# Electron beam melting of titanium – problems and prospects of development.

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## 1. Introduction.

Long ago electron beam melting has won a time-proof position in world metallurgy as an effective method of production of reactive and refractory metals and alloys, such as titanium, zirconium, niobium, tantalum, molybdenum and others.
The electron beam melting has started to be applied for titanium manufacture essentially later, than to other metals - only from the end of 1980th years. The main reasons of such situation were complexity and high price of the equipment which result in high production cost of titanium ingots in comparison with vacuum-arc remelting (further – VAR). Insufficient homogeneous allocation of alloying elements in an ingot was considered as the other disadvantage of electron beam melting in application for melting of titanium alloys.
In those years for these reasons electron beam melting was used basically as auxiliary process for manufacture of the most high-duty titanium alloys for aircraft building because of this branch was the least sensitive to cost of materials. Electron beam melting applied for providing of reliable refinement of metal from different kinds of impurities owing to application of cold hearth. Then further one- or two-stages vacuum-arc remelting was used in order to provide homogeneous chemical composition in all body of ingot.
But from the end of 1990th electron beam melting engineering and technology has been developed with increased rate, and now this method has won a strong place in the world industry as an effective method of manufacture of titanium ingots.
Heating sources of materials in this technology are electron beam guns which possess extra high level of controllability and power efficiency. Due to these features electron beam melting allows solving a wide spectrum of problems which are very complicated or even impossible for other methods of vacuum metallurgy. At the same time electron beam melting permits meet the requirements of commercial expediency.

Further in the present report all stated here will concern electron beam cold hearth melting (EBCHM) furnaces because other kinds of electron beam melting furnaces are not applied in titanium manufacture.

EBCHM technique provides a number of the important technological advantages in manufacture of titanium ingots in comparison with VAR, namely:

- possibility to eliminate ingress of unmelted charge, high and low density inclusions to ingot;

- possibility to use different kinds of charge including metal scrap and waste without complicated preparatory operations;

- possibility to produce ingots and slabs of very different cross-sections including hollow;

- possibility to control separately processes of melting, refinement and crystallization. These features allow on-line regulating of technological mode of running melting process over the wide range, control for metal solidification and thereby guarantee the production of high quality ingots with perfect macrostructure.

The most effective applications of EBCHM are production of ingots from commercially pure titanium and low-alloy titanium alloys which are intended for civil applications, remelting of titanium scrap and especially manufacture of slabs (flat ingots) which can be set on the rolling mill for manufacture of sheets, plates and coils without additional processing.

**Taking into account predicted increase of civil application of the titanium, the general considerable growth of consumption of the titanium and connected with this fact the increase of quantity of scrap and waste, it is possible to predict the further expansion of application of EBCHM for manufacture of titanium ingots.**

## 2. Demand expansion states new problems.

However expected increase of demand for EBCHM equipment states a number of new problems for designers and suppliers of such equipment. Earlier these problems were considered as insignificant but now they can become the key conditions for successful distribution of EBCHM technologies of the titanium in the world.
**These problems are connected with inevitable and cardinal re-orientation to a new circle of potential customers of EBCHM equipments due to asymmetrical rates of development of titanium industry all over the world.**

## 2.1. Electron beam technologies – unauthorized persons not admitted?

The historical circumstances were such that development of electron beam technologies, and in particular EBCHM, had taken place only in the several countries - in the former USSR (basically at Paton Welding Institute, Kiev), Germany and the USA, Japan has joined much later to these countries. As a rule, some companies designed and produced melting equipment for sale and other companies operated by these equipments and developed melting technologies. Perhaps, only in Kiev research and development works and manufacture always were inseparably linked.

Right up to the beginning of 2000th new EBCHM furnaces were put into operation basically at the enterprises of the mentioned countries as expansion of manufacturing capacity or updating of park of the equipment. And only these countries possessed the schools for preparation of appropriate skilled staff. It is worth to emphasize that professional skill and experience of staff at operation by EBCHM furnaces defined a great deal of work because automation of melting processes practically was absent and melting process was conducted by the operator manually.

## 2.2. A new audience for EBCHM technologies.

Such situation was earlier. Now the countries of Asia become basic consumers of EBCHM furnaces because they expect the greatest growth of consumption of the titanium and at the same time they have the greatest shortage of melting capacities. First of all it is certainly China but also India and Korea with time which has their own plans for development of titanium industry.

