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Lathe Tool - It's Development from the Ancient times to Nowadays

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Abstract - One of the most important wood processing machines from ancient times till our times is the lathe. The tool of lathe occupies a prime position in the group of wood cutting machine tools and is a valuable invention for human mankind, since it offered the possibility of constructing a huge variety of objects and surfaces. The specific work indulges in the history of the lathe, the progress and evolution of this tool from the past time to the present. Additionally, the construction and operation of the lathe is analysed, presenting also some general information on lathes, the key components, types of lathes, the main turning types, the cutting tools and the tool holder's axis of the lathe and how some of them changed through the years.

CNC / lathe / revolver lathe / tool / turning / wood processing

1. INTRODUCTION

Over the centuries, mankind has recorded very significant progress, part of which was the development of a range of tools and machines that contribute to the use of different materials, such as wood, metal, etc. satisfying in that way several human needs. For the treatment of materials and the production of various products, various tools were devised and implemented in machines, using energy to achieve the work with much less effort and time.

Such tools are mainly used in the treatment of materials (wood, metal, etc.) in such a way as to obtain the desired configuration of shapes, forms and dimensions, by means of material removal. Apart from the conventional tools that work manually, now there are also automatic tools (CNC, NC, etc.) connected to a computer, which are characterized by accuracy and clearly greater efficiency. There are several tools which work by removing material, such as "cutting" machine tools, that basically cut the raw material into smaller pieces or cut shaped pieces of the material, in order to avoid creating much waste during the process, while the material is being transformed into an accomplished in form and dimensions product. Also, in recent years, there is a confluence of several separate machines that work on a production line or a flexible machining system.

The lathe occupies an important position in the group of cutting tools and a valuable invention for humans, since it offers the possibility of constructing a huge variety of objects and surfaces. The specific work indulges in the history of the lathe, the progress and evolution of this tool from the past time to the present. Additionally, the construction and operation of the lathe is analysed, presenting also some general information on lathes, the key components, types of lathes, the main turning types, the cutting tools of the lathe and how some of them have changed through the years.

2. HISTORY OF LATHE

Lathe is one of the first tools used and very useful to mankind, even nowadays that the technology has been recorded a great progress (STEEDS, 1964). The lathe took its name by the prefix «τορ-» («tor»), which comes from the verb «τείρω» («tiro»), which means rub (or chagrin intensively) and the suffix «-νος» («nos»), and basically, it is a tool built with the

intention of formulating a material through the clamping and rotation of the force under appropriate cutting means.

The operation of the lathe is based on a very simple and understandable principle. Wood is forced to rotate on an axis, while a sharp tool cuts, scrapes or smoother it, in order to give the final shape to the product. The wooden element is fastened at two points, which form the axis of rotation (STEEDS, 1964). This simple machine, the machine of lathe, is used for thousands of years and some of the reasons are listed below. Essentially, with pretty much ease, lathe produces objects of round surface, it is a machine of inestimable value and contribution to the construction of wheels for carriages, windmills or pumps. With the help of the lathe, rotating spindles are easily assembled in structures of high complexity, such as chairs, tables, beds and other furniture. From an aesthetic standpoint, the lathe helps in creating aesthetic, decorative objects and surfaces, which would be impossible to be constructed without the use of lathe. Combining simplicity in engineering, adaptability, and high aesthetics, turning has been proven to be a valuable practice adopted and strongly requested by the market, while it is part of the European culture (RETTIE, 2009).

The invention of the lathe is placed in the ancient times. More specifically, it was initially known to the Egyptians, and some years later on the Syrians, Greeks, Romans and later throughout all the Byzantine Empire. One of the earliest depictions of lathe was the fresco found in Ptolemaic dynasty tomb. In those years, the lathe was also known by other names, derived from the turbulence and rotation or the material removal, while later people began to use the word "tearing" as the name of the lathe. Several sources indicate that the tool of lathe was used since 1300 BC by the Egyptians. Also in the work of Herodotus the use of the lathe in pottery is reported, demonstrating the fact that they had already known and used the lathe, but as evidenced by scholars such as for example, by Varoufakis, who studied the crater of Derveni, the lathe of metal objects seems to be used already those years. The type of “arched” lathe depicted in the images that follow, was a revolutionary discovery of those ancient times, since for the first time only one craftsman was enabled to handle the lathe, while the earlier lathes required definitely two craftsmen. These earliest forms of lathe were the vestibule of the evolution of the lathe, and the mechanical evolution in general (NOESIS, 2012).

