiral milling

It often requires milling spiral grooves or streams, so when you produce a lot of artifacts, such as: spiral drills (torsional), screws with spiral cutting edges (torsional), milling cutters with spiral teeth (oblique longitudinal teeth) and others. This kind of milling Can be produced on horizontal milling machines, or at general milling machines (Universal purposes) by adjusting it's division with discriminating division, using universaldivision head, where the craft piece which will be operatedby spiral milling in this case two movements at once, namely:
- Longitudinal feeding movement by the milling machine.
- Rotational movement by the division head. Regular rotational motion is done through the guiding spindle (which gives the feedingto the table via the gearsgroup and conical gears and straight gears and division catcher and a worm gear and from there to the division head spindle axisthen to the craft, each of the Division head and craft is movingwith the guiding spindle, Feeding screw of the upper table which is diagonal by step angle of the milling spindle axis, and it is natural to have rotational movement of the cutting tools (milling knives).

In this case it requires tilting the craft by tilting the machine furnishing according tothe axis of milling section with the installation angle, and must release the partitioning disk to be movement free and able to spin, and this can be done only on the Universal milling machine(universal purpose). To abbreviate the times of partition and conversion which are relatively large compared to the milling times themselves, and achieve greater accuracy, automatic visual division or hydraulic or pulmonary or electrical devices are used. Cutting tools (milling knives) draw a spiral line on the surface of the cylindrical craft, such as what occurs during cutting the spiral on the lathe. Spiral milling can be accomplished only on the artifacts which can adjust it's division with direct division.

We must in such cases calculate the change gears group that transmit rotational motion to the guiding column (which gives the feeding to the table) to the division head spindle and craft piece.

To calculate the change gears set, the pitches of each of the craft and the guidingspindle must be known.Andby calculating the requiredratio between the guiding spindle pitchand the spiral pitch to do the milling on the craft, so it can deduce the number of change gears teeth, as the ratio between the two pitches is equivalent to the proportion of transport in these gears, bearing in mind that the rate of transmission in the division head equal to 1:40, and on this basis it can calculate the ratio between the number of gear teeth necessary for spiral milling from the following relationship:

The ratio between the number of change gears teeth = (guiding spindle pitch * number of division Attachment revolutions 40) ÷ (required spiral pitch * 1)
= Number of leading gears teeth / number of submissive gears teeth

Gears

Gears is a cylindrical disks their surroundings contain a number of teeth, these teeth can be done through teeth cut milling, which means the use of milling cutters (knives) with appropriate cutting edges togapsforms between the teeth.

The gears in general movethe torque of a spindle to another, especially when the distance between them is relatively small, and transmission movement with gears is considered positive transmission without slippage between the leading gears and submissivegears, unlike transmission with conveyors or frictional disks which a slippage occurs between the leading movement and thesubmissive movement.
Transmission movement with gears is featured that there is no slippage, because of theoverlapping of gear teeth with the gaps of other gear, it can also convert rotational motion to straight motion using a gear and rack.

The gears are generally used in the following cases:
- When dimensions among the leading axis and submissive axis is not great.
- Positive transmission without any loss in the slippage.
- When a large and specific changing in the proportion of speed transfer.
- When transmission between the un parallel spindles (orthogonal or misaligned with certain anglesspindles).
- When changing rotational motion to straight motion as is the case of the rack.
- When the opposite direction of rotation is meant.
- When it is intended to change the speed from time to time without the need to install or disassemble parts using speed gear set.

