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A recollection: early aircraft construction, the prerogative of wood craftsmen

Abstract: In this article, the author tried to consider the place and role of wood processors in the early period of the aeronautical industry, approximately 1910-1940, when most aircraft were built of wood. The professions in this field and the woodworking tools or machines used at that time are brought back to attention. Starting from the accounts of a first-rate craftsman who worked during the WWII at the *Romanian Aeronautical Industry Plants* in Braşov, Romania (going through the hierarchy from carpenter to foreman) and from the way the *Bristol and Colonial Airplane Company* in Filton, United Kingdom works (as reflected in the aerospace museum from Filton), but also from a *technical regulation* imposed by the United States War Department on factories that produced and repaired military aircraft, the author tries to reconstruct the form of organization and work during the pioneering period of aviation and during the first factories in the field. It can be considered that this article is a tribute to these woodworkers, but also a reconsideration of how the aeronautical industry developed and a remember of its beginnings for those of today. The author also tries to give pertinent answers, in his opinion, related to the causes of wood replacement as the main material for the construction of aircraft. Later days steel and aluminium, then fiberglass, modern composites, and, nowadays, the nanomaterials have taken its place, but it can never be forgotten or ignored. This year is the half-centenary of the death of Henri Coanda, a Romanian scientist, one of the pioneers of jet aviation, since 1910. This article is intended to be the first in a series of homage articles, designed to bring the work and personality to this genius.

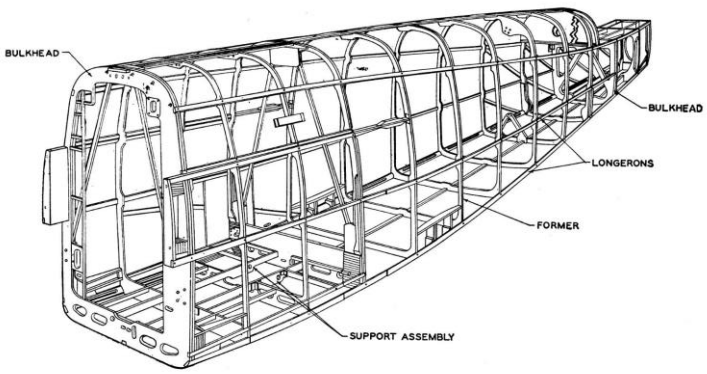
Keywords: wood, aviation, aeronautical industry, woodworkers, woodworking tools, woodworking machines, Coanda.

The Half-Centenary of Henri Coanda's Death

Introduction

Few people know today that the first aircraft were made of wood; originally, the airframe/ cell (*Barnes, 1964*) (the plane itself) was made of wood and was covered with canvas, before being made of metal components: the wood provided the structural function and the canvas provided the load-bearing medium. From Hiram Maxim (1840-1916), Octave Chanute (1832-1910), Otto Lilienthal (1848-1896), Clément Ader (1841-1925) to the Wright brothers: Orville (1871-1948) and Wilbur (1867-1912), Alberto Santos-Dumont (1873-1932), Louis Blériot (1872-1936) or the Romanians Traian Vuia (1872-1950), Aurel Vlaicu (1882-1913), and to the stage of setting up the first aircraft factories, as is the case with BCAC (*Salcă, 2006*) from Bristol, United Kingdom, but also IAR (*Cowin, 1967*) Braşov, Romania, could not have been conceived otherwise. Even after overcoming the paradigm: lighter / heavier than air, aeronautical constructions constantly tried to use relatively light materials, and wood was the handiest of them; the same material was

used for gliders. Until after the Second World War, wood occupied a privileged position, although both steel and especially duralumin had begun to replace it (in 1915 took place the first flight of an all-metal aircraft, the German Junkers J1, nicknamed the Blechesel, "Tin Donkey" (*Accueil a les origins l'evolution et es limites de l'avion en bois, 2016*); in the case of gliders, the place of the wood was taken by reinforced plastic using glass fiber or, in short, fiberglass. The titanium alloys (the most widely used alloy today is Ti-6Al-4V (*Hunter, & Bryant, 1991*) and modern composites appeared much later, and, nowadays, the nanomaterials. It is, therefore, natural that a leading place among aircraft manufacturers should be occupied by woodworking specialists, and that factory jobs should be predominantly occupied by such craftsmen. This article explicitly covers a period of time between about 1910 and 1940 (because the airplanes remained of wooden manufacture until the end of the 1930s).



I would also like to complete with the idea that the last mass-produced wooden aircraft was the '*Mosquito*', by De Havilland, a British bomber used in World War II. It is also known as *'The Wooden Wonder*' or '*The Wooden Terror*' due to its remarkable performance. This bomber features a birch and balsa wood frame. Its wooden design also makes it possible to minimize the use of strategic materials such as aluminium and steel, precious in times of war, and proves to be an asset when the first German radars appear, its wooden structure the making it difficult to detect, unlike metal structures (*Diorama at the Bristol Aerospace Museum in Filton, 2016*). There were 7,781 de Havilland planes built, 30 survive today, three of which are airworthy (*Iconic planes from the past, 2018*).

Stages in the construction of an aircraft

The construction of the planes was done in the era we are referring to (as now, by the way!) in large factories, with *large hangars*. The *engineer* was responsible for the design of the aircraft and also developed and improved its structural features. At the time, he also dealt with the *strength* of the component parts, the choice of materials (i.e., type of wood or plywood) and the coordination of the manufacturing process; today whole teams of engineers specialized in different fields participate in the accomplishment of these stages, and all the processes are assisted by computers.