A.  B. 

Figure 1. A., B. Arched lathe (http://www.archimedesclock.gr/gr/kataskeves/diafora/tornos.html)

The lathe was also used by craftsmen who made pulleys, gaskets, carriages, connectors, copper utensils, anvils, bells, etc. From 4th to 7th century, there is evidence that show the lathe in England, while in 1180 according to data the first turner guild was established in Cologne (Germany) (RETTIE, 2009). In the Middle Ages, European turners seem to prefer a kind of lathe called "Spring" lathe. In this form of lathe, there is a frame of sufficient height in order the turner to stand comfortably in it, which holds tightly the fixed element and rotates it between two points of an axis, fixed on two sharp metal parts that otherwise are also called centres. There is a string that runs all the way from the tip of the pole, to the base, so as to take easily place the phenomenon of recoil, necessary for the rotation of the wooden piece. The string is well fastened around the piece that is going to be turned, at the point where exactly it is needed to be turned, in order the piece to be drifted by the string as it moves, while the string ends in this kind of a pedal (or pedals) located at the lowest point the lathe. At

this point where the operator applies his leg, he causes the movement, while as the operator leaves the pedal, the movement is released. Simultaneously, the operator apply to the surface of the wooden element, knives and other cutting tools, in order to give the appropriate shape and dimensions to the material (http://www.historicgames.com/lathes/springpole.html).

The string lathe has been proven to be of particularly high adaptability. It is lightweight and portable, two very important factors for manufacturers of that time, who may be moved and travelled to places where raw materials were in abundance. That lathe was also easy to be manufactured, and most of the necessary for its construction parts, were easy enough to be fixed by the manufacturer himself. The main drawback mainly derived from the design of this lathe was its relatively low speed, and the limitations in size and weight of the wooden object that was going to be turned. Until the mid 19th century, despite these limitations, the lathe that uses string remained the most popular among other types of lathe, and was preferred mainly by chair and various artefacts manufacturers (RETTIE, 2009).

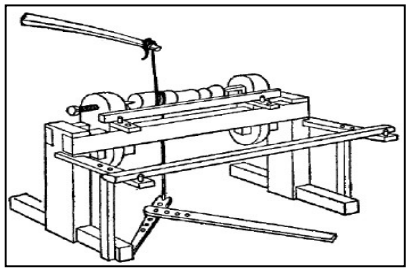
a)  b)  c) 

Figure 2. a) foot spring lathe, b)hydrokinetic turning (1425-1523), c) lathe with band (UOC)

Many variations of this lathe design followed, incorporating also a lever (handle), in order to replace the specific frame that was situated above the head of the operator, with a frame on the basis of the tool or with a bow that holds the string and converts the whole process, to produce a constant rotational movement, providing greater convenience to the operator (RETTIE, 2009).

In the late 15th and early 16th century, the point of cutting tools deposition as the turning object was rotating appeared for the first time in lathes of that time. This added surface was based on pins, as is shown in figure 3, and the surface is fixed in the desired angle using some wedges, in a way that the cutting tools can rely on a stable surface to achieve greater accuracy during turning and secondly, to increase the possibilities of turning and range of turned surfaces that could be achieved.