Accordingly sharp changes in base requirements to EBCHM equipment and conditions of its purchasing are appeared.

We take, for example, our own experience.

The team of specialists which we represent has essential achievements in the field of development of EBCHM equipment and technologies. More than 10 EBCHM furnaces were installed at the various enterprises of the former USSR with the assistance of representatives of our team in different years. The most of them successfully operate to this time producing not only the titanium but also other reactive and refractory metals [1]. For last three years our team had executed a number of contracts on delivery of gas-discharge electron beam guns of GGE series of our own design to the metallurgical enterprises of Russia and the USA. At our participation it was spent the reconstruction of EBCHM furnace TICO-15M at electron beam metallurgy plant of Company «Strategy BM Ltd» (Kiev). At the present time we are carrying out the updating of several EBCHM furnaces on Public Corporation «Chepetsky Mechanical Plant» in Russia. Now we realize the project of creation of EBCHM furnace of new generation BMO 3000/01 for electron beam metallurgy plant of Company «Strategy BM Ltd». Work is good, life is good.

But when we try to exit outside the limits of our usual audience all of us have faced with the statement of some new and unusual problems for us.

**1) First of all rather low even base level of knowledge about the content and possibilities of EBCHM was the greatest surprise for us.**
It was necessary to explain to potential customers the ABC of EBCHM techniques and technology, starting from physical bases of formation of an electron beam and principles of operation of electron beam guns and ending with the peculiarities of behavior of the molten metal in cold hearth and withdrawal mold at the EBCHM process.
Earlier existing enterprises with ready professionals (as in the examples stated above) or the enterprises of defense industry with very skilled staff were customers of new EBCHM furnaces. But now all development of application of EBCHM is connected with those industrialists who understand that EBCHM is necessary, knows that they can not do without EBCHM in any way, but practically poorly imagine what is it.

Both earlier and now the most part of reports, articles and the monographs devoted to EBCHM were intended for a narrow circle of experts. At the best only some paragraphs were devoted to opening of basic ideas. And it was very difficult to the new interested in these subjects persons even technically educated to understand these information without special schooling.

**Therefore providing of wide opportunities for introduction with the base information about EBCHM, beginning from literally popular scientific style is the very important common problem for everybody who is engaged in development of EBCHM, especially first of all for scientists.**
After all the majority of the companies which have plans of creation and development of titanium manufacture has the teams of really competent engineers and scientists who are able to gain knowledge very quickly. But they can gain this knowledge only during personal contacts and presentations - there are no more other sources for this.
Everybody knows that lack of knowledge generates uncertainty and fear.
(But sometimes it can be an opposite reaction such as full and desperate self-confidence. We have faced such facts too.).

But what is the next step after the fact that the potential customer was introduced to bases of EBCHM and has gained enough knowledge?

**2) After overcoming of this stage many interested in this subject people loose their heart because they have an impression that the EBCHM equipment and technologies are very difficult and their usage demands some special fantastic grounding.**
They have no doubt that the good equipment will be delivered to their address, that it will be put into operation and representatives of the supplier will melt on it a few fine

ingots (after all the well-known companies with long-term experience and the developed service infrastructure are suppliers of such equipment). They also have no doubt that in case of occurrence of any problems suppliers of the equipment will not leave them in a trouble even after the end of warranty periods, will arrive, will bring spare parts, everything will be repaired and adjusted, again some ingots will be melted and … they will be away again. But they with nervousness (and even with horror) think that they need to do it by themselves. Owners and investors of such enterprises who wish to count on the long trouble-free work of the equipment according to declared indicators of productivity, stably qualitative production and high efficiency of work even more worry.