Manufacturing began with the production of wooden parts, but included the production of tools and devices and related activities. The fuselage subassemblies, doors and parts of the wing

and tail coverings (outer surfaces) were in plywood, cut and profiled, and the rest was covered of canvas. All parts were cut and formed by hand or on several types of machines, such as those shown below. Aircraft assembly began with the assembly of components into subassemblies. The main subassemblies are the wings, the tail, the fuselage sections, the landing gear, the door and some interior components. The assembly of the wing is particularly delicate; a large number of holes must be drilled precisely for the rivets or bolts that will be inserted later. During the final assembly, the fuselage sections were fastened together, then the engine (*Technical Manual of Aircraft Woodwork, 1942*), landing gear and avionics were installed. Various tie rods/wires were provided for reinforcement, mostly made of steel cables. The aircraft was subjected to a series of ground and flight tests, the latter of which were performed by the *test pilots*.

Those who are interested in the history of technology, especially with the history of industrial production systems know that in the first two or three decades of the 20th century, until the widespread use of electric motors, in many factories the power was still provided by a single motor or motor group, which could be operated by water, by a steam engine or, less frequently, by an electric motor and was transmitted by belts to *machine tools* (still little diversified), in this case the *woodworking machines*.

The *line shaft system* had a lot of disadvantages: the arrangement/layout of the machines depended on the location of the line shaft rather than efficiency; the systems were noisy, dangerous and dirty; they required frequent lubrication, which meant that the oil was constantly leaking everywhere. In addition, the air quality was deplorable, with the belts throwing and dust constantly circulating - right next to the worker using the machine. When the factories switched to electricity, the producers noticed an increase in productivity, but also an improvement in the health of the employees [1].

Aircraft factory employees in action

The tasks listed in the *BCAC Time book* of 1911 show the variety of skilled and unskilled worker at the factory (*McVey, 2015*), in alphabetical order: Assembler, Caretaker, Carpenter, Clerk, Coppersmith, Deputy foreman, Draughtsman, Engineer Assistant, Engineer, Errand boy, Fitter, Foreman, French polisher, Gnôme mechanic, Inspector, Joiner, Labourer, Leading Coppersmith, Leading trimmer, Mechanic, Mess room, Office boy, Packer, Painter, Propeller hand, Propeller hand leading, Sewing biplane fabrics, Storekeeper, Stores Assistant, Trimmer, Turner, Watchman, Welder, Wireman, Woodworker.

It is easy to see that some of these professions are specific to the woodworking industry: Assembler, Carpenter, Fitter, French polisher, Joiner, Leading trimmer, Painter, Propeller hand, Propeller hand leading, Trimmer, Turner, Woodworker.

For clarification for those unfamiliar with the field, here is a brief description of some of the lesser-known professions: *Trimmers* are responsible for controlling the finish wood parts. They may also shape, trim, and assemble wood pieces as well as alter and repair machines with hand tools; *French polisher* was in charge of polishing pieces, so-called *French polishing* which is a wood finishing technique that results in a very high gloss surface, with a deep colour and chatoyancy. French polishing consists of applying many thin coats of shellac dissolved in denatured alcohol using a rubbing pad lubricated with one of a variety of oils; *Propeller hand leading*

and *propeller hand* were the people responsible for the production, maintenance, and inventory of the propellers.

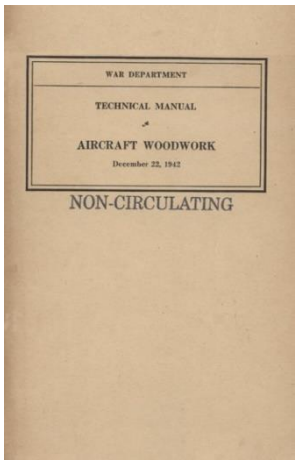
And some other professions, such as coordination, supervision and control, were related to the woodworking industry (or, at least, required good knowledge of): Engineer, Engineer Assistant, Foreman, Deputy foreman, Inspector.

If we add the latter to the above, with obvious professions in wood processing, we reach a proportion of over 50%. However, if we take into account not only the nomenclature but also the number of people actually employed in similar positions, the balance is in favour of woodworking professionals, without taking into account the fact that the official responsible for ordering materials – *Clerk* and those who kept those who kept raw materials and usual materials in the warehouse – *Storekeeper* and *Stores Assistant*, could not have managed without solid knowledge in the field: types and qualities of *lumber*, *plywood* and *veneer*.

Woodworking tools and machines

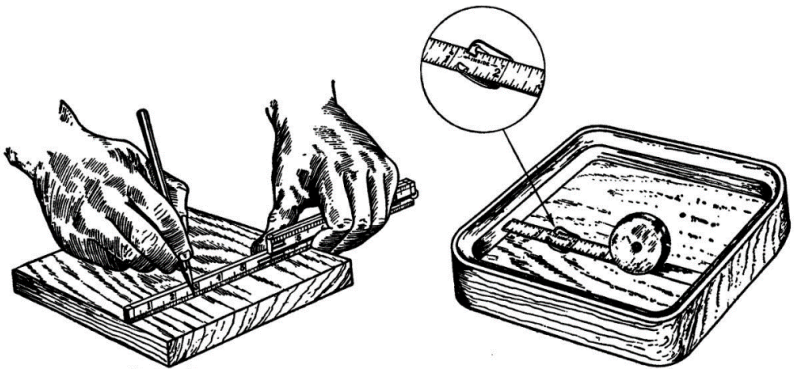
The bibliography is quite poor in this regard, but an unexpected chance led me to find a digital book, *Aircraft woodwork* (*Ferrer, 2020*), which is nothing more than a norm imposed by the War Department of the United States of America to those who produced and repaired airplanes and aviation parts, made of wood. From here we have extracted valuable information, able to provide the reader with an image as close as possible to the reality of woodworkers and tools: hand- or mechanized-tools (woodworking machines) that they used. Moreover, the book offers a series of suggestive images, which I used, being convinced that a picture is worth a thousand words (*A guide to the carpentry skills needed in historic aircraft construction, 2014*).