The most popular lathe used in the Middle Ages was the “spring” lathe. One of the main achievements in the operation of the lathe was the passage of the back and forth motion in continuous rotational movement, which ensure faster rotation, while giving the possibility of processing parts of much larger dimensions. In addition, the design and construction of this lathe, reduced the effort and energy consumed by the turner. As evidenced, from the Middle Ages, it was known how to converse the reverse movement into a rotational movement. With the help of some mills that were taking advantage of the running water movement, the motion was transferred using some arms, to reciprocating saws, giving a continuous rotary motion. Over the years, the mechanical skills of craftsmen were further developed and the complexity of the mechanisms as well, which was often increasing the cost of these structures and machines. To sum up, initially, the first lathes that appeared were moving with the power of man muscles (foot turning), and then with the help of water movement (hydrokinetic turning), referring to downstream mills and finally the motorized turning lathes (UOC, 2012).

Some lathe designs have been found also in sketches of Leonardo da Vinci, who besides having captured, is likely to have also improved some of these lathe designs that have already existed. The existence of continuous rotational motion lathes was set in from 1560 to 1570 and was often depicted in books ("Book of Trades" by JOST AMMAN, etc.).


B.

C.


Figure 3. a) Lathe continuous rotary motion bearing burin (Archive of Samian Folklore, 2008), b), c) Furniture and objects which required turning for their construction

The use of these lathes of the continuous rotation was quite limited in those years, mainly due to higher costs, the abundance of older lathes of reverse motion, and probably, due to the restrictions that were being raised by the trade unions of that era. More specifically, the urban trade unions set often restrictions on the use of specific tools or methods used by themselves as craftsmen. For the lathe, in particular, there have been many conflicts over who has the right to use it, while the regime that tried to establish a situation where one had to have a special permission in order to be able to use the lathe was not preceded. In the countryside, the restrictions were not so intense and craftsmen could trade lathes and use their own tools.

There were many furniture pieces and small objects that required turning during their construction, as well as various connections of wooden or metal components such as the most frequently used type of connection "Mortise and Tenon" (*Figures 3 b and c*).

The lathe operator undertook mainly indoor furniture, and one of the most popular furniture manufactured with lathe was the tripod stool (*Figure 3 b*), which is a highly stable cabinet formed after connecting wooden pieces of cylindrical section. It used to adorn the homes of both villagers and wealthy families (nobles, clergy, scholars, etc.) and many images of this furniture have been recorded dating from the early 16th century onwards. Various elaborate versions of this turned furniture followed, while the following years back and also slots for elbows were added to the furniture, giving an integrated chair (17th century). Except furniture, plenty of other objects were being manufactured using lathe, such as wind, mortar, mugs, cups, plates, tool handles, castors, trolley wheels, boxes, sieves, various games, pulleys, buttons, cuffs, scales, pumps etc.

The artisans of lathe in the Middle Ages were using a variety of wood species, and based on found Anglo-Saxon and Scandinavian artefacts (ca. 990-1000 AD), it has been proved that maple, birch, walnut and ash were the wood species chosen more often, while yew, pixos, beech, and the black pine were used under certain conditions. As it is known, each wood species has different physical and mechanical properties, and therefore, its behaviour during machining can greatly vary. Generally, denser wood achieves better results, better turning and smoother surfaces. The oak, for instance, although was routinely used in furniture wooden joints construction, as it was demonstrated after some years, it is not easily machined, due to the structure and layout of the annual rings, therefore it was abandoned.

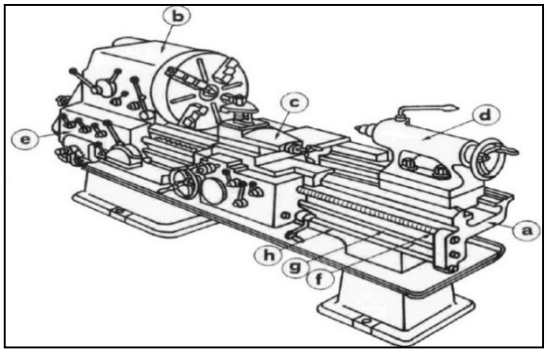
In Middle Ages, the turners worked mainly with non-conditioned wood, of high humidity. The cause of using wet wood during turning is that the humidity makes the wood softer, which is more easily cut and thus, the operation of lathe is better. As the wood fibres are soft and flexible, the technician applies the gouge in rotating piece, removing material as a continuous wooden strip. Of course, the wet timber is not suitable, when the machining should be done internally, which means on the inner side of the object, a cavity, for example in glasses, cups etc. The reason is that when the timber starts to dry, different dimensional changes in the transverse, radial and tangential direction of wood will be caused, which will lead to deformation or breakage of the structure. The timber can be machined wet, but during the connection of the pieces and the construction of the wood product is necessary wood to be dry (10-12 % moisture) (RETTIE, 2009). As LEON BATTISTA ALBERTI also reports, during the