I will cite an extract from the report "The Electron Beam Cold Hearth Melting Technology", which was made by representatives of Chinese company BAO Ti Group Ltd. last year in Kyoto at 11th World Conference on Titanium [3]. Company BAO Ti Group Ltd. as it is known is the largest manufacturer of titanium ingots in China and the same Company became the first in China who has installed the big industrial EBCHM furnace with planned annual production capacity of 2500 tons. It is obvious that all Chinese industrialists watch closely on this first experiment and carefully analyze all seen and heard from the point of view of their own plans of development.
Therefore the opinion of respected experts of this company which is made under the first impressions from operation of new techniques is very important and also can essentially influence upon the rate of entry of EBCHM technologies to the Chinese titanium market.
I will not quote the advantages of EBCHM listed in the report as they coincide as a whole with our message stated in the beginning of the report.
What had dear colleagues written about weakness of EBCHM (I would tell - about weakness how do they see them)? The first point they underline is the following:

(1) EBCHM is a complicated technology, i.e. needing the vacuum technology, electron and physical knowledge than melting craft other. Operators have to carry on with high-level training…

Namely this characteristic of EBCHM is named the first not without reason.
First of all, the Chinese customers understand that they have no ready staff and they can not quickly prepare enough number of the skilled workers - after all only for service of one EBCHM furnace in a round-the-clock mode they need more than 20 skilled specialists (technologists, operators, engineers etc.).
Secondly, they understand that suppliers of the equipment at all desire do not have such quantity of necessary specialists which could at least temporarily close such problem with staff. As it was said above suppliers of the equipment earlier practically did not need to be engaged in training of the personnel of customers - on the contrary customers more likely could teach them because they always had to prepare staff without any assistance.

Thirdly, high requirements to qualification of the personnel eliminate one of the basic advantages of the Chinese manufacturers - a cheap labor because expenses on the personnel are not only salaries but also cost of education and special grounding.
And, at last, fourthly, absence of own scientific and industrial school compels new customers of EBCHM equipment to worry concerning development of technologies of titanium melting. After all EBCHM furnace is only the tool which help to make something, it is the big and expensive pan, and the recipe of preparation of a high-quality dish needs either to be got or to be developed by own efforts. But at this moment customers face the problem that suppliers of EBCHM furnaces provide only working out and delivery of equipment and they have not their own production experience without which they can not master all nuances of technology. Certainly the set of delivery always includes the instructions for melting and the other technical documents about furnace operation, but it is far from being the technology. Certainly it is possible to develop melting modes without assistance - all enterprises go by such way with the lapse of time. But it is necessary to carry out the production program, to pay back investments already today, immediately after equipment putting into operation. And the cost of each error, each rejected ingot is very high especially if it weighs 10-12 tons. The cost of ineffective time is even higher.

**Thus we consider that suppliers of the equipment should think over the decision of the designated problems, and customers during decision-making about the signing of contract should look not only at the price of furnaces and their beauty but also at all complex of accompanying problems.**

In our immodest opinion at the moment only in Kiev the customer has a possibility to receive the integrated decision of a problem of creation of electron beam melting plant for production of titanium. Here in cooperation with Company «Strategy BM Ltd» we will show to customers EBCHM furnace in operation and we will introduce them to functioning of operating manufacture of titanium ingots. Here the customer can order working out and delivery of EBCHM furnace according to own requirements. Here the customer can start to prepare for itself the personnel in real industrial conditions long before the putting of the own equipment into operation. Here it is possible to get the developed melting technologies checked up by time.

**Providing of the most possible and admissible automation of melting processes is separate and very important problem for designers and technologists of EBCHM equipment. It will allow to decrease requirements to qualification of the personnel and to reduce influence of the human factor on production quality.**

## 3. New approaches to the decision of old problems.

Increase of the general economic efficiency of EBCHM technology is not less important condition for growth of demand on EBCHM furnaces for manufacture of the titanium. During many years major problem of manufacturers of the titanium all over the world is the reduction of the total production cost of titanium production from raw materials to finished product. Experts in the field of EBCHM technologies of the titanium can and must to bring their contribution to this common cause.
Especially because the new prospects of the titanium market open new possibilities for the decision of this old problem.

### 3.1. Structure of the production cost of titanium ingots.

Let's consider approximate structure of the production cost of the titanium ingots produced by EBCHM for the analysis of possible ways of price reduction.
The percentage ratios given below are calculated on the basis of actual indicators of industrial activity of the Kiev enterprises which produce titanium ingots on EBCHM furnaces. They also consider cost of the investments which are necessary for creation of EBCHM manufacture of titanium ingots with annual production capacity about 2500 tons according to authors opinion. Cost of raw materials in calculations is not considered as it is unstable parameter during last time. Besides the analysis of the prices and production costs of various kinds of titanium raw materials is a problem of other speakers. That is the calculations stated below concern the production cost of electron beam melting as production step.
So, the basic components of the production cost of titanium ingot at EBCHM are following items of expenses:

- The electric power -10 %
- Wages -20 %
- The operational and other field costs -15 %
- Investments into creation of plant -55 %.