Another chance, which made possible the publication of this article, is the indirect knowledge of the life and activity of a modest and extremely hardworking man, a talented carpenter (but not only!), Gheorghe Viaşu, who worked at the IAR Braşov Plants during the Second World War, in the production of airplanes. His stories and memories helped me to understand this activity *from the standpoint of the craftsman*. Gheorghe Viaşu was born in Ilovăţ Commune, Mehedinţi County, on April 1, 1911 and died on July 6, 1997, in Braşov. He did his apprenticeship as a furniture carpenter in his native village and later, he worked since 1942 at the aircraft factory IAR Braşov, as a gifted carpenter and woodworker, then with some interruptions, probably for schooling, he returned as a metal modeller and toolman at the Tractorul Plant in Braşov, successor of the former IAR. He retired in 1971 (by retirement decision he received a pension of 1161 lei after 30 years of work). He is not limited to work; in his free time, he always worked: furniture, repairs of any kind, he could not sit idle. At the age of 80, when his legs could not hold him so well, he started making his famous frames, then manufacturing tapestry, gobelins type (in Romanian language 'gobelin' is synonymous for 'tapestry'), what else... he was a character! Most of the furniture in his own and daughter's house was made by him...



Woodworking tools:

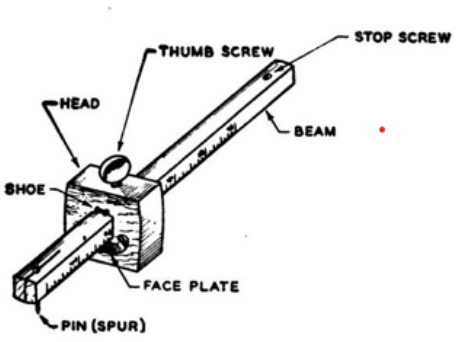
1. *Rules and tapes* are graduated measuring devices and commonly included: straight rule, zigzag rule, folding rule, steel tape rule, and steel tape.



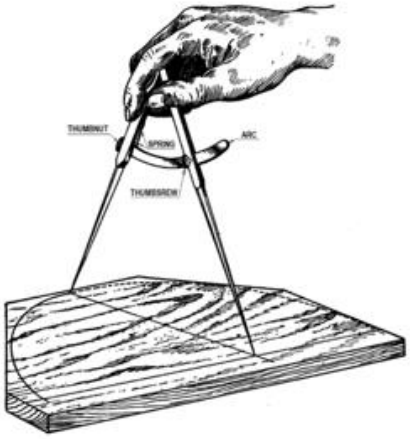
2. *Squares*:

- The *framing square* used for level testing, testing squareness of large surfaces and assembled pieces, and for marking stock preparatory to cutting or assembling. It is also frequently used to lay out various angles other than right angles;
- The *try square* used for laying out and testing square cuts, testing squareness of small assemblies, and for general truing operations;
- The sliding T-level used for laying out and checking angles.

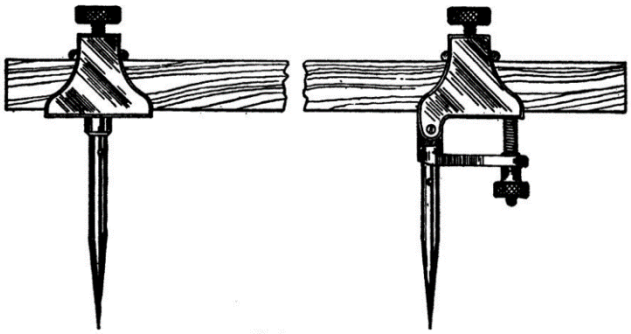
3. *Marking gage* was used for marking lines parallel to a surface of wood stock.



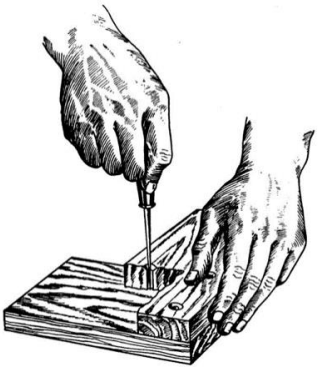
4. *Dividers and compasses* used for laying out circles and parts of circles.



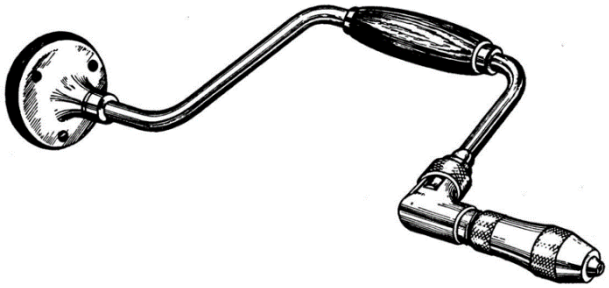
5. *Trammel* consisted of a wooden bar to which trammel points are attached; the assembly was used in the manner of dividers or compasses.