15th century, turners used to immerse the timber in water before the use and often leave covered with mud for 30 days in order to facilitate its handling, contributing to a more stable material and avoiding checks and distortions of wood (RETTIE, 2009).

It is striking that some researchers report that the history of modern mechanics starts in the last years of the 18th century, when Henry Maudslay, of English origin, produces the first lathe which created thread, generating the known screw. Clearly, if one compares the 18th century lathe, to today's lathes, he would undoubtedly conclude that the lathes of that era were very time consuming, laborious and of low accuracy, but it was of great significance that that tool was developed in the lathe that we know today (BURGHARDT *et al.*, 1959).

3. THE BASIC COMPONENTS OF LATHE TOOL

The lathe is a machine tool used in the construction of objects of circular cross section, as mentioned above. The main movements during turning up of the main motion are the rotary motion of the object and the feed motion of the cutting tool which is rectilinear (BURGHARDT *et al.* 1959). Some of the most important pieces of a common machinist lathe are the lathe bed (on the lathe), the electric motor, headstock and propulsion, or turning area with predetermined dimensions (diameter, turning length), the tool axis or the centre line/ tailstock, the drive threading axis, feed or propulsion axis and sleeve axis (PARIKOU, 1988). The tool of lathe can yield rotational, curved, concave or flat surfaces.

a) 

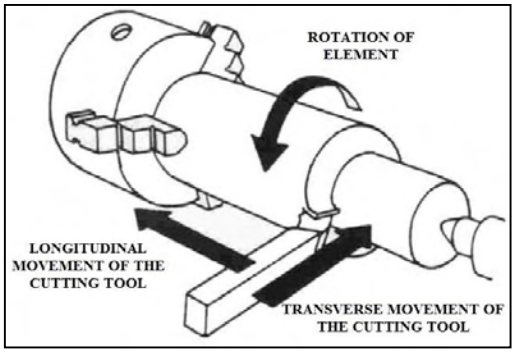
b) 

Figure 4. a) The basic parts of a lathe: a. lathe bed, b. headstock, c. tool axis, d. tailstock, e. feed gear box, f. drive threading axis or lead screw, g. feed or propulsion axis, h. switch bar, b) Turning and the motions carried out (UOC)

One of the most basic parts of the lathe is the lathe bed, which is based on two pedestals together via a very strong beam. The lathe bed features in the upper flat slides or prisms, which should be in perfect alignment and highly resistant to corrosion. During the turning, as mentioned previously, a rotational movement is performed around the axis of the wood, while the tool is displaced continuously linearly parallel to the axis of the piece until the desired shape of wood is achieved. This longitudinal turning can be internal or external of the material. Apart from this longitudinal turning, it is possible to have a frontal, collateral, lateral, conical, spherical, curved turning and the corresponding surfaces, and also threading, grooving, cutting of shoulder nerve etc. (PARIKOU, 1988).

