Proceedings of the 17th International Conference on Manufacturing Systems – ICMaS
ISSN 1842-3183
University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania

DESIGN ASPECTS IN MACHINE TOOLS EVOLUTION

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Abstract: *The paper proposes to present some important aspects in the design evolution of some representative types of machine tools, as the evolution of some basic structural elements which compose machine tools majority. The paper, also, present the aspects regarding the machine tools aesthetics, like a result of shape modeling, bounded by the functional role, and with the posibilities of artistical modeling of the structural-geometrical elements, respecting the essential principles of the composition and design, such as: the proportion, the rhythm, the symmetry and the contrast. Respecting these principles were determined the ensemble constructive for milling machines.*

Key words: *machine tool, lathe, milling machine, evolution, design, aesthetics, proportion.*

1. INTRODUCTION

Because of the constructive and functional complexity of machine tools it is very hard to establish in time and in space, their apparition and evolution, and the name of the author. For this reason in many cases this study was based on the consense of many specialists from the science and technology field.

The majority of machine tools were invented at the end of the 18^{th} century, but after 1850 they have developed and they have become the industrial machine.

În the last decades, once with the development and the increasing of the number of capable functions to be realized by a machine tool, there is the necessity to conceive the aesthetics of a machine, regarding the visual composition. It can also remark a tendency to obtain the aesthetics effects through stylisation of some traditional shapes applied at the level of the whole composition of machine tool, or only at the level of some subassemblies for to improve the product aspect.

2. THE STRUCTURE AND FUNCTIONS EVOLUTION OF MACHINE TOOLS

When the first clay piece was transformated into a earthen pot (Sumer, about 3500 B.C.) with the help of potter wheel, through turning, using the human force it can consider that the first machine tool was born. From the period 1500 – 1000 B.C. it knows that an old lathe for wood processing with a rotation motion given through the pulling of a wrapped rope on an axle or through the friction between a lever and an axle. On an Egyptian grave (about 300 B.C.) it can find a relief representing a primitive lathe actioned by the help of a cord wrapped on a device like a violine bow [2, 3].

In 1400 is achieved a lathe with flywheel actioned by foot or through a lever, and în 1561, the mathematician Jacques Besson (1510 – 1576) designed an improved lathe using the mathematical calculations, and where the first gearings appeared which seemed a continuation of Leonardo da Vinci's designs. În 1578, Besson publicated the work "Théâtre des instruments mathématiques et mécaniques" which presented an evolution of turning technic and the references were made the apparition of the first chuck and the first fixed stays.

Charles Plumier (1646 – 1704) present in "L'Art de tourner ou de faire en perfection toutes sortes d'ouvrages au tour" ("The Art of Turning or to Make all Kinds of Turning Works Perfectty", 1701) a lathe for the metals with wooden body. În 1718, Russian mechanic A. K. Nartov (1693 – 1756) invented and achieved different lathes and drilling machines [3], [5].

Jacques de Vaucanson (1709 – 1782) a French mechanic and a clockmaker created and improved, în 1751, a steel lathe with a chariot (Fig. 1) and a drilling machine, both of them with the devices which will become the essential subassamblies of modern machine tools. After some specialists, Vaucanson is considered the inventor of perfectioned lathe in modern acception.

In 1769, John Smeaton (1724 – 1792) considered like a father of British civil engineering, discovered metal drilling machine used initially for processing of the cylinders bore of the steam engins of Thomas Newcomen.