6. *Scratch awl* is a pointed steel instrument used for marking lay-outs and locating points for nails, screws, hole centers etc. For marking lines, the awl was used as a pencil, scratching the wood lightly.

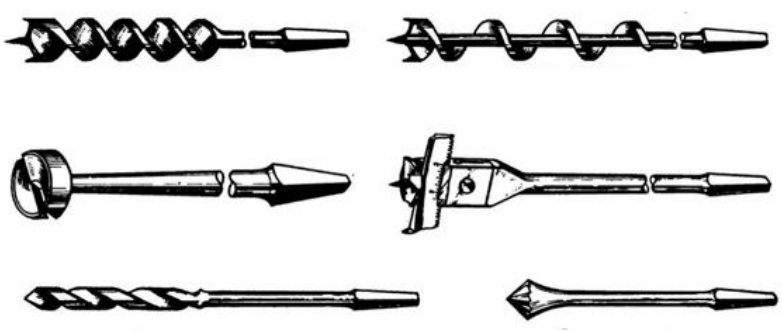


7. *Brace* was used to hold various wood bits, screw driver bits, and similar devices.

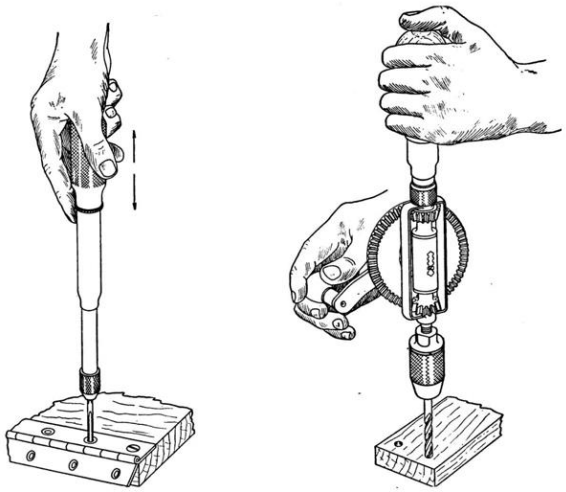


8. *Wood bits* used to bore and shape holes in wood to accommodate bolts, screws, nails, dowels etc. The usual types:

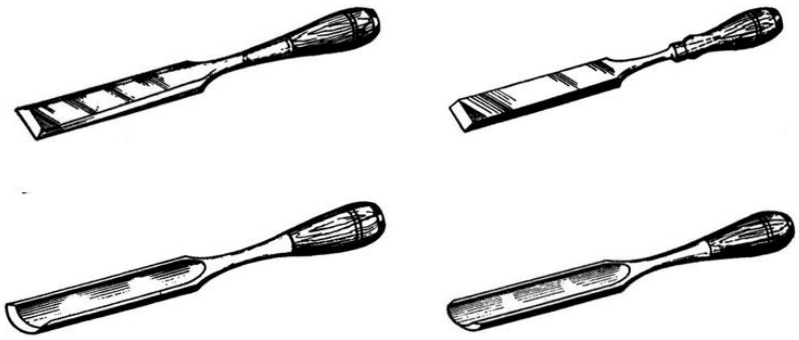
- Auger bits;
- Forstner bits;
- Expansive bits;
- Twist bits;
- Countersink bits.



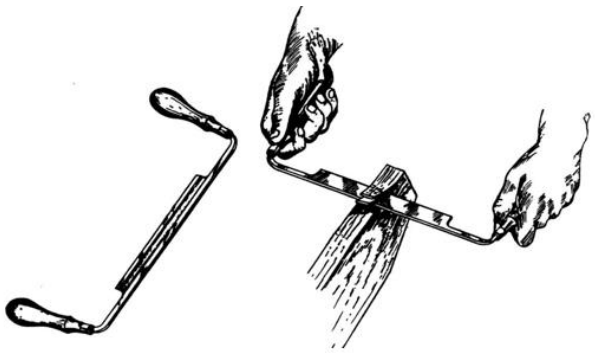
9. Drills: holes smaller than ¼ inch are usually drilled with an automatic drill or small hand drill. These drills are faster and less cumbersome than the brace.



10. *Wood chisels and gouges* are used for various cutting and paring operations involved in chamfering, mortising, grooving, recessing etc.



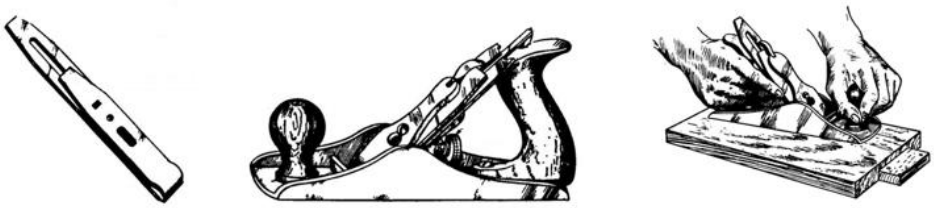
11. *Drawknife* used to remove surplus stock which cannot conveniently be removed by planning, sawing, or other means.



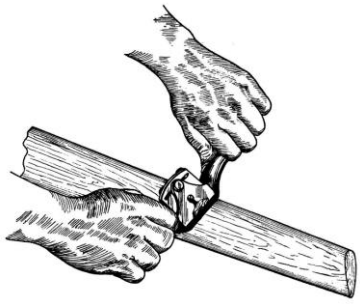
12. *Plane/hand plane* is used for smoothing, truing, and for removing excess stock. The common types:

- Smoothing plane;
- Jack plane;
- Block plane;

- Jointer.



