# FABRICATION AND REFABRICATION OF HEAVY DUTY MACHINE TOOLS

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Abstract: During this brief presentation the authors try to present the state of the art of production of heavy machine tools in Romania. The current trends in the design and manufacture of these machines are presented. The opportunities of making modernizations ore refabrication of older machine tools for transforming them into modern and competitive ones are discussed in technical and economical terms. The cases in which refabrication is preferred are presented with their advantages regarding simplified construction and running in better conditions of vibration, heat transfer and machining accuracy. The authors highlight some of the most representative achievements in this area, insisting on a number of Romania production companies, among which they can mention TITAN HEAVY MACHINERY, GPM INTERNATIONAL, TEHNOCOSULTINVEST, ANTONELLO, TITAN AUTOMATION, OPEN SERVICE.

Key words: heavy machine tools, fabrication, refabrication, CNC machine tools, machining centres.

### 1. PRODUCTION OF MACHINE TOOLS IN ROMANIA

The evolution of industrial developments shows very clearly that today the enterprise is under the influence of triplet: timelines-cost-performance.

Under the terms of the transition from a manufacturing economy to a market economy or, in other words, form the "mass production" to "production required", the fabrication and refabrication are highly topical.

The school of machine tools (MT) from Romania, developed during the years 1955–1985, focused on the requirements of the new machines in a relatively large variety of sizes. Therefore, the industrial park of heavy duty machine tools (HDMT) and specialized machine tools (SMT) in the 1990s, consisted of outdated technology, many being considered non-performing in terms of the equipment used in their construction (elements of fine mechanics, hydraulic system, electrical and electronic driving and control equipment).

Up in 1990 Romania was among the top ten producing countries of machine tools and, especially, the heavy machinery and even very heavy. These machines have been produced on the basis of the obtained licenses from leading companies such as: WALDRICH COBURG, MORANDO, LINE, PAMA, SCHIBAURA, etc. By producing the first machine tools, a series of unique or of different machine sizes were imported during the period 1960–1980 from above presented companies, but also from others, such as: WALDRICH SIEGEN and HOESCH.

After 1990, these machines have been the subject of three basic activities:

- the refabrication (modernization) and their use in factories in the country or abroad;
- export in the condition in which they were or after an eventual modernization;
- cassation and turning in scrap metal.

### 2. DEFINITION OF THE RECONFIGURATION CONCEPT FOR MACHINE TOOLS REFABRICATION

Refabrication and reconfiguring of MT [4 and 8] represents modern solutions applied on a large scale by the specialized companies in Europe and the U.S.

Where machine tools had found a place in production, in the country or abroad, the issue of modernization or even refabrication rose. These activities have proven to be very close and most of the time confused. The truth is that very often in an objective manner, it is hard to find the line of demarcation between the two types of intervention in order to ensure a continuation of their use, especially under the conditions imposed to the current manufacturing – high productivity, increasing the usability, flexibility, etc.

We believe that it is considered the refabrication if the machine tool has been completely dismantled and it has intervened on the structure components, such as reprocessing or changing guides, changing bed, columns, traverses and guides. Also, remanufacturing is considered if architectural changes are made on machine tools, for example: the plateau of a carousel lathe is mounted on a sled moving on guides; on a boring and milling machine bed a portal of carousel lathe is adapting and moving, so obtaining Gantry milling machine.

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Upgrading may be a freestanding activity or can be applied together with refabrication. Typically, upgrading affects:

- the mechanical part, consisting of guide replacement, changing lead screws, modification of gear boxes [13] (for speed or feed);
- electrical drive or control, consisting of the replacement of electric motors, gearboxes, electrical cabinets, control panels;
- hydraulic part, consisting of the old hydraulic equipment replacement (eg. valves, pumps, directional valves, etc.);
- electronic part, consisting of CNC equipment replacement, including transducers;
- related plants: replacement of lubricating equipment, pneumatic actuation, the use of modern accessories , etc.