The Englishman John Wilkinson (1728 – 1808) invented, în 1775, a drilling and boring machine for cylinders used initially for the boring of gun barrels. This machine tool was used by the firm Boulton and Watt

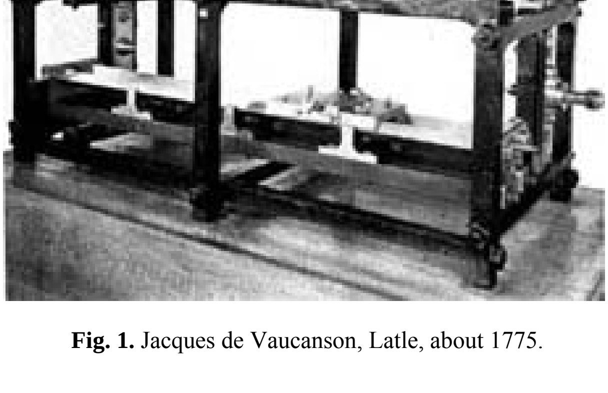

Fig. 1. Jacques de Vaucanson, Latle, about 1775.

where cylinders of steam engins were after wards realized for James Watt's machine.

In 1793, the Englishman Samuel Bentham (1757 – 1831) achieves the first circular saw for cutting metals, and over a year the British mechanic Philip Vaugham obtained a patent for processing of ball bearings which were improved by Cardinet în 1802, by Lechner (1898) and by Wingquist (1907).

Joseph Bramah (1748 – 1814) invented, în 1795, a hydraulic press using Pascal's hydrostatical principle. His pupil Joseph Clement (1779 – 1844) achieved a lathe and a planing machine (1817).

Henry Maudsley (1771 – 1831) remarked, especially through a new concept in the construction of machine tools increasing their precission through the introduction of fine mechanic elements. In 1797, Henry Maudsley achieved a lathe for the first time with a chariot and a mobile puppet actioned by leading screw (Fig. 2). This subassembly is considerated one of the most important invention from the machine tools field, because, for the first time the worker did not hold the cutting tool with the hand [8].

Maudsley realized a slotting machine too (Fig. 3).

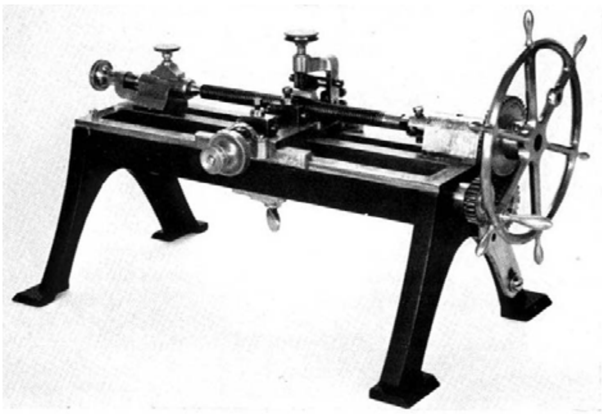

Fig. 2. Henry Maudsley, *lathe*, 1797.

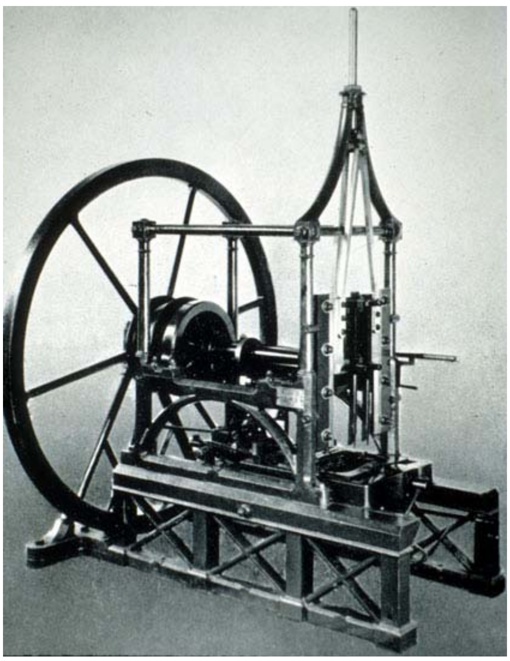

Fig. 3. Henry Maudsley, *slotting machine*.