From these data it is possible to draw a conclusion that the key parameter which influence on pricing of titanium ingots in EBCHM manufacture is the cost of the equipment and its service which makes together about 70 %.
At the second place under the contribution there are personnel wages. And only at last place - the electric power, though earlier it was considered that high power consumption is one of weakness of electron beam technologies.

**Thus it is clear that the basic resources for price reduction of the electron beam titanium are in hands of designers, manufacturers and suppliers of EBCHM equipment, in particular EBCHM furnaces.**

What are these resources?

### 3.2. Ways of cost saving of EBCHM furnaces.

Let's remember how earlier decisions were made about creation of EBCHM furnace and requirements for it.

As a rule draft proposal to designers of the equipment were made mainly by scientists and technologists who always try to receive for themselves more technological possibilities. Each furnace was intended for manufacture of a wide spectrum of standard sizes of ingots and grades of alloys, they could melt molybdenum and zirconium, copper and special steels, titanium and niobium at one furnace. Volumes of manufacture of ingots of each kind were insignificant and requirements to optimum loading of capacities justified the maximum universality of furnaces.

Thus both ingots and slabs were melted at one furnace, the equipment had to provide possibility of use of the diversified charge, for example sponge, powder, electrodes, cast billets, scrap, chips, etc. Different materials have strongly different physical characteristics, absolutely differently behave at melting, technologies of their manufacture demand different residual pressure in the melting chamber, and their charge differently influences on this residual pressure. And EBCHM furnaces had to provide performance of the whole complex of such various technological problems. Certainly, efficiency of performance of each separate problem on such equipment was far from being ideal.

For the same reason each EBCHM furnace created in past was unique, developed for the concrete customer for its exclusive set of problems. Working out of design and engineering specifications for each furnace began practically with zero, manufacturing of units of the furnace each time demanded new industrial equipment. Also we should take into account that new EBCHM furnaces were built seldom enough. Due to these reasons the research and development share made considerable, may be the basic bulk in cost of EBCHM furnace.

Besides basically small EBCHM furnaces were installed earlier.

**Considerable growth of volumes of titanium manufacture allows another approach to the question of universality of EBCHM furnaces. Now, at last, there is a possibility to develop EBCHM furnaces for the optimum decision of a narrow circle of problems, in an ideal case - for manufacture of one or two kinds of product.**

**Therefore manufacturers and economists equally with technologists should participate in working out of very exact draft proposal to designers depending on the planned production program.**

For example, why EBCHM furnace should have such options as samplers, many-level cold hearth, alloy feeders and the other set of devices providing melting of alloys for high-duty application if it is installed near the rolling mill for coils, it is obviously

intended for manufacture of commercially pure titanium, and the size of made slabs is specified once and for all?
Especially as the titanium for civil application is much more sensitive to the price than alloys for aircraft building. After all by definition, materials of “low cost” type need to be made on the equipment of “low cost” type.

One more extract from mentioned above report of BAO Ti Group Ltd. at 11th World Conference on Titanium:
« The structure of the electron beam cold hearth is completed (such as vacuum system, electron gun system and so on) and using and maintenance cost are highly».
These are those stereotypes with which we should fight all together, otherwise EBCHM technologies of titanium will not move ahead too quickly.

The decision of problems intended on reduction of the production cost of the titanium at all stages of manufacture demands new more careful approach to a complete set of furnaces. It is not necessary to seek maximum universality of furnaces while growing consumption of the titanium moves up the equipment for its manufacture in the serial and large-capacity type intended for the performance of long-term and stereotyped problems.
Each option essentially raises cost of EBCHM furnace, complexity of its operation and simultaneously reduces its reliability and efficiency. Besides using of principles of modular design will always reserves possibility for fast and inexpensive modernization of EBCHM furnaces in case of need.