Heavy duty machine tools that were representative for Romanian industry are lathes, boring and milling machines, milling portal machines, some specialized machine tools used in the oil industry, metallurgy, energy and nuclear equipment, machine construction industries, etc.

## 3. TECHNICAL AND ECONOMIC CRITERIA FOR JUSTIFICATION OF THE REFABRICATIONI AND RECONFIGURATION OF MACHINE TOOLS

1) How much is preserved and replaced in case of refabrication of a machine tool?

- There are two criteria to determine this, namely:
- customer requirements;
- the price of the product.

Typically, the customer has specific requirements of the destination of the machine that wants to buy, such as overall dimensions, load, speed and feed rate ranges, rapid traverse speeds, cutting parameters, technological processes which may be applied on the machine, degree of automation, control system, etc. Depending on these, the basic machine tool is chosen and then it is decided what is preserved and what is changed from its composition. This analysis is based on the existing offer for second hand parts, but also for the prices for production of semi-finished products (castings, welding, and cutting) and for processing.

In the case of machine tool refabrication, even for its holder, another approach is required. Sometimes, the machine is already at the customer, who is wanting, depending on his requirements at a time, a "new" machine tool, more productive, more accurate and more reliable. The refabrication can be done by the owner or by a specialized company.

It was found that the performance of the refabricated SMT and HDMT are superior to new machine tools, the price being lower. The refabrication is more profitable by 2–3 times than manufacturing a new one. Although large, the MT needs to be very precise, geometric precision being at the level of hundredths of millimetres. Qualitatively, a refabricated MU is better than a new one, because the technical characteristics are known and one can propose solutions for improving them, the mechanics being more stable.

2) Banking and insurance systems compatible with those world-wide.

3) In order to ensure the competitiveness of the machines tools made they should contain up-to-date, modern constructive solutions according to users' requirements.

4) With what differ machine-tools produced after 2 000 than those produced in the 1980s?

Here are some answers:

1. Increasing the cutting speeds. So, in turning for SC14, speeds of 1 700 m/min for aluminium has been reached, and in SC33 of 700 m/min for steel. The lathes VERTITURN having diameters of up to 2 800–3 200 mm can machine parts of 25 t with speeds up to 110 rot/min.

2. Overlapping the feed kinematic chain with the so called positioning kinematic chains [1] in terms of maximum speed of 10-12 m/min in tables of 200 t. The increase compared to the machines of 80s is spectacular. Thus, in MORANDO lathes the ram speed increased from 2 to 10 m/min.

3. Complex kinematic chains for threading, rolling, etc. on rigid structures are replaced by CNC axes.

4. Automation of the supply of parts and tools. Tool magazines are present more often.

- 5. Reduction of noise, pollution and warming.
- 6. Housing of machines.

7. New machine structures on the modularized variants.

## 4. MAJOR CHANGES IN THE WAY OF MACHINE TOOLS PRODUCTION IN ROMANIA

- The design institutions practically disappeared.
- The design is usually carried out through specialized companies. These are small companies, specialized on design, technical assistance, commissioning.
- Specific processes are carried out by specialized firms also equipped with machines, equipment and qualified personnel. Thus, many manufacturers of moulded items provide them with preliminary processing completed. Other treatments are very expensive, requiring very qualified personnel but who at one company does not have a permanent loading time. Such a case is the grinding of guides. Thus, in the south of the country, there are 3–4 companies where the necessary grindings are executed. Before the year 1989 only in the former IMUAB there were 6 grinding machines for guides with 12 employees.
- Many machine tool companies are actually machine integrators. They carried out the work contracting, supply of the necessary components, design (possibly through collaborations), installation and commission-ing. Also, all these firms will provide warranty and post-warranty maintenance interventions.
- Qualified personnel, usually experienced workers over the age of 40 years paid with sums comparable to those in the West. Unfortunately, young qualified personnel under the age of 40 is very hard to find, not existing post-secondary or professional schools in the field.