Marc Isambard Brunel (1769 – 1849) invented a lot of machine tools as: plugging machine for wood (1801) drilling machine, metal slotting machine, machines for wood processing. In 1806, he invented a method of achieveing of pulley wheels for ships, the proceeding considerated like the first authentic industrial manufacturing line.

He colaborated at this proceeding with Samuel Bentham and Henry Maudsley. Two years later using Brunel's proceeding, The British Navy installed at Portsmouth the first line of 45 special machine tools which manufactured 130 000 pulleys wheels on a year for sail ships.

In 1804, German firm Reichenbach achieved the first shaping machine. In 1807, W. Newberry invented the hand saw, and in 1814, Matthew Murray (1765 – 1826) invented the perfectioned metal planing machine.

In 1818, the American Thomas Blanchard (1788 – 1864) achieved for The Arsenal from Springfield a copying lathe for the guns manufacturing and the engineer Eli Whitney (1765 – 1825) designed and achieved the first milling machine with the independent motion of the tool (the first milling machine from the machine tools evolution). În 1828, Joseph Bramah invented and achieved a parallel lathe with mechanisms for the comand of advance motions. Bramah also had big contributions at the machine tools design [8].

Joseph Whitworth (1803 – 1887) achieved, in 1835, a rotation speed variating device for the lathe for the metal manufacturing. In 1841, he introduced standard thread (The Thread Whitworth or "English") which was adopted under the name "Britisch Standard Whitworth". Amoug others machine tools, he achieved, in 1833, a lathe (Fig. 4) and, in 1835, a planing machine (Fig. 5).

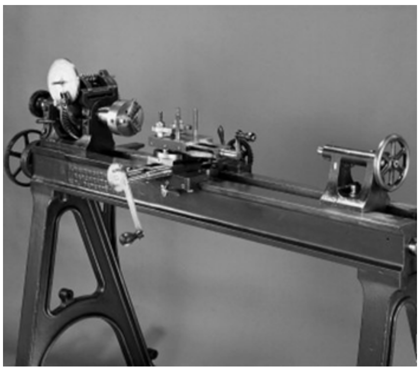

Fig. 4. Joseph Whitworth, *lathe*, 1833.

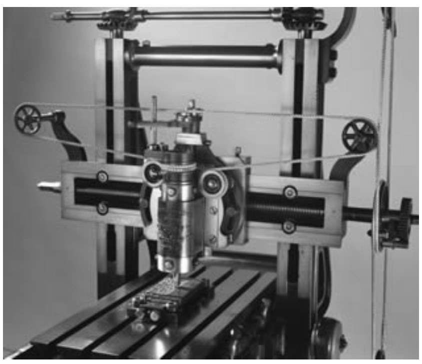

Fig. 5. Joseph Whitworth, *planing machine*, 1835.

In 1870, Whitworth used the deformation through hydraulic pressing of the steel pieces instead of the deformation through mechanical striking.

In 1839, the Swiss mechanic Johann Georg Bodmer (1786 – 1854) obtained a patent and he achieved a vertical lathe.

The Americans Frederic W. How, Richard S. Lawrence şi Henry D. Stone designed and realized (1849) the first turret lathe, and, in 1862, two Americans Joseph Rogers Brown (1810 – 1876) şi Lucian Sharpe (1830 – 1899) realized the first universal milling machine with console (Fig. 6). The machine had the posibility to manufacture helical borer too [9, 10].

In 1873, Christopher M. Spencer realized a type of automatic lathe for processing screw (automatic screw machine). Its design stayed at the base of the future automatic lathe which manufactured from bars.

During 1874 – 1877, J. Rogers Brown şi Lucian Sharpe realized an universal grinding machine (Fig. 7). This was produced by Brown & Sharpe Company, founded in Providence, Rhode Island, in 1833.