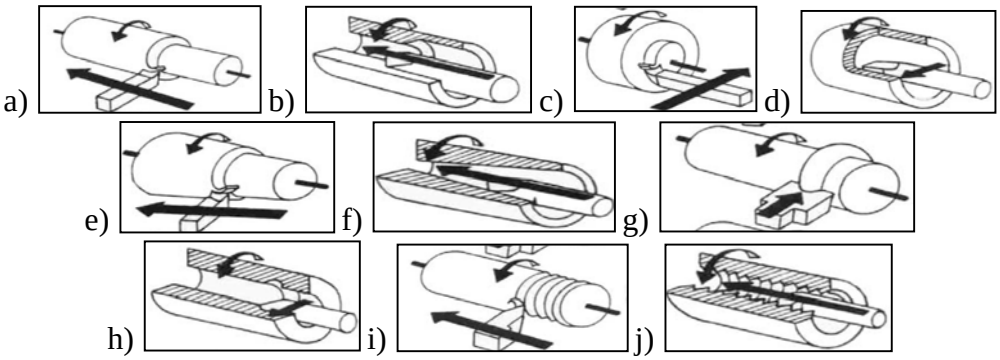


Figure 5. Types of turning treatments: a) external longitudinal, b) internal longitudinal, c) external transversal, d) internal transversal, e) external taper/conical, f) internal taper/conical, g) external profile, h) internal profile, i) external thread, j) internal thread (UOC)

A lathe of general uses can implement the following basic turning types: Turning external and internal cylindrical surfaces, turning of flat surfaces / transverse turning, turning of conical surfaces, boring small or deep holes, eccentric turning (cams, crank shafts), turning of specific shape / profile, cutting internal or external threads of all forms, treatment of external and internal spherical surfaces, making winding of springs knurling etc., sanding onto lathe bed, grooving and cutting.

At the left edge of the bed, there is the gearbox, with the necessary number of gear means / clutches, necessary for the transmission of the rotational speed to the spindle motor. The alongside and transversely promotional moves are achieved through the tool axis, which comprises the longitudinal, the transverse slide and the slide of the rotating plate. All the cutting tools are fixed in a tool holder, which is located in front of the bed (tool carrier box) and run along slides. The movement of tool axis is accomplished either manually with the help of the lever, through a rotation which press the gear wheel engaging with a toothed rack fixed to the bed or automatically through the rotating axis, the propulsion axis, while for threads cutting, respectively it is accomplished through a threading axis (PARIKOU, 1988).

4. CONSTRUCTION AND FUNCTION OF LATHE

While the pieces of circular cross section rotate around their axis in lathe machine, various types of cutting tools are applied on the surface, forming the desired design. Undoubtedly, the range of patterns that may be achieved is very wide (BURGHARDT *et al*. 1959). The cutting tools may be held by the operator and the machine to be driven in an appropriate manner by him or they may be applied to the moving element tool axis carrying the selected tool and then the operator just drive the entire system. Of great importance is the stabilization of the piece that is going to be turned, in order to avoid accidents and destruction of wood.

There are lathes of various sizes depending on the dimensions of the treated material. It is very important the placement of the lathe at a suitable height, and the stabilization of a solid substrate, in order the turning process to be convenient and safe for the operator (ERNEST, 1980). A lathe of acceptable quality usually has an engine of ¾ or 1 horsepower capacity. Most lathes are capable of switching 3 or 4 different speeds. Higher accuracy and purity are usually achieved at higher speeds. Initially, when the material is still completely raw the speed is kept rather low, while the material is shaped as the speed rises. Additionally, the heavier and denser wood we have, the lower speed should be applied (ERNEST, 1980).

The cutting motion that is carried out by the rotation of the object is called cutting speed (Vc) (MANTEMIS, 1996). There are lathe beds that give approximate values of cutting speed for each material and diameter of the object. Upon the engine of lathe one can usually find a

fixed chart to read the speed n with which the lathe operates, while there is also the possibility of calculating the speed through beds, putting the cutting speed and wood element diameter one can find the respective speed of the lathe (MANTEMIS, 1996).