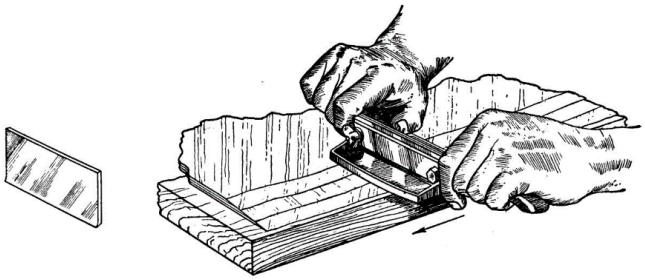
13. *Spokeshave* is a form of plane. It has a short bottom, enabling it to follow curves readily.



14. *Saws/hand saws* are used for a variety of cutting operations. Those most commonly used are:

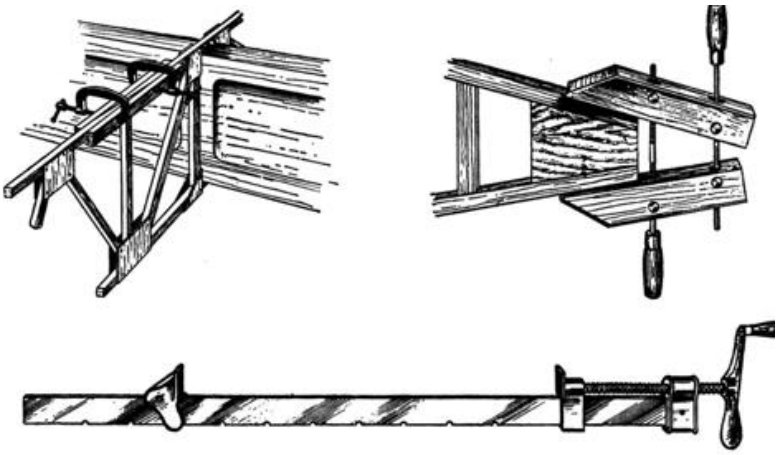
- Crosscut;
- Ripsaw;
- Coping saw;
- Back saw;
- Dovetail;
- Miter saw.

15. *Scraper* very useful in smoothing surfaces having the grain running in various directions, where a plane could not be used.



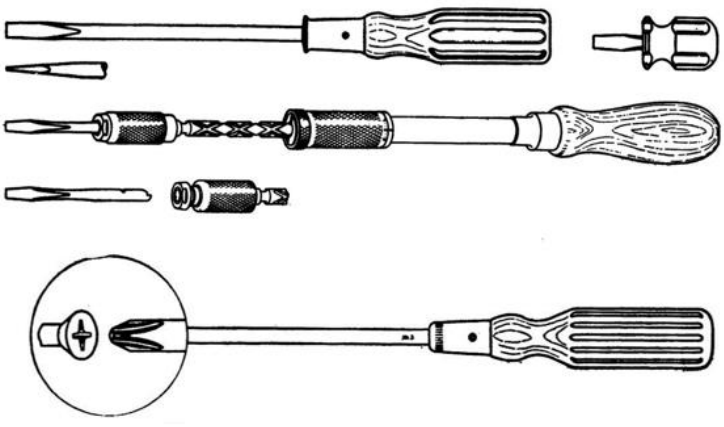
16. *Clamps* used extensively for temporarily holding stock when assembling, working etc., and especially for applying pressure to stock being glued. Types commonly used are as follows:

- Screw clamp;
- Hand screw clamp;
- Bar clamp.



17. *Screw drivers*. Types:

- cabinet screw driver;
- close quarter screw driver;
- spiral ratchet screw driver (for rapid driving).



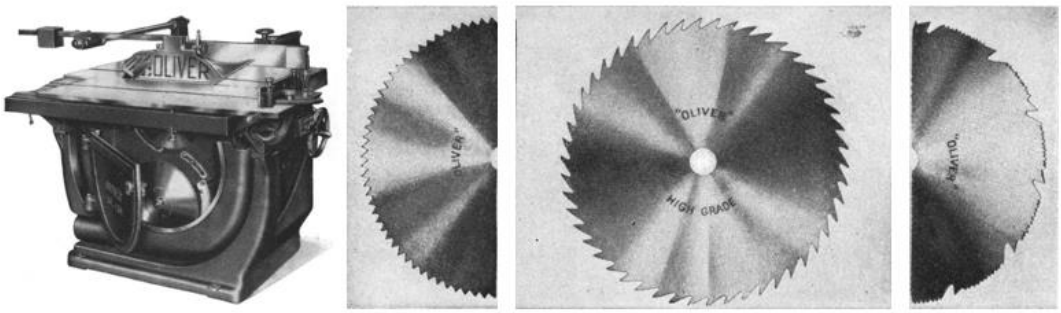
18. *Wood rasp and file* are occasionally used in place of edge tools for removing excess stock or for finishing parts.

19. *Hammer*: the *claw hammer* was most commonly used for general purposes in the wood shop, adaptable for both driving and drawing nails.