### 5. REFABRICATION, HOW FAR?

When the refabrication of a machine tool is in question and when not? It is a question whose answer depends on a number of factors, such as:

- machine tool type,
- its size,
- existing offer of such new machines (technical and commercial).
- not every machine tool can be refabricated; there is a maximum age of the machine to which their reabrication is in question; Figure 1 shows the case of small vertical lathes [1 and 2] (the plateau of up to 2 000 mm).

Notice that the "architectural" structure of machine tools manufactured before the 1970s, as well as their kinematics, make them devoid of interest for refabrication.

In reality, when a heavy machine tool is achieved (especially in unique), manufacturers of such machines search for similar ones, which can adapt to the new requirements. In some cases, it recovers only certain elements of the structure. Thus, in case o vertical lathes, beds and columns are searched, and in the case of machine tools of boring and milling machine type – beds, columns and housings. Recovered items are used as they are, but as we shall see further, they will undergo specific processing.

# 6. FABRICATION AND REFABRICATION OF GENERATION KINEMATIC CHAINS

In machine tool construction, the function of transmission the translation and rotation movements is provided by the kinematic chains. Depending on the type of movement, of technological and productivity requirements and the degree of specialization of the machine,



NO



YES

Fig. 1. Changes in machine toll design over time.

the kinematic chains have to include mechanisms and adjusting systems of variables such as speed (linear and rotational), force and torque. In case of universal machine tools, the adjustment ranges are great while in specialized machine tools like the aggregated machine tools, it is possible that the processing to be done without adjustment. Still, the object of this article will be the family of heavy duty machine tools of universal and CNC type.

### 7. MECHANICAL SYSTEMS FOR ADJUSTING MAIN KINEMATIC CHAINS

These systems, commonly called gearboxes, vary depending on the machine size, its field of use and depending on the manufacturer. Gearboxes in these machines can be with horizontal or vertical main spindles. Those with horizontal spindles are older solutions, simpler ones that do not affect the working area. Because the shafts are horizontal, in some cases, like in vertical lathes for driving the main spindle, a group of bevel gears is needed. They introduce specific noise and uncontrollable backlash.

Gearboxes with vertical spindles are more complicated, involving the use of systems to ensure the vertical sliding gears are found close to the work area. However, they remove conical groups and therefore the backlash and noise.

Figure 2 shows the kinematic scheme of an older lathe with horizontal gearbox. The AC electric motor EM has a single speed. Note that for adjusting, the gearbox has a three position sliding gear and two ones with two positions which is ensuring 12 adjusting steps. To these the reduction belt ( $\emptyset$ 235 /  $\emptyset$ 385) and the final pinioncrown mechanism (18 / 113) are added. At the level of the gearbox there are five spindles. This gearbox was used by Russian manufacturers in the smallest vertical lathes.

A gear box used in a vertical lathe with a plateau of 6 000 mm, manufactured before 1960, is presented in Fig. 3 at kinematic scheme level.

The electric motor is mounted vertically without belt transmission. The gearbox has four steps supplied by



**Fig. 2.** Horizontal gear box (EM – electric motor;  $T_M$ ,  $n_M$  – torque and speeds in motor;  $T_{MS}$ ,  $n_{MS}$  – torque and speed in main spindle).



**Fig. 3.** Vertical gear box (*EM* – electric motor;  $T_M$ ,  $n_M$  – torque and spees in motor;  $T_{MS}$ ,  $n_{MS}$  – torque and speed in main spindle).

two double couplings in shafts II–III and IV–V. In constructive terms, the solution with couplings is simpler, the speed adjustment being easier, the sliding gears not being demarcated. In heavy machines having plateau of 6 000 mm, some firms producing vertical lathes for ensuring power required use two motors each having its own gearbox. The motion transmission synchronization is done electronically.