The cutting speed or as it is called otherwise, the speed of rotation of the turned wooden piece and the speed of propulsion which is also called movement of the tool in a direction parallel with the axis of wood, depend mainly on the nature of the treated material, the material that the tool is made of, and the desired quality of wood surface one wants to achieve (MANTEMIS, 1996). In planning treatment, usually a large propulsion and cut depth is adopted, while in treatments where great attention is crucial for the final result, such as the finishing treatment, usually small cutting depth and propulsion is selected. Referring to propulsion, essentially one means to the movement that the tool completes (in millimetres) in one rotation and is selected according to the engine power and the desired final surface quality.

Cleaning the lathe is a very important and necessary process and should be take place when the lathe is idle. A small piece of cloth soaked in kerosene, can be used to remove dirt and oils, while the surfaces should be passed with a dry cloth in order to remove residual of kerosene. The quiet running bearings should be lubricated each time before use, with the necessary quantity of oil and checking of pipes that lead the oil in different parts of the machine should be frequent, in order to avoid their blocking (BURGHARDT *et al*., 1959).

The number of shapes and kinds of cutting devices used in lathe is quite large, despite the efforts that have been made in the direction of standardization of these cutting tools and thus reduction in their number (STEEDS, 1964). Very important is the form of the waste coming from the cutting tool and tool material and its resistance to wear and tear. The hardness of the tool should be maintained even at high temperatures, in order to prevent the occurrence of cracks (MANTEMIS, 1996). The tools are typically made of steel (either pure steel, or alloys), a very durable material which is sufficiently elastic and resistant at high temperatures (400-600 ^{o}C). Tools are usually coated with titanium nitride to withstand even more to wear.

5. LATHE TYPES

The tool of lathe, following the general technological development has been evolved and has met all the requirements of structures characterized by accuracy, productivity and automation. Those three factors are essential in each tool for high volume production, good quality product and low cost. In terms of use, the lathes are divided into lathes of general use and lathes of special purposes.

In the lathe of general use, almost all turning processes can take place. There is the potential to receive wooden items between the centres and for this reason, this lathe is also called "lathe of the centres". These lathes are usually equipped with mechanical motion for propulsion and therefore, are often called "propulsion spindle lathe" (MANTEMIS, 1996).
In this category of lathes is also included the “centre-line parallel” lathes, or “universal”, (equipped with propulsion axis and screw threads), the “centre-line parallel productive” lathes (equipped only with a propulsion axis or a hydraulic transmission of propulsion), “parallel” with a variety of knives, “rotational” or “revolver” lathes, the “copying” lathe, the “semi-automatic” and “automatic”, “vertical” and “frontal” lathe.

The “revolver” lathe, referring to the facilities it offers, lies between the “universal” lathe, that all operations are driven by the craftsman and the completely “automatic” lathe. The automatic lathe operates either with a purely mechanical program of automation, or by an electronic control unit (NC or CNC). The “revolver” lathe is characterized as "semi-automatic machine", used mainly where there is a relatively large production. In this way, in a wide variety of products, the “revolver” lathe performs the same work in much shorter time, compared to the conventional lathe, while the accuracy achieved is quite the same.

Called also as "expertised" or "sectoral", lathes of special purposes are used in specific processing and turning of objects in various industries. For example, lathes for cutting threads, lathes of the automotive industry, lathes machining crankshafts, lathes in the railway etc. The classification of lathes in this category depends on the use, the characteristic structural dimensions and different sizes.

6. CONCLUSIONS

Taking all the above into account, turning can provide various forms of the work piece through the combination of various movements, and use of appropriate cutting tools. Apart from conventional lathes, which are guided by the operator who makes all the necessary movements and arrangements for the treatment, lathes can also be driven digitally and in this way the movements and settings require much less human involvement since the electronic guidance unit and the developer undertake all the main work. In conclusion, it could be mentioned that the lathe is one of the emerging tools used during the evolution of humanity, has been a valuable tool over the years, enabling the production of a huge variety of surfaces and objects of high quality, usability and aesthetics. Through the years, several features of lathe machine have been changed and improved, providing greater precision in dimensions and shape of the wooden elements, higher machine efficiency, higher production speeds, ease of machining, and less effort and risk of accidents for the operator of lathe.

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