There are different shapes, sizes and types of gears, they all should be linkedwith essential condition which is the teeth of leading gears have to pair with submissive gears teeth smooth engagement between them, and to achievesmooth engagement between gears the teeth has been designed with specific forms and directions, for example, straight teeth, oblique teeth, which tend a certain angle to the axis of the gear, and the double teeth that are found on the V-shaped and others.
For example, the cylindrical gears with straight teeth are used in the transfer of rotational motion between the parallelaxes, and cylindrical gears with oblique teeth used in the transfer of rotational motion between the parallel and perpendicular and deviant axes, and conical gears used in the transfer of rotational motion between the intersecting or obliqueaxes, and worm gears and worms, they are used in the transfer of rotational motion between the perpendicularaxes, worm gears and worm are commonly used when there is a need to reduce a large proportion of the speed, as for straight gearsand racks they are used when converting rotational motion into a straight movement.
And gears with straight teeth are cylindrical disks their surroundings contain a number of teeth, these teeth can be done by milling with cut, or by the use of milling cutters (knives) with appropriate cutting edgestogapsformsbetween the teeth.
rotational motion is transferred using gears in general (torque transfer) from a spindle to another, especially when the distance between them is relatively small, and transmission movement with gears is considered positive transmission without slippage between the leading gears and submissivegears, unlike transmission with conveyors or frictional disks which a slippage occurs between the leading movement and thesubmissive movement.

Straight gear contains a number of teeth has upper surface or top passes through it a circle called the top circle or the outer diameter of the gear, and have the bottom passes through it a circle called the bottomcircle or the inner diameter of the gear, while there is at a specific height of imaginary circle called the pitch circle.
These circuits are divided into equal sections called each of them atooth pitch, and the number of pitches on the pitch circuit surrounding is also the number of gear teeth, the length of each pitch contains a full tooth and gapare equal in width, it does not mean from this division that teeth top of the leading gear touches the tooth bottom in submissive gear, but must leave clearance to prevent this contact to avoid damage, as well as to submissive gear teeth shouldn't touch the bottom teeth of leading gear but leaves the same clearance, it does not mean that the side surfaces of the teeth are at full length, but there is a high or a certain depth for each toothcontiguity or sliding happens on, and then clearance must be left.

Knife's number:

Each type of milling cutters (knives Group) are numbered with serial numbers, and each number of milling cutters (millingknives) fits a certain number of teeth of the gears andshouldn't be bypassed to ensure the scope of the form of teeth of the gears when engagedwith each other.
For example, when you open the teeth of gear type 2 and the number of teeth 50 years, we must choose milling section (cutter) No. 6, which allows gear teeth cut off between 36 to 54 years.
When you open the gear teeth type 2 number of teeth 100 teeth, you must choose the knife No. 7, which allows to cut gear teeth between 55-134 teeth, the knife No. 8 is used to open gears teeth which exceed 135 teeth.
The following table shows the knife's numbers used for gears up to type 2

Knife's number	Number of teeth that can be cut
1	13-12

2	16-14
3	20-17
4	25-21
5	35-26
6	54-36
7	134-55
8	From 135 and more

The following table shows the knives used for gears with type greater than 2

Knife's number	Number of teeth that can be cut
1.5	13
2.5	16-15
3.5	20-19
4.5	25-23
5.5	40-26
6.5	54-42
7.5	134 -80

It must consider the following:

- When you transfer the power it should roll sides of teeth on each other smoothly with reducing friction and noise from them.
- Linear speed for each point must be on a circle of equal lines.

The gears can be produced with cut or without, in the formation without cutting method gears are accomplished in the following ways:

- Casting.-Die metalworks.- Pressing sintering.
- Stamping molding.- Rolling.- Cutting dies.

The method of machining gears using cut is done through the formation milling with milling cutters, as it can also scrape and grind the sides. The choice of the production method of the gears depends on the purpose of its use and achieve the requirements for fast and quiet rotation.

III. CONCLUSI

The method of metalworkingwithcutbyremovingswarfis considered one of the best operating methods in the field of industrial production, and that is because it results high precision and quality products, so we can find that the development of machines is increasing day after day, until it'suse gives the best results with lower cost, especially with mass production machines and one item production machines that produces wholesale uniform, or with automatic machines. And I explained through this effort the subject of engineering production and metalworking by milling machines, I hope from God that this work benefitsothers.

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Contents

Introduction

- Types of milling machines
- Milling process
- Running surfaces milling operations
- Flat horizontal running surfaces
- Linking crafts on milling machines.
- Basic cutting elements and calculations of

Billing.

- Division heads.
- Division ways.
- Spiral milling.
- Gears.
- Table shows the knives used for gears with type 2

Table shows the knives used for gears with type greater than 2

- Conclusion.
- References.
- Table of contents.