The kinematic scheme of a vertical gearbox currently produced by and European company [6] is presented in Fig. 4,a. The unfolded section o the gear box is shown in Fig. 4,b.

A DC electric motor with frequency converter is used having a rated power of 100 kW and a rated torque of 636 Nm for a rated speed of 1 500 RPM. The maximum speed is 4 500 RPM. At the main spindle axis, the supplied speed range is  $n_{MS} = 0.27 - 33.65$  RPM, correspon-



**Fig. 4.** Vertical gearbox (EM – electric motor;  $T_M$ ,  $n_M$ , – torque and speed of the motor;  $T_{MS}$ ,  $n_{MS}$  – torque and speed of the main spindle).



**Fig. 5.** Variant of gearbox used in SC17(EM – electric motor;  $T_M$ ,  $n_M$  – torque and speeds in motor;  $T_{MS}$ ,  $n_{MS}$  – torque and speed in main spindle)..

ding to the motor speed range  $n_M = 50-1500$  RPM. These adjustments are in the range of constant torque. In the range of constant power the maximum speed can be  $n_{MS} = 100$  RPM. On this vertical lathe, there is also the possibility of milling, the main kinematic chain turning into a circular feed kinematic chain.

The motion is brought by the electric motor through three poly V belts [2]. Having only two speed steps (1/2.5 and 1/11), the gear box built in a welded housing has a reduced size and is simple driven.

For the vertical lathes with plateau in the range 1 200 mm - 4 000 mm produced in Romania in the last two decades, it has been widely used a three step gear box (1:1, 1:3 and 1:9) whose kinematic scheme is shown in Fig. 5 [3] that presents the variant used for SC17 with pinion-rack mechanism having a transfer ration 20/217.

It is a compact gearbox having only three shafts, two of them being coaxial. The driving of the sliding gear with three positions is done hydraulically.

The motor is coupled directly to the gear box, the exit being on the same direction.

A modern solution used in new refabricated vertical lathes is the two step gear boxes produced for machines tool by specialized companies [3 and 6]. These have a series of advantages such as:

- low backlash in reversing that enables their use in vertical lathes that perform milling operations removing the gearboxes for circular feed;
- separated lubricating circuit from the rest of the machine, which reduces the transmission of heat to the main shaft;
- it is coupled to the main spindle through toothed belts preventing transmission of vibration;
- low noise;
- simple and compact construction with direct coupling to the drive motor;
- high efficiency, over 95%;
- changing the range is done by using an integrated device with the gearbox and being operated electrically, pneumatically or hydraulically.

The kinematic scheme for such gearbox having the transfer ratios 1/1 and 1/4 is shown in Fig. 6,*a* and a view of such boxes in Fig. 6,*b*.

The electric motor 1 is mounted directly on the gear box 2. The motor shaft is driving the gear 3. If the sliding coupling 4 is on position I (in holes *a*), the motion is transmitted to the satellites 6 and then to the exit shaft 7. The wheel with inner teeth 9 is blocked. This step enables the ratio 1/4 [6].







**Fig. 6.** Two step gearboxes produced for machines tool by specialized companies (1 – electric motor (EM); 2 – gear box (GB); 3 – gear; 4 – sliding coupling; 5 – bearings; 6 – satellite pinions;, 7 – exit shaft; 8 – bearings; 9 – inner toothed gear).

If the sliding coupling is on position II (in holes b), the satellites 6 and gear 9 supplies the ratio 1/1. The bearings are denoted by 5 and 8, respectively.

The motion is transmitted usually from the exit shaft of the gear box to the main spindle by means of pinioncrown mechanism or belt transmission. This solution eliminates the heat transfer and any vibration to the main spindle.

Due to their design, these gear boxes are considered as an extension of the electric motors. They can work in any position, provided that the lubrication to be enabled as recommended by the producing company.