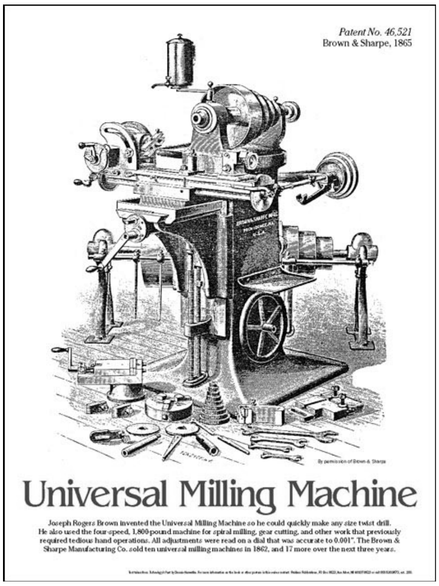

Fig. 6. Brown & Sharpe, *universal milling machine*, 1865.

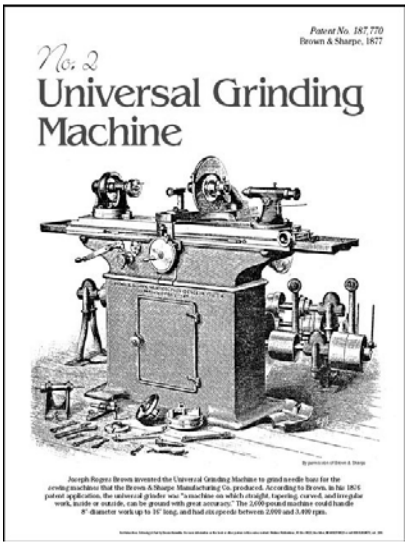

Fig. 7. Brown & Sharpe, *universal grinding machine*, 1877.

In 1879, the English engineer C. W. Parker designed an automatic lathe for threading, and Wendel P. Norton invented, in 1892, the mechanism with sliding collar gearings, named "Norton Gearbox" which gave the flexibility in the function of lathe.

The firm Barnes Drill Co. realized, in 1907, a multi-axle drilling machine equiped completely with gearings. This was used especially in the cars industry from Detroit.

In 1914, the firm Index-Hahn &Kolb, from Germany, started the manufacturing threading machines with cams controle.

In 1918, the Amarican engineer Henry H. Timken (1868 – 1940) obtained a patent for radial-axial bearings with conical rolles, and, in 1922, Hoffmann-Nadella obtained, in Germany, a patent for needle bearings.

In the years 1920, is move and more electrical and hydraulicat action.

At Leipzig Spring Fair (1927), the firm Krupp AG presents a new technology which uses wolfram carbide, like a material for cutting tools. This was named WIDIA (the acronime of German expression "Wie Diamant"). The machine tools design took the advantages of this technology with impact under the working conditions.

In 1927, in Cleveland, takes place the first Exhibition "Machine Tool Show" which then became "International Manufacturing Technology Show" or I.M.T.S.

Magnus Wahlstrom and Rudolph F. Bannow realized, in 1929, the first stroke limiting devices with electric action, which contributed at the increasing o the automatization machine tools degree.

In the years 1930, The Monarch Machine Co. produced the first cutting machines on outline and Barnes Drill Co. Realized the first horizontal and vertical honing machines used for finishing of motor cylinders. Moore Special Tool Company manufactured, in 1932, its first product, a coordinate drilling machine.

In the years 1940, the Swedish firms Sandvik and AB Hammarby-Lampan started to manufacture tools armed with metalical carbides. The Lampan firm gave hard alloy (dolotit) to Sandvik which produced the tools named Coromant [9], [10].

In 1943, the Russian B. R. and N. I. Lazarenco realized the first manufacturing machine through electroerosion (sparks).

After the Second War World, because a lot of drawings of machine tools were lost, numerous firms copyed parts of machines and many improvings realized which contributed at a new design.