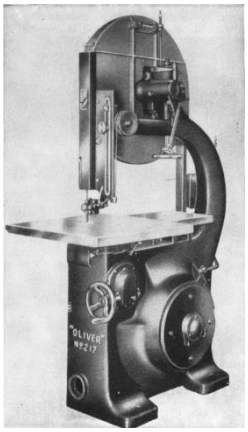
Although a wide variety of tools were available, only those most commonly used in the woodshop were described in the precedent paragraph. Most tools were designed for specific purposes and have been used as intended and properly maintained to provide good service. Woodworking tools, especially the edge of cutting tools, required special care and careful handling to keep them sharp and in good condition. To all the above standard tools were added various other tools produced by self-tooling and self-equipping, adapted to the immediate needs of the factory and produced on site, as a result of the practice, imagination and ability of adapters and innovators of their own staff.

Woodworking machines:

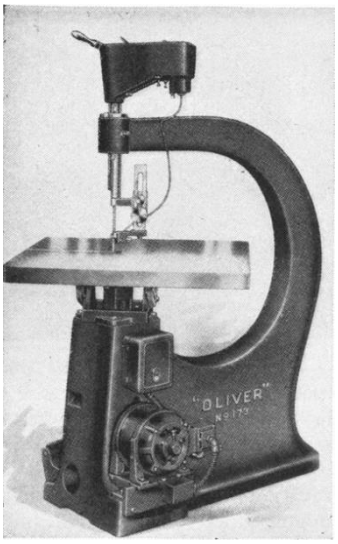
1. *Circular saw* was one of the most used machines in the shop. While it is employed principally for ripping, beveling, crosscutting, and mitering, many other operations, such as grooving, dadoing, rabbeting, molding etc., can also be performed, by using special attachments and set-ups. The most common types of circular saw: universal saw and variety saw.



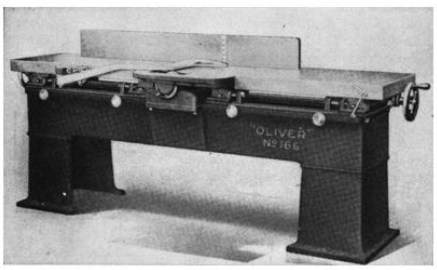
2. *Band saw* constructed in a wide variety of sizes and types depending on its use. The most adaptable for the wood shop is referred to as a band scroll saw, designed particularly for cutting curved outlines and lines not parallel to an edge.

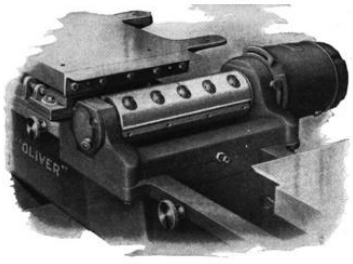


3. *Jig saw* differs radically in construction from the band scroll saw although the type of work for which it is intended is very similar. It is more adaptable for cutting small, sharp curves because much smaller and finer blades may be used.



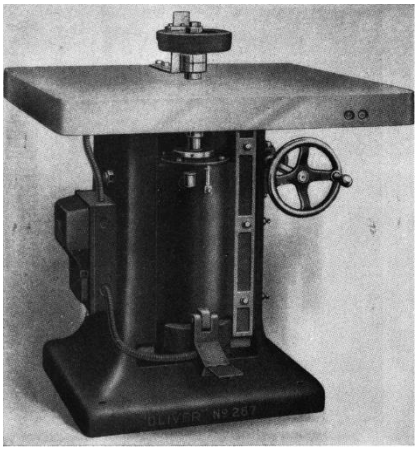
4. *Jointer/hand planer* consists essentially of a frame, cutter head, tables, fence, and guard.



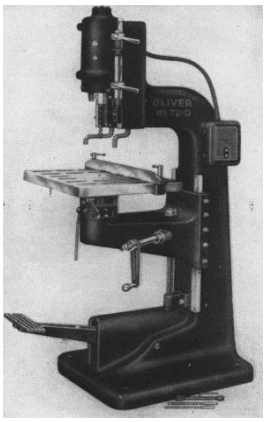


5. *Planer or surfacer* used mainly for finishing surfaces of flat stock and reducing stock to thickness. The more common type planes one surface at a time and is referred to as a single surfacer.

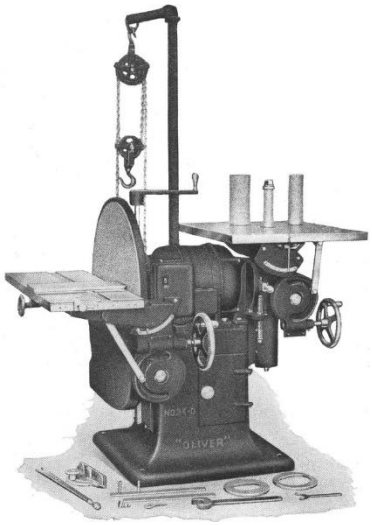
6. *Shaper* used mainly in trimming, shaping, and moulding stock irregular in outline. Various types were produced, a single spindle type being shown in next figure. The shaper consists essentially of a spindle, spindle top, cutters and cutter heads, table, yoke, and base.



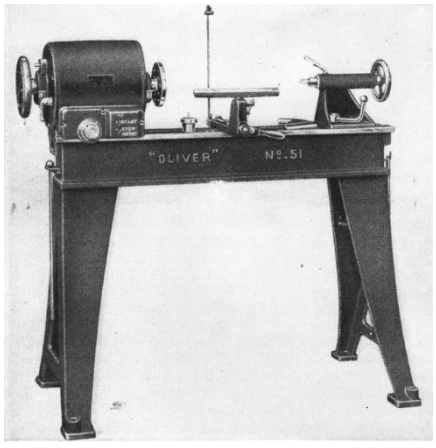
7. *Boring machine* was designed to hold and operate various wood bits. The single spindle manually operated borer is most adaptable for the general wood shop. It consists essentially of a frame or column, boring head, table, and various machine wood bits.