The major resource in creation of new EBCHM furnaces for titanium melting is the scale factor, after all distinction in cost of working out and manufacturing of EBCHM furnaces not so strongly differs depending on their annual production rate. Cost of operation of the equipment also depends much more on its quantity, than from the sizes. Besides modern rolling mills and forging equipment allow processing of ingots and slabs with very big sizes and weight.

And, at last, it is a problem of optimum equipping of EBCHM furnaces with electron beam guns though here I can be accused of some subjectivism.
The majority of EBCHM furnaces existing now are equipped by the thermo-cathodic electron beam guns due to working out of which the development of all electron beam technologies was begun in one's time. Only from the beginning of 1990th years in Kiev the first tests of gas-discharge electron beam guns (still they also can be named as guns of the high-voltage glow discharge) in melting processes of titanium sponge have been conducted [4].
Gas-discharge electron beam guns have proved themselves from the best side in these experiments and after that they became for our experts a basis for working out of EBCHM equipment of new generations. Their main advantage is weak sensitivity to

changes of pressure in the technological chamber, to influence of metal vapor and even spray during running of melting process. It is especially important at melting of such gas-saturated charge as the titanium sponge. Gas-discharge electron beam guns differ by the simplicity of a design, they are simple and reliable at operation, do not demand the use of individual high-vacuum pumps. Gas-discharge EB guns have attractive prices due to using of inexpensive materials for production and maintenance of them.
Long-term operating experience of gas-discharge electron beam guns at electron beam metallurgy plant of Company "FIKO Ltd", Company "ANTARES" and Company «Strategy BM Ltd» (all of them are in Kiev) proves their operational and economic advantages in comparison with traditional thermo-cathodic electron beam guns. For example service life of the cathodes applied in gas-discharge electron beam guns according to data of electron beam metallurgy plant of Company «Strategy BM Ltd» reaches 800-900 hours and it is at melting of titanium sponge!

The next extract from report of BAO Ti Group Ltd. at 11th World Conference on Titanium:
« EBCHM requires high vacuum. The using proportion of titanium sponges must be restricted».
But do we build EBCHM furnaces really in order to keep any limitation for the customers especially in used raw materials?

We do not want to tell something bad about thermo-cathodic electron beam guns. This is excellent and unique equipment. They remarkably work in processes of refining and production of high-pure materials in high vacuum, in technologies of an electron beam coating and welding, they are good enough at melting of solid charge such as titanium scrap. But at the processes where vacuum conditions are unstable and difficult the thermo-cathodic electron beam guns yield to gas-discharge EB guns in stability and reliability.
For example on manufacture of niobium in Public Corporation «Chepetsky Mechanical Plant» (Russia) only gas-discharge electron beam guns of GGE series which are the result of joint working out of Company "Design Office of Vacuum Metallurgical Equipment, Ltd." and National Technical University of Ukraine "Kiev Polytechnical Institute" are used for the first melting of gas-saturated pressed charge for a long time because only these guns provide stable melting process literally «in a smoke». And the further melting of solid ingots they fulfil already in higher vacuum with use of thermo-cathodic electron beam guns.
Therefore we here call to pay attention that universality cannot provide equivalent possibilities for running of essentially various processes. What is good in one case happens to be inexpedient in other. Creators of thermo-cathodic electron beam guns must solve variety of difficult technical problems including overloading of guns with additional pumps in order to adapt them for severe conditions of melting of titanium sponge. As a result such guns become more and more difficult and expensive. At the

same time gas-discharge electron beam guns have been specially created for such difficult operating conditions, it is their element.
Customers of EBCHM equipment should pay attention to this aspect.

**Thus the main resources of cost saving of EBCHM furnaces in our opinion are:**
**- Refusal of excessive universality of EBCHM furnaces, use of a reasonable set of options on the basis of the careful analysis of the production program planned for new facilities;**
**- Creation of large-capacity EBCHM furnaces with the big annual production capacity;**
**- Reduction of a share of research and development in cost of EBCHM furnaces due to transfer of the most successful and saleable samples to the category of the serial equipment;**
**- Optimum complete set of EBCHM furnaces by the equipment, first of all by electron beam guns, according to planned furnace application.**

**Solving of the above-stated problems also will automatically provide solving of one more defined before problem - simplification of operation and maintenance of the equipment.**

### 3.3. About reduction of metal loss at EBCHM.

It is necessary to consider one more important indicator of production efficiency which directly influences on total cost of titanium ingot. It is metal loss at melting.