În 1948, in Massachusetts Institute of Tehnology (M.I.T.), Servomechanisms Laboratory, Frank L. Sluten şi John T. Pearson develope semi-automatic and automatic machine tools with numerical control (CN). These were mono-axle or multi-axle, hydraulical, mechanical and electrical actioned, manual or automatical supplied. The first machine tool conected at a system endowed with perforaded cards, was a milling machine which will be used in the aeronautical field by U. S. Air Force, refers of a research agreement for M.I.T.

General Electric aplied the numerical control and it replaced perforated card with paper bands with 8 channels. In 1958, G.E. Co. also used numerical controls Mark Series II at mechanical production center in Kearney & Trecker Company. The Barnes International Co. realized drilling and boring machines with numerical control which had the possibility of automatical change of the tools.

Scientific and technical developement had an impact under machine tools evolution. If at the middle of 1960's, numerical control (NC) used transistors, begining from 1966, through using of the integrate circuits CN device, became more compacte, modifing the design of the control systems. Through numerical control, automatization and the digital indication systems (produced from 1968), CN machines could realise complexe operations, similar with 8 manual comand machines (function of manufacturing type).

The increasing of performances of machine tools through the increasing of productivity and of the precision degree, imposed the increasing of the control capacity. In this direction, in 1960's realized high frequency translators, contact tranlators and ultrasonic rapid fault detectors.

In 1970's, GE Fanuc Automation firm invented the control system Mark Century 550 Series, complex and efficient, which imposed: ready programed cycles of execution; the monitorising of Gearbox; the compensation of cutting and RAM memory. In 1973, GE Fanuc firm present MC 8500 Series, one of the first Computer Numerical Control Machines (CNC), having a PDP-8 microcomputer [9, 10].

The French designer Roger Tallon (born in 1929) realizes, in 1973, lathe design from the type "Gallic" 16 and 14 (Fig. 8), which reprezent through the composition of prismatic forms and colour a new way in machine tools aesthetics [8].

In 1983, Flow International Corporation sells cutting metal machine with water jet at high pressures (abrasive water jet cutting). This was used initially at glass cutting from cars industry.

In 1980's, the developement of computers led to qualitative increasing in the using of numerical control machine tools which manufacture with reduced times, high flexibility, high quality. In 1982, Gibbs & Associates realized NC programs and the graphical interface of Apple firm led to the developement of Gibbs CAM programs (Computer Aided Manufacturing).

Fig. 8. Roger Tallon, *lathe* "*Gallic*", 1973.

Fig. 9. The *numerical control milling machine.*

Fig. 10. Mazak, *CNC lathe quick turn*.

Gene Hass, also, developes in this period, an index system (HBI-5C) destinated to the milling machines.

In Fig. 9 are representated numerical control milling machine.

At I.M.T.S. 2000, PCC Olofsson Corporation presented a machine tool which could manufacture, turning, milling, drilling, threading operations, with 30 different configurations.

In Fig. 10 are representated CNC Lathe – Mazak Quick Turn 28N – 2 Axis with 8 Station Turret, 16 Position Indexing [12].

It is very hard to imaginate, how the future of machine tools design will evoluate without a view in the past under of the developement of them in the century which ended.

3. THE MACHINE TOOLS AESTHETICS

Along the time, the machine tools aspect was very bound by their structure and function, but also by artistical and intelectual conceptions of the epoch.

The machine tools aesthetics is the result of the shape modeling in the report with functional role. In the machine desing, the shape like an essential characteristic under aesthetic aspect is bound in function of disponibility created for to responde to an aim in the using of the user [1, 4].