8. *Combination disk and spindle sander*, adaptable to the majority of sanding operations and is the type generally used in the wood shop.

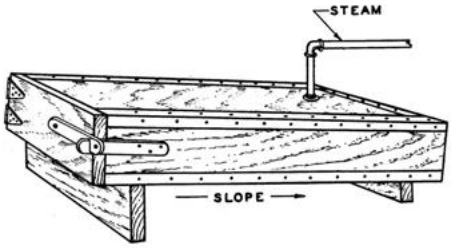


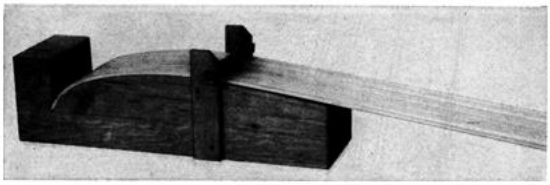
9. *Wood lathe* used for turning wood stock to shape. The motor headstock speed lathe was most adaptable for general wood turning and consisted mainly of the bed, headstock, tailstock, live and dead centers, tool rest, and tool rest holder.

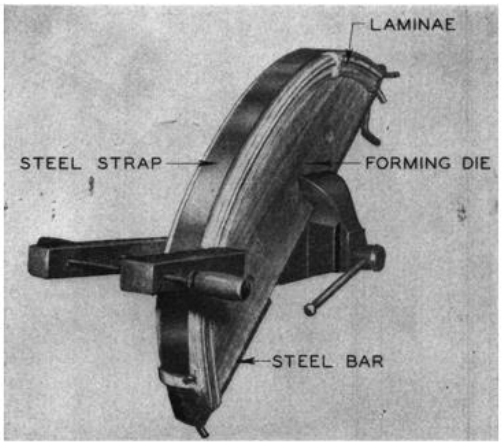


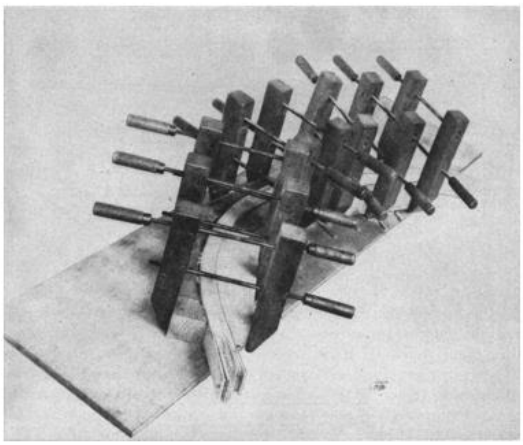
10. *Bending and steam bending accessories*: curved wooden parts of an airplane were either steamed and bent to shape, or laminated and bent without steaming or other preparation. The types commonly used are as follows:

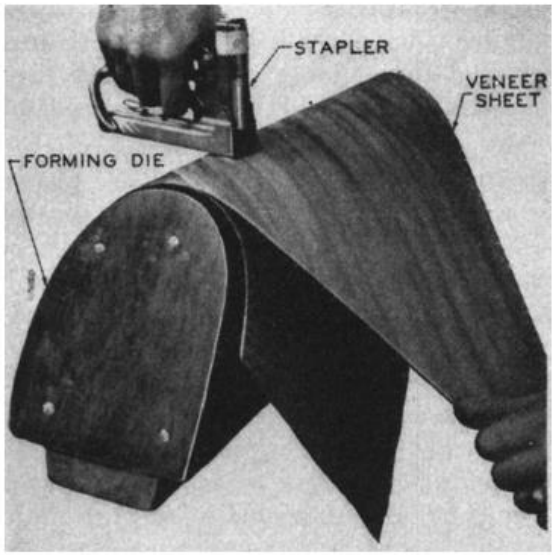
- Steam frames;
- Forms for bending;
- Steel straps.

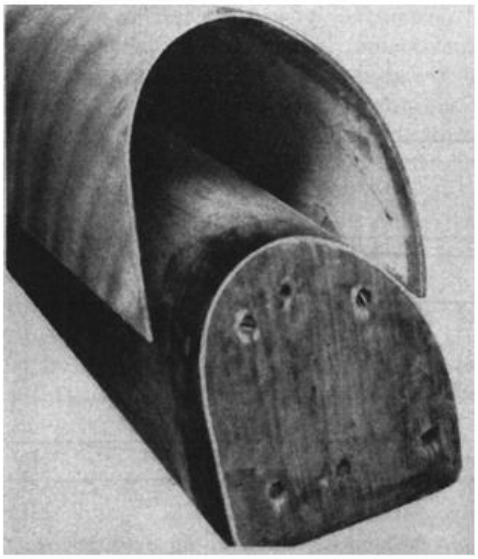


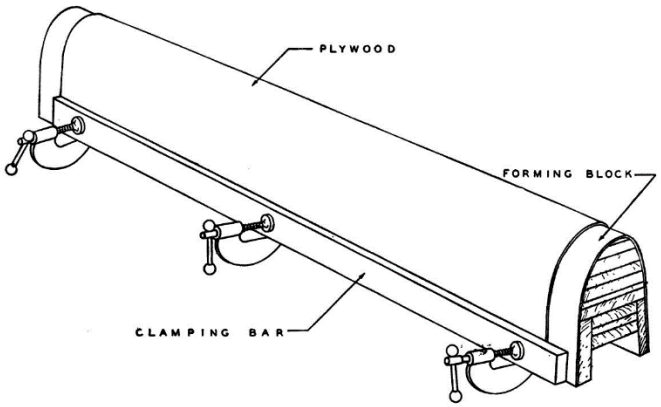












As in the previous paragraph, I also used images from the War Department regulations cited above to illustrate this paragraph. It is noted that all woodworking machines bear the mark of the manufacturer, Oliver [2].