These gearboxes are characterized by low noise and low backlash, so that they can be integrated in the feed kinematic chains.

At the same asynchronous electric motor with frequency converter, in terms of speed adjustment there are no differences, the two-speed gearbox being preferred. Problems can occur in terms of torque developed considering that the maximum reduction of the gearbox with two steps is 1/4 and in that with three steps it is 1/9.

Depending on the machine kinematics and machining necessities, we can distinguish between the following variants:

- the developed torque is enough (there are no roughing processes in hard materials);
- new speed reducing mechanisms are considered;
- choosing a higher power or torque motor.

For SC14 and SC17 lathes, the use of these two speed gearboxes with two steps became usual in the variant with preservation of the secondary shaft, according to the kinematic diagram in Fig. 7.

The electric motor is mounted vertically coaxial to the gearbox. The movement is transmitted from the gearbox by means of special toothed belts (usually of carbon fibre) to the secondary shaft, but without using the bevel gearing. From the secondary shaft it is preserved the pinion that rotates the main spindle crown. From the electric motor to the secondary shaft the motion is transmitted without backlash, but the classical pinion-crown mechanism has backlash with unacceptable values for the feed kinematic chains.

If the machine performs milling operations, pinions with backlash removing or a kinematic scheme o the type presented in Fig. 8 can be used.

The secondary shaft is replaced by a toothed belt transmission, which eliminates all backlashes in reversing, the main kinematic chain being able to take over specific functions of the circular feed kinematic chains.

In machines with plateaus of over 2 000 mm, this last solution still cannot be applied as there are no toothed belts that can replace the pinion-crown mechanism.

Mechanisms and adjusting systems of the main kinematic chains of vertical lathes have simplified from the mechanical point of view due to the development of electronic adjusting systems by means of frequency converters. The adjustment in the main kinematic chains is done by technological considerations: cutting speed and torque. In terms of speed adjustment, theoretically the gear boxes are no longer needed. However, if these



Fig. 7. Two speed gearbox for SC14 and SC17 lathes.



Fig. 8. Two speed gearbox without backlash in transmission.



gearboxes would not be used, the drive motors were oversized and very expensive.

Such solutions have been successfully used in boring and milling machines, boring and milling machines with portal and also in lathes e machines.

It is recommended that for achieving the final transmissions in the gearbox to the main spindle to be used toothed belts. This eliminates transmission of vibration and heat and provides the possibility of correlation of the feed movements with that of main spindle rotation, ideal for CNC machines.

In the case of vertical drive, the brake is incorporated into the electric motor. Gearboxes with ratio i = 1/5, have lower backlash in reversing that do not affect positioning accuracy. Gearboxes for the two axes are presented in the order in Fig. 11.

### 8. CONTROL MECHANICAL SYSTEMS OF FEED KINEMATIC CHAINS

For the new CNC machine tools or for refabrication of old ones, the gearboxes are abandoned in favour of reducers coupled to electric motors with adjustable speed.

Regardless of the work axis, presently two types of actuation are used. The first version having the kinematic scheme shown in Fig. 9 is using reducers with toothed belts.

In case of horizontal axis (Fig. 9,*a*), the table of mass  $M_X$  is maintained on position through the motor loop or eventually after removing form axis, with hydraulic blocking systems. For the vertical case (Fig. 9,*b*), it is recommended the use of an electromagnetic brake *B*, and balancing system [8] and, if applicable, a blocking system to be used after removing from axis. In Fig. 9, it was also noted: *LCA* – feed kinematic chain, *R* – reducer, *EMX* and *EMZ* – electric motors, *S* – lead screw, *p* – lead screw pitch; Mxg – weight of slide and ram; Mzg – ram weight,  $F_i$  – inertia force,  $F_f$  – friction force, vx –velocity on axis *X*, vz – velocity on axis *Y* and *i* – reducer transfer ratio.