In a qualitative and quantitative study of the realion function – shape, it can determinate three big groups of relatios among machine tools subassemblies:

- Machine tools with shapes which depend on integrally of the functional role, the change of shapes of some subassemblies disturbing the good function (for exemple gearing machine);
- Machine tools with some shapes dependent in part of function. In this case it can count the subassemblies which must fulfil a functional role which is not influenced in totality by shape (the body configuration, mobil puppet shape and so on) and parts whose shape have not severe restrictions imposed by functions (covers, frames, the stiffening ribs, the part of sustaininig the electric engines and so on). At the design of such elements must not use a very big type of shape which would lead at the deterioration of machine aesthetics;
- In this group there are: the machine parts and the subassemblies which have at the base a relation function – shape where the functional elements can he realized applying the principles of the industrial design until the achievement of aesthetics composition imposed by epoch or bythe user. Here it can be put with easy: frames, different subassemblies, bodies, control panels, control and measure devices and so on [7].

For to realize machine tools with high aestetics, the designer must know, the laws of constructions and the functional rationality he also must know the posibilities of technical and artistical modeling of the space and of structural-geometrical elements, so that the macine tool to became functional and aesthetical in the same time. At the design of the shapes and of the structural composition it must respect the basic principles of the design: the proportion, the rhythm, the simetry and the contrast.

In machine tools design, the geometrical shape must by functional and aestheticalin in the same time and the proportion can by realizes through using Gold number (s = 1, 618...), Plastic number (ψ = 1,324...), values from Fibonacci Series, dynamical rectangles with the modulus an irrational number [6, 8].

Le Corbusier established a proportion scale named Le Modulor (Le Modulor 1, from 1948, and Le Modulor 2, from 1954) the first mathematical method for adapting to human phisiological scale (Fig. 11). Geometrical, Le Modulor is a segment with the lenght 226 cm (the whole height of a tall man – 183 cm – with an arm up).

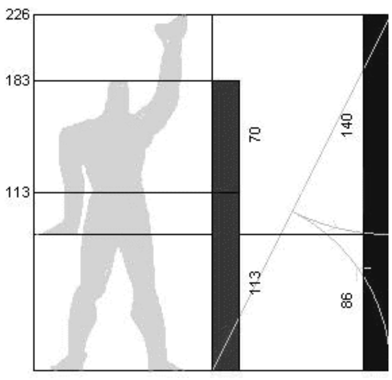

Fig. 11. Le Corbusier, Le Modulor 1, 1948.

With the help of Modul and Gold number, Le Corbusier established a Red Series (0,27; 0,43; 0,70; 1,13; 1,83; 2,96; 4,79) and a Blue Series (0,53; 0,86; 1,40; 2,26, 3,66; 5,92; 9,57).

The use of modulus proportions, in geometrical shape design of machine tools, must realize, respecting the certain principles and rules. Startings from a modulus, through successive combinations and established cruiterious, it realizes harmonious proportions of designed assembly. If it is chosen a base modulus M_0, with Gold number s = 1,618..., it can obtained complementary modulus such as: $M_1 = M_0/s$; $M_2 = M_1/s$; $M_3 = M_2/s$; $M_4 = M_3/s$; $M_5 = M_4/s$. In Figs. 12 and 13 are representated drilling machines with geometrical configuration established using above relations [8]. Using the base modulus M_0 and the derived modulus it can obtained different modulus series:

- $M_2 – M_1$; $M_3 – M_1$; $M_4 – M_1$; $M_5 – M_1$; $M_6 – M_1$;....
- $2M_1$; $2M_2$; $2M_3$; $2M_4$; $2M_5$; $2M_6$;...
- (1/2)M_1; (1/2)M_2; (1/2)M_3; (1/2)M_4; (1/2)M_5; (1/2)M_6;...