The extract from report of BAO Ti Group Ltd. at 11th World Conference on Titanium:
«The high vacuum degree and high energy density make metal losses greater. Metal losses reach about 3-8 % generally ...».

Such values of metal loss twice struggle against EBCHM efficiency of the titanium. First, it is high cost of the metal which goes like a shot from a gun in literal sense. Secondly, it is a condensate on walls of the melting chamber and enormous loading on electron beam guns and pumps. At melting of 12-ton ingot even 3 % correspond with 360 kg from which not less than 250 kg remains on walls of chambers after each melting. And if is it not 3, but 6 %? And if in EBCHM furnaces is it used slide gates between the melting chamber, the chamber of an ingot and loading devices for charge for the purpose of running continuous melting of several ingots? What to do with these tons of the titanium hanging on walls?
From own experience we know that it is possible to reach smaller loss.

**Thus one more problem for technologists and designers is the working out of melting techniques which allow reducing of metal loss in technological process.**

## 4. Destruction of stereotypes - future or reality?

However what is customers' vision of weakness of EBCHM technologies considered in the report - real problems or stereotypes?
After all the listed doubts are not new, they accompany EBCHM technologies long years.
About two years ago friends-partners from three companies – "Design Office of Vacuum Metallurgical Equipment, Ltd.", «Strategy BM Ltd » and JSC "SPA "Chervona Hvilya» - have decided to analyze all these problems by integrated approach and to create really convenient and effective EBCHM furnace. Together we have formed team which represents an alloy of experience of designing, experience of manufacture and experience of management. We were sure that synergetic effect of such cooperation will allow finally to approach for solving of EBCHM problems in system type, with the account not only features of EBCHM furnace operation, but also with the account of all stages of technological process of manufacture of titanium ingots/slabs.
The main points of the draft proposal on working out of the new furnace were:

- Simplicity and reliability of construction;
- Simplicity and reliability of control;
- Simplicity in operation and maintenance;
- Low metal loss at melting - no more than 2 %;
- The low production cost;
- High quality of finished products;
- The general high efficiency of all production cycle.

Guarantee of success in achievement of this aim should become on the one hand all the best checked up by time and own experience technical solutions and on the other hand the newest engineering ideas and the advanced achievements in hardware and software.
As result it has been developed EBCHM furnace of new generation BMO 3000/01 with following basic characteristics:

| | |
|---|---|
| *the maximum weight of ingot/slab, tons | 12 |
| *the maximum cross-section of slab, mm | 500 × 1325 |
| *the maximum diameter of ingot, mm | 1100 |
| *the maximum length of ingot/slab, mm | 4000 |
| *the installed power of the electron beam heating unit, kW (7 gas-discharge electron beam guns of type GGE 450) | 3150 |
| *annual production capacity, tons | 2800 |

As you can see there is nothing outstanding in these characteristics. After all we did not have a purpose as a result of this work to set up any records at any cost or to show to the world any new super-possibilities. Simply we wished to show that **EBCHM is a simple and accessible technology of melting.**

By present time practically all units of EBCHM furnace BMO 3000/01 are already made and we have begun the preparatory work for it assembly on the production area of electron beam metallurgy plant of Company «Strategy BM Ltd» in Kiev. In the fourth quarter of this year the furnace will be put into operation.
It is necessary to note the invaluable contribution of Research-and-Production Enterprise "FOTON" (Kiev) into works on creation of computerized control system of EBCHM furnace BMO 3000/01. Also engineers of Physical and Technical Institute of Metals and Alloys of Ukrainian National Academy of Science took part in works on the furnace.