For vertical operation, Fig. 9,*b*, the mass  $M_Z$  is of ram with all that is on it. For the slide displacement on *X*, the slide mass is added yielding  $M_X$ .

A second version, shown in Fig. 10, uses a planetary gear coaxial to the electric motor and lead screw.

The notations are the same as in the first case.

In the case of vertical drive, the brake is incorporated into the electric motor. Gearboxes with ratio i = 1/5 have lower backlash in reversing that do not affect positioning accuracy. Gearboxes for the two axes are presented in the order in Fig. 11.

Linear motors [3, 6 and 14] can be used in machine tools primarily in feed kinematic chains drive. Among the advantages of linear motors we can mention: greater positioning and feed rates, high efficiency, reduced complexity, rigidity. Existing linear motors can develop forces over 20,000 N and speeds greater than 400 m/min.

In case of the older structure (with rotary motor), the characteristics of the motor are known, being of the type shown in Fig. 12.





b

**Fig. 11.** .Gearboxes with ratio i = 1/5, and lower backlash.



Fig. 12. Torque characteristic in rotary motors.



Fig. 13. Force characteristic in linear motors.

The characteristics of linear motors used for feed kinematic chains of machine tools are of the type shown in Fig. 13.

In Fig. 13 it was noted:  $F_{MAX}$  -maximum force [N],  $F_N$  - rated force [N],  $v_{MAX1}$  -maximum speed for maximum force,  $v_{MAX2}$  - maximum speed.

A linear electric motor (or more) will be chosen so that the following relations are verified:

$$v_{MAX1} \ge v_{MAX}, \tag{1}$$

$$F_N \ge F_{MAX} \,. \tag{2}$$

Linear electric motors represent a modern solution of the feed kinematic chain drive in new machine tools and also in those refabricated [14]. By using them, the feed system construction simplifies, disappearing the electric motor, couplings, transformation mechanisms of motion (usually lead screw-nut) and any gears. Currently, there are motors covering a wide range of speeds, but there are limitations in terms of the forces developed. There is the recommendation of their use in small and medium machines with the perspective of using them in heavy machine tools.

### 9. SIMPLIFICATION OS KINEMATIC CHAINS IN HEAVY MACHINE TOOLS

Among modern mechanical transmissions, which largely removed the gear systems, the most spectacular evolution in was that of toothed belt transmissions [3]. Used initially only in feed kinematic chains due to their reduced capacity of power transmission, currently they are used in the main kinematic chains, enabling the



**Fig. 14.** Kinematic scheme of the lathe SC14CNC with gear transmissions.

transmission of powers of the order of 100 kW. Among the obvious advantages they have over the gear transmissions, we can mention:

- lower cost;
- they are made by specialized manufacturers;
- reduced noise operation;
- they transmit motion at distances greater than that between the axes of gear;
- they do not require lubrication;
- operating with no backlash in reversing.

This last advantage imposes them in CNC machine tools.

Where necessary, the gearboxes usually with two steps and provided by specialized companies can be used. They are selected from catalogues [4 and 6] depending on the power to be transmitted and transfer ratios required.

They have a number of advantages such as:

- low backlash in reversing [2 and 3] enabling their use in vertical lathes that perform milling operations and removing gearboxes in circular feed;
- separated lubricating circuit from the rest of the machine, which reduces the heat transmission to the main spindle;
- they are connected to the main spindle through toothed belts, preventing the transmission of vibration:
- low noise;
- simple and compact construction and direct connection to the driving motor;
- high efficiency, over 95%;
- changing a range is done using a device integrated with a gearbox and operated electrically, pneumatically or hydraulically.

The kinematic scheme of a vertical lathe SC 14 CNC with classic support for turning-milling is shown in

Fig. 14. It is a modern machine at the level of the 2000s, which already uses toothed belt drives in the feed kinematic chains [5].

