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Theoretical justification and application of resource-saving technologies of electrosmelting and continuous casting billets

Specialty: 3312.01 - “Technology of materials”

Field of science: Technics

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ABSTRACT

Of Dissertation presented to get the scientific degree of
Doctor of Sciences

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The dissertation work has been conducted at the Department “Metallurgy and metallurgical science” of Azerbaijan Technical University.

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GENERAL CHARACTERISTICS OF WORK

Actuality of theme and its development level. Metallurgy complex constitutes the basic of heavy industry in each country. Without metal production it is impossible to product heavy and material-capacity machines, equipment and constructions. In comparison of non-metallic materials, provision of high solidness, work ability and reliability via metals and alloys always make actual their use. Amongst metals and alloys the mostly applied ones are black metal and alloys, including steels. Organization of steel production on the basis of innovative technologies in our country requires conduction of large scientific research along extension of raw material base.

So, based on this approach, with the initiative of the national leader of the Azerbaijan people Heydar Aliyev “Baku Steel Company” LLC was operated in Baku city in 2000. Company works with 50 tonnes electric arc furnace of Siemens firm and produces various fittings for construction sector. At first periods company was working by only using metal wastes with technology of reprocessing.

However at late periods “Baku Steel Company” LLC pays special attention to the application of innovative technologies. For example, choice of charge components by sorting and application of continuous loading technology of charge to the furnace, organization of ferroalloys’ production, their use in enterprise, smelting of steel with the use of physical effects of electrotechnics and electrometallurgy on the basis of recent achievements of electric metallurgy, deoxygenization, forming continuous casting billets from it include priority directions of the company.

Generally during the late 25-30 years application of innovative technologies in electrometallurgy, especially electrosteelsmelting gained the great scope. A number of new smelting aggregates, continuous casting plants of off-furnace reprocession and steel, evacuation systems of smelting shops and electrosmelting units with raw materials, smelting products established, utilized in industry scale and applied, too. Casting - rolling complexes used and applied, new electrometallurgy mini – factories operate and new ones are built. They provide finished products for the needs of construction and

engineering. Thus, electrometallurgical production is at the stage of equipment modernization and technical re-equipment.

Solution of all these mentioned problems makes “Baku Steel Company” LLC- flagman of metallurgy in our country responsible. This company not only provides itself with qualitative charge materials, but also keeps the problem of correct and continuous improving of equipment for production of these materials, casting and furnace equipment for electrosteelsmelting, equipment for reproduction of off-furnace steel, equipment for cooling native ores/bullions, machines for molds’ cleaning and lubricating, furnace and casting equipment of ferroalloys productions.

Nowadays “Baku Steel Company” LLC has directed scientific-technological directions into the problem of reprocessing of Dashkesen ore and production of its metalized irons in order to itself and other metallurgical factories and shops of the state.

It is clear that among these numerous problems development of theoretical basics of power-saving electrosteelsmelting process is a wide scientific capacity. At the same time the problem of metal volume from finished steel and production of convenient billets in terms of geometry is of important significance. Known that billets acquired by continuous casting turn into intermediary or final product by rolling mainly at next stage. Of these products continuous casting pipe billets from the view of rolling technology demand the implementation of more massive scientific-research works. Because mostly this field is the least studied field in electrometallurgical steel production. For reliable and effective application of this technology development of newly constructed rolling couplings has necessary significance.

Solution of all these complex scientific – technological problems determines research direction of dissertation work and undoubtedly implementation of these researches will give a big thrust to the development electrometallurgy in the state.

Purpose and duties of study work consists of studying methods of power-saving processes in electrosteel production, physical effect methods in continuous casting process, improving of billet-rolling

couplings and developing of measures for rejecting the emerged defects.

In order to achieve this purpose following issues have been solved:

1. Studying mutual effects of thermodynamical parameters in steel electrometallurgy, enlargening available clauses in this field and assessing equilibrium coefficients of going reactions;

2. Developing of new metallurgical processes, such as physical effect methods, as well as electromagnet mixing, vibrant reprocesson, steel degassing in continuous casting;

3. Studying of billets' cooling speed in continuous casting machine and setting algorithm identifying cooling ability of the billets;

4. Researching utilization opportunities from metalized iron in alloy in electro arc furnace and by this purpose, offering the setting of magnet clusters in the walls of smelting furnace;

5. Developing of offers for application of vacuumator unit in casting of metal jet to increase continuous casting billet's quality;

6. Developing of their new production technology by increasing the quality of metal of digging pipes used in oil and gaz extraction from continuous casting billets;

7. Developing of production technology of continuous casting pipe billets at available continuous cast machine of "Baku Steel Company" LLC (R – 10.2) ;

8. Increasing the economic efficiency of rolling process, offering their new bimetallic construction and materials and application of production technology for the purpose of increasing the quality of rolling couplings;

9. Developing of their thermic strengthening technology for the purpose of increasing quality of metal of couplings of protective pipes produced at "Baku Steel Company" LLC;

10. Studying of possible defects happened in continuous casting billets, analysis, detecting of their appearance causes and developing of recommendations to prevent;

11. Taking technological, organizational and economic measures for application of conducted researches on production and determining technical-economic efficiency of these developments.

Research methods. Theoretical researches have been conducted on the basis of scientific basics of the technology of materials, material studying, physical-chemistry, metallography and radiography.