## 5. Increase of effectiveness of EBCHM - a complex problem.

And, at last, we still would like to pay attention to the following.
**We emphasized that our common purpose is reduction of total production cost of titanium products i.e. at all processing stages - from raw materials to finished product. So we are sure that also experts in deformation processing could take part in increasing of effectiveness of EBCHM in titanium manufacture. Only they can solve problems of working out of special operating practices of forging, rolling, pressing, drawing etc. of the ingots/slabs received by EBCHM.**
So it is historically developed that all these operating practices have been developed for VAR ingots which have rather different structure and properties. At the same time our experience says that EBCHM metal has its own specific characters which on the one hand can open new possibilities and on the other hand the cases of their ignoring can lead to defects at stages of deformation processing.
For example, still in the early 1990th it was held the joint works of Paton Welding Institute, Kiev, and State Tube Institute, Dnepropetrovsk, on production of seamless thin-walled pipes directly from ingot Ø152 mm passing a stage of forging and pressing. The received results have shown full conformity of the received pipes to requirements of standards by all controllable parameters [5].
Other example: forging of even not alloyed titanium of grades BT1-0 and Grade 2 at facilities of Sumy Frunze Engineering Plant at first led to certain problems in spite of considerable experience of staff in processing of titanium. It became possible to solve these problems only after inviting to cooperation of appropriate expert who reconsidered forging operating practices which were applied on this enterprise before.
One more example: during commercial negotiations about sales of the titanium slabs received by EBCHM we have chances to hear doubts concerning possibility of reception of qualitative rolled coils from such slabs without a preliminary forging stage.

**Only metallurgists and technologists of the further deformation processing stages can make correct conclusions on expediency of working out of special operating practices for EBCHM metal which are distinct from the traditional.**
We consider that more careful approach to this question will be useful in any case.

## 6. CONCLUSIONS:

· **Predicted increase of civil application of the titanium, the general considerable growth of consumption of the titanium and connected with this fact increase of quantity of scrap and waste will require the further expansion of application of EBCHM for manufacture of titanium ingots.**

· **The key condition for increase of demand on EBCHM furnaces is reduction of their cost. It can be achieved by exact statement of problems to designers, an optimum complete set of furnaces by the equipment and options, transfer of EBCHM furnaces in a category of the serial and large-capacity equipment.**

· **The major condition for promotion of EBCHM technologies on the new markets is ensuring to the customer not only deliveries of EBCHM furnace and its commissioning but also providing of complex services in the creation of electron beam melting manufacture of the titanium, including high-grade schooling of the personnel and transfer of the developed and checked up by time melting technologies.**

· **The designer and technologists during working out of the EBCHM equipment and technologies should think first of all about simplification of techniques of operation of the equipment and increase of automation of melting processes in order to lower requirements to qualification of the personnel and to reduce influence of the human factor on quality of production.**

· **Effectiveness of the deformation processing of the titanium ingots received by EBCHM can be increased under condition of working out of special operating practices of deformation by corresponding experts.**

· **The general problem for all who is engaged in EBCHM development is the increase of the accessible and clear information about this technology, destruction of the developed stereotypes which delay wide expansion of EBCHM technologies in the industry.**

**Electron beam melting technologies are conventional and open to general use technologies of metallurgy!**

**The titanium and titanium alloys - conventional and open to general use industrial metals!**

## **References**:


1. Kondratii N.P., Vasjura V. N. Perspective directions of activity of "Design Office of Vacuum Metalurgical Equipment, Ltd." in the field of electron beam metallurgy.//Titan.-2006, ³1 (18), pp.29-30.

2. Kostenko V. I, Pap P.A., Kalinjuk A.N., Kovalchuk D.V., Kondratii N.P., Chernyavsky V.B//Advances in Elektrometallurgy.-2007, №3 (88), pp.24-25.

3. Xiaojun Wang, Zhanqian Chen, Feng Chen, Wei Zou, Jing Jiang, Qi Gao. "The Electron Beam Cold Hearth Melting Technology": Proc. Of the 11th World Conf. on Titanium, Kyoto, Japan, 3-7 June 2007. - Vol.1 - pp. 185-188.

4. Tikhonovskij A.L., Tur A.A., Tunik A.V. "Electron beam melting of the spongy titanium - a new method of manufacture of titanium alloys and slabs.//Problems of Special Elektrometallurgy.-1993, №10 (1), pp.66-70.

5. Tikhonovskij A.L., Lashuk N.K., Tur A.A., Tunik A.V., Geiko I.K. "Electron beam melting of the spongy titan with use of high-voltage glow discharge guns //Problems of Special Elektrometallurgy.-1993, №10 (1), pp.66-70.