In Fig. 14 the following notation were made: 1 – electric motor for the main kinematic chain; 2, 3 – motors for driving the feed kinematic chains (X and Z); 4 – electric motor for driving the main kinematic chain in milling; 5 – electric motor for driving the circular fee kinematic chain; 6 – drive motor or positioning kinematic chain (Y); 7 – speed gearbox with three steps for turning; 8 – bevel transmission; 9 – pinion-crown mechanism; 10 – two-speed gearbox for milling; 11 – gearbox for circular feed and mechanism for elimination the backlash in reversing; A and C – control axes (threading).

In newer machine tools of the late generations, the following are abandoned: gearbox 7, bevel transmission 8, pinion-crown mechanism 9, gearbox with sliding gears 10, feed drive motor and circular feed gearbox 11.

The kinematic scheme of such a machine is shown in Fig. 15. The operations that can be made are the same but a dramatic simplification of the whole assembly can be seen.

Notation on Fig. 15 are: 1 - electric motor of main kinematic chain; 2,  $3 - \text{drive motors of the feed kinematic chains ($ *X*and*Z* $); <math>4 - \text{drive motor of the main kinematic chain for milling; <math>6 - \text{electric motor of the positioning kinematic chain ($ *Y* $); <math>12 - \text{toothed belt transmission made of carbon fibres; <math>13 - \text{gearbox}$  with two steps and electric switching in main kinematic chain and also circular feed one; 14 - gearbox with two steps and electric switching in main kinematic chain for milling and drilling; A and C – controlled axes (threading).

Comparing Figs. 14 and 15, it can be seen the disappearance of the positions 5, 7, 8, 9, 10 and 11 and occurrence of the position 12 (toothed belt drive of carbon



**Fig. 15.** The kinematic scheme of the lathe SC14CNC with toothed belt transmissions.

fibres), 13 - two-speed gearbox and electric switching for main kinematic chain [9] and circular feed and 14 two speed gearbox and electric switching [6] in the main kinematic chain for milling and drilling. For vertical axes (Z) it is recommended the hydraulic balancing of them [8]. It is noted the removal of an electric motor and gearboxe for circular feed 11. Classical gearboxes 7 and 10 are replaced with modern gearboxes 13 and 14, without backlash in reversing and mechanisms of gear type 8 and 9 are replaced by the belt drive for the main kinematic chain that becomes also circular feed kinematic chain in milling and drilling operations. The costs of these changes are acceptable taking into account that only circular feed gearbox 11 can reach \$ 20,000–25,000 without hydraulic system.

In the construction of heavy and very heavy machine tools, mainly in CNC machine tools, it is possible to reduce the number of gears that must be processed. This eliminates the processing of different types of wheel toothing: cylindrical, bevel, worm, worm wheel [2, 7, and 10]. They can be replaced by precision systems, reducers or even gearboxes produced by specialized companies. The reversing backlashes are thus eliminated and the noise is reduced considerably. New toothed belt drives of carbon fibre allow the transmission of high power without play and at distances that classically require long trains of gears. The example shown in Fig. 15 presents a CNC machine tool for which the manufacturer did not machined any gear. The reducers and gearboxes were purchased from specialized manufacturers. This solution is successfully applied to new heavy machine tools (over 10t) and also refabricated.

## 10. HEAVY DUTY MACHINE TOOLS MANUFACTURED AND REFABRICATED IN ROMANIA

The authors highlight some of the most representative achievements in the area of refabrication, insisting on a number of Romania production companies, among which they can mention TITAN HEAVY MACHINERY, GPM INTERNATIONAL, TEHNOCOSULTINVEST,

ANTONELLO, TITAN AUTOMATION, OPEN SERVICE (Figs. 16–31).



Fig. 16. AFP 200 POPECI Craiova.



Fig. 17. AF 105 for US ARMY (now 6 pieces are in execution).



Fig. 18. SC 33 CNC Turning and milling, TMG.



Fig. 19. FLP 2000 produced at POPECI for the railway industry in Hungary.