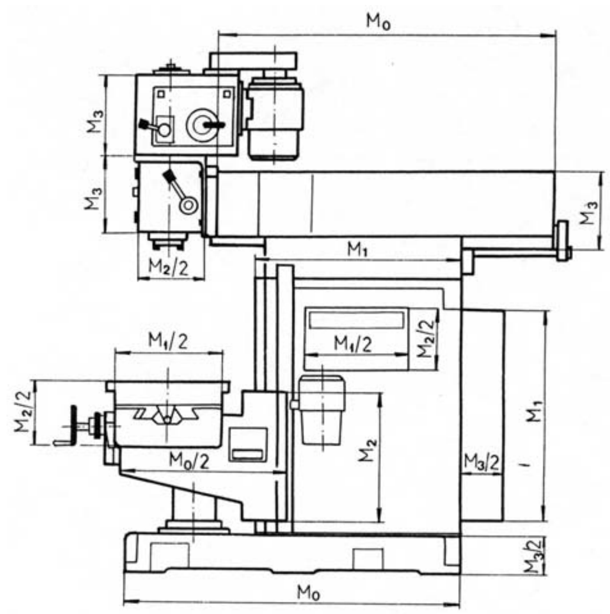

Fig. 12. The scale down for a milling machine.

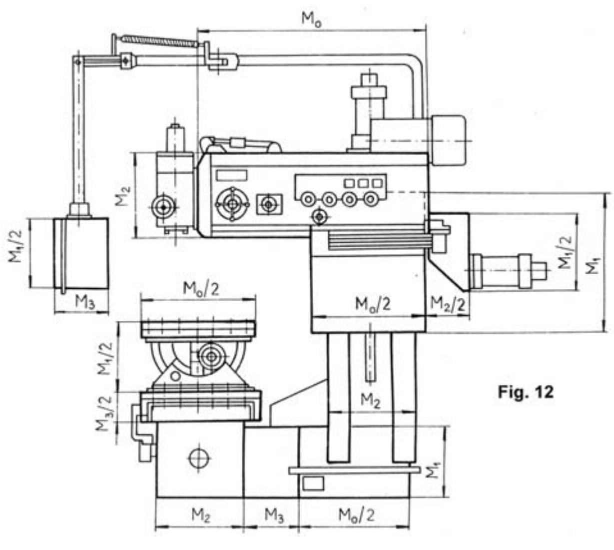

Fig. 13. A scaled down milling machine.

- $M_1/10$; $M_2/10$; $M_3/10$; $M_4/10$; $M_5/10$; $M_6/10$;...

The modulus use for shape optimization of machine tool elements, must be in a perfect concordance with machine structure and to correlate with its working. Industrial design is applied to shape design and to structure of the the electronic control panels (Fig. 13), like and to digital display systems (Fig. 14).

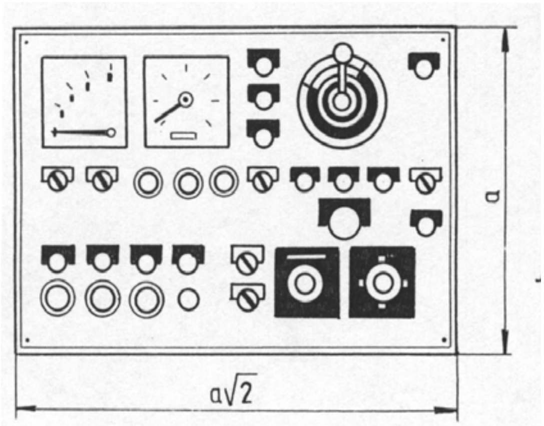

Fig. 13. The scale down for a control panel.

Fig. 14. Design for a digital display system.

4. CONCLUSIONS

The machine tools configuration, in the context of function – shape relation must assure: the working with a high precision, safety and productivity, maxim comfort (ergonomicity) with minimum expenses for working, maintenance and environement protection. If shape design is separated from function (working) then it can find the "new machine tool types" very attractive, but from point of view of precision and productivity, they don't distinguish from the oldest machine tools, which were not so aesthetically. A mathematical relation between functional element and aesthetical shape is not still determined because of subjective factors regarding the machine tools aesthetics. A machine tools modifies itself shape in time for to adapt to science and technology evolution and aesthetical concepts of epoch. It does not include aesthetical values sum of component parts, because these can be different perceivedif they depend on other type of spatial compozition or structure.

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