And yet, why was the wood replaced?

Over time, despite its light weight, the wooden plane ended up being used less and less in aviation. The culmination is that those properties that were initially attractive end up being abandoned because of its drawbacks. This chapter of the history of technology related to aviation and the wood used, wants to provide the reader with a conclusion about the abandonment of wood, so I have tried to summarize in the following lines some of the reasons that led to the replacement of wood as a basic material in aeronautical constructions.

An excellent indicator of the suitability of an aeronautical material is the *mechanical resistance/density ratio* (or the *specific resistance*), the values of which must be high. It must be taken into account that these properties must be maintained, whatever the operating conditions of the aircraft: on the runway of an airport, where temperatures can reach 40°C (approx. 100°F) in summer, in high humidity conditions, or during the flight, at an altitude close to 11,000 meters (approx. 36,000 feet), where temperature drops to -50°C (approx. -60°F). The wood used in aeronautics is a material sensitive to climatic variations. When there were very high temperatures in flight, the wood suffered cracks. It should also be taken into account that during their operation, structural elements are subject to radical changes in the distribution of loads. At the level of the embedding of the wings, for example, the areas of traction and compression are reversed: on the ground, it "supports" the wings; in flight, it "supports" the fuselage due to the lift generated by the wings. It is also necessary to take into account the vibrations to which the aircraft is subjected. The problem appeared from the first regular flights, because the materials used had not been chosen according to their resistance to fatigue and some planes presented many problems after years of good operation. With the evolution of materials within this sector, research has focused on two areas: increasing their specific strength and improving the feasibility of manufacturing aircraft and their components (*Ferrer, 2020*).

The most important piece of evidence that definitely influenced the decision was the "test of fire": when it was used by the military in combat, both during World War I and the beginning of World War II, there were many situations in which the planes break in flight, especially during violent combat manoeuvres. In air battles, planes carried heavy payloads, such as weapons and

ammunition, as well as missiles or bombs. The problem with the wood was that it was not strong enough and when the loads were too heavy the plane would break.

Although their density is low, some woods are quite resistant; however, this material is affected by biological action and reacts negatively to moisture.

Conclusions

Early aeroplanes were simple machines by the *high-tech standards* of today, being mainly constructed from wood and cloth / canvas. This simple construction, though dangerous for the aviator, was a joy for the woodworker (*A guide to the carpentry skills needed in historic aircraft construction, 2014*). The behaviour of the wood material through the prism of factors such as: specific resistance, climatic variations, resistance to fatigue, sensitivity to biological action, but also the permanent concerns of researchers focused on two areas: increasing the specific strength and improving the feasibility, led to the replacement of wood the aviation industry: new, better materials have taken its place. However, an important chapter remains that of the period of pioneering and enthusiasm, when the specialists in wood processing were the aircraft builders. This article is dedicated to their memory, which wants to highlight their contribution and bring them back to the readers' attention. Today, this technique and the wood material are used in the repair and restoration of old surviving airplanes, in aero-modelling and for the realization of some experimental airplanes, i.e., at a fairly high level of amateurism. However, the question remains: will wood return to aviation on a large scale?

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Notes:

[1] Numerous oral reports by Daniela and Horia Şchiau, which kept alive the memory of Gheorghe Viaşu stories and activity as a woodworker: carpenter and foreman in the IAR aircraft plant, in Braşov, Romania.

[2] The American company was originally founded by Joseph Oliver around 1890, under the name American Machinery Company, with factories in New Haven, Connecticut. He was a machinist by trade who developed his own version of a wood (miter) trimmer machine after selling another company's wood trimmer for a number of years, probably W.R. Fox's Fox Machinery Co. Oliver tried and eventually did make a better tool and he succeeded. Oliver's wood trimmer won him a gold medal for merit at the 1900 World's Fair in Paris. But it was just the first of many innovative woodworking products that would come from the Oliver Machinery Company. In 1907, the company built a new factory on Clancy Street in Grand Rapids, and then, in 1908, Oliver introduced a cylindrical cutterhead that would eventually replace the square - and more dangerous - cutterheads commonly used in certain machines of the time. There was also his Straitoplane, introduced in 1923 as a combination jointer / planer, which could surface a warped board straight and flat in one pass. It is a design other companies would emulate in the years to come. From its factory in Grand Rapids, Michigan, Oliver also produced a variety of woodworking machines as well as other tools as the market presented new opportunities, cf. Jeff McVey, Early History of The Oliver Machinery Company, reproduced with the permission of the author at http://wiki.vintagemachinery.org/OliverEarlyHistory.ashx.

Credit photo:

Hayward, Charles H. (1971). *The Woodworker's Pocket Book. Receipes, Materials, Fittings, Tools, Geometry, Woodworking Data*, London: Evans Brothers Ltd.

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