Fig. 20. Deep drilling machine for Romanian energetic industry.



Fig. 21. AFP 200 Pama for Germany.



Fig. 22. SC22 for turning, produced for Singapore.



Fig. 23. SC 22 CNC for turning and milling, U.S. Client, completely new machine.





Fig. 24. Heavy vertical lathe for cement industry VOLOS, Greece: a – installation phase; b – at the beneficiary.



Fig. 25. Vertical lathe (5 600–6 000 mm) manufactured by a Romanian-Italian company in Canada.



Fig. 26. SC 22 CC for Egypt.



Fig. 27. GANTRY milling machine, customer from Romania.



Fig. 28. Vertical lathe of 12 m, completely new machine made by TMG for a partner from India, the largest machine tool made after 1989.



Fig. 29. CNC drilling machine for aerospace and automotive industry (turbines); completely new machine.



Fig. 30. Heavy normal lathe refabricated: part of 200 t and 20 m maximum length.



**Fig. 31.** SC14 lathe made for Germany: a – before refabrication; b – after refabrication in the testing phase (SC14 CNC); c – machine installed at the client (bed, positioning kinematic chain and traverse were kept, the rest is new).

New requirements for machine tool producers:

1. Increased cutting speeds for vertical lathes and boring and milling machines; speeds above 2 000 rpm in boring and milling machines with portal AFP 180–200.

2. Increased feed rates over 8-10 m/min.

3. Increase of workpiece weight that can be processed with direct influences on vertical lathes, grinding machines and GANTRY machines.

4. Using heads with independent axes.

5. New systems tools; magazines with multiple tools and high precision; the operation of magazines from CNC; magazines purchased from specialized companies; more efficient cutting tool cooling systems; cooling systems with emulsion at high pressure (100 bar); air cooling systems of VORTEX type.

6. Improved aesthetics of machine tools; modern housing systems.

7. Noise, warming and pollution reduction,

8. Major components modularization.

9. Bold design solutions: linear motors, efficient hydrostatic guides, guides without lubrication, magnetic sustentation, lubrication and cooling systems monitored.

10. Implementation of new solutions due to modern information management.

11. "Free" zones establishing, where the manufacturers of machine tools can extend: new structures, hydraulic, lubrication and cooling systems, modernization.

#### **10. CONCLUSIONS**

In the construction of heavy and very heavy machine tools and especially in CNC ones it is possible to reduce the number of gears that must be processed. This eliminates the toothing processing for different types of wheels: cylindrical, conical, worm-worm wheel. They can be replaced by precision systems, reducers or gearboxes produced by specialized companies. Reverse backlash are thus eliminated and the noise is reduced considerably. New toothed belt drives of carbon fibre allow the transmission of high power with no play and at distances that classically require long trains of gears. Reducers and gearboxes can be purchased from specialized manufacturers. These solutions are successfully applied to new heavy machine tools (over 10t) and also in refabrication o machine tools.

Vertical lathes and boring and milling machines have been and remain some of the most popular universal machine tools. The development of electric drives and occurrence of adjusting systems through frequency has reduced the number of adjustment steps in gearboxes. Basically, the speed adjustment can be pure electric over the entire engine range, now the gearboxes having the role of torque amplifiers.

In case of small lathes (SC14 and SC17) even the final mechanism pinion-crown can be removed. In this case, milling operations can be performed using the main kinematic chain used for turning as circular feed kinematic chain in milling.

Choosing the type of machine to be acquired depends on a number of factors linked to the production requirements, not only on the machine price. Lately, the conventional machine tools equipped with complex mechanical part, with several kinematic chains, several gears and couplings and other transmission systems have comparable prices with those of the second hand CNC machines. These, due to the simplifications introduced by the modern drives and controls, allow that using a simple mechanical part to machine complex surfaces in terms of precision and high productivity. On mechanical structures of 10–15 years old, high performance machine tools can be build.

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