Relevancy of theoretical results has been approved by experiments in the condition of laboratory and production. Experimental researches have been carried out using the modern technical equipment (electric arc furnace, continuous casting machine, electromagnetic mixer, processing device with vibration) and tools (fine research devices).

Results of processing experimental data have been obtained with mathematical statistical methods evaluating on Student Criteria.

Scientific developments and technical solutions used in the dissertation targeted for energy saving resources and increasing of quality characteristics and exactness of the produced product have commonly been directed at creation of new technologies, ways, processes, methodologies, and units, plants. The results of this dissertation can be applied not only in metallurgical and machinery enterprises of the Republic of Azerbaijan, but also in corresponding enterprises of CIS states and other foreign states.

Main clauses presented to defending thesis:

1. Features of electrosteelmelting thermodynamical reasoning;
2. Magnetic mixing of fluid steel in continuous casting in crystallizer and reprocessing with vibration;
3. Degassing of fluid steel with utilization of special camera with profiled nozzle in continuous cast;
4. New construction of deoxygenizing– alloying firm;
5. Bimetallic shaft from new material with new construction and working part;
6. Reconstructed variant of available continuous cast machine for production of pipe billets and new R-10.2 PFTM and VD;
7. Classification of defects in the production of “Electrosteelmelting continuous cast billets”, ways of their elimination. Developed recommendations in this field.

Scientific innovation of research. Clauses available in this field have been concise and expanded, thermodynamic assessment of processes going in electrosteel alloy by using metal wastes and

metalized irons. Calculation formulas of isobar-isothermic potential of the system in re-electroalloying of metal wastes. Intereffect schemes of additives have been developed with iron oxides in repetitive metal charge.

Equilibrium coefficients of reactions of oxidation processes of slagforming component of electrometal bath determined. Formula to identify formation intensity of emerged new phases has been offered. Removal reactions of phosphorus in fluid metal bath and their equilibrium coefficients have been assessed. In alloys of FeS – MnS graphics have been illustrated depending on manganese concentration in different temperatures of sulphur share communicated with manganese. Functional dependence formula of desulphurization speed of steel for electrosteelsmelting process.

Using repetitive metals in electrosteelsmelting impacts of physical effect methods on fluid metal and effects of degassing process clarified and evaluated. In production of continuous casting billets electromagnetic mixing of fluid metal in crystallizer, reposition with vibration and interconnection of steel degassing with its quality determined.

Theoretical and experimental summary of discipline obtained by the result of study of intereffective features of tool has been implemented in pipes and other various billets with reposition through the pressure. On the basis of mathematical modelization limiting factors of some processes creation of effective resource saving production technologies of steel billets with continuous casting and electrosteelsmelting, important scientific-technical problem of improvement and application have been solved.

Based on the demands of market economy for obtaining different sized pipe billets reconstruction of scientifically reasoned available PFTM has been made at “Baku Steel Company” LLC and imaginations in this field have been enlarged. Therefore new contribution has been done into production technology of pipes with continuous casting method.

To increase rolling process's effectiveness of continuous cast billets and raise the quality of finished product newly constructed bimetallic shaft offered and its working part has been offered to be

made of internal steel, and surface of new composition of highly solid cast iron. Patent of the Azerbaijan Republic has been given to material of offered bimetallic shaft(i 2017 0045).

To increase quality of coupling obtained from continuous cast billets their scientific reasoned thermic strengthening technology has been developed. For tabbing of billet, the technology consists of its induction heating, cooling in water, high temperature tabreduction. In the result of thermic strengthening lessening of metal structure, increasing of solidness characteristics (σ_d , σ_{ax}), maintaining of flexibility features (σ , ψ) occur.

With the purpose of increasing effectiveness of production process “Electrosteelsmelting - continuous casting billets” metallurgical, structural, mechanical defects appeared in billets have been detected, reasons of defects analyzed and preventive ways been displayed. This approach established scientific reasoned presumption to application of more perfect metallurgical technology.

Theoretical and practical significance of study. On the basis of application of processes “Electosteelsmelting - continuous casting billets” effective resource saving production technologies developed and applied within the condition of “Baku Steel Company” LLC. These technologies have been aimed at improving chemical composition, structure and features of smelted metal, increasing the quality of final product, intensifying of production processes, reducing of cost price of production, making ecological state better and decreasing of capital investment.

2. For steelsmelting utilization of metallized rolls in the selection of charge composition and determination of parameters providing the rise in intensity of melting as a result.

3. In continuous casting process development of physical impact metals, as well as rolled electromagnetic mixer, processing devices with vibration and their application has been realized.

4. Regulation of steel chemical content and provision of oxygenizing liquid metal, special deoxygenizing-alloying nozzle/tuyere and reprocessing.

5. New bimetal rolling shafts developed to increase the quality and speed of rolling process.

6. Thermal strengthening process developed to improve the structure and character of pipe-billets obtained by continuous casting technology after rolling.

7. Developed the classification of defects to be emerged in billets obtained through continuous casting process, their reasons identified and recommendations for preventive events made up.

8. Developed the algorithm for cooling of billet in continuous casting machine, and impact of cooling speed on plastical deformation of husk appeared in billet.

9. Algorithm of rasional cut of billet produced by continuous casting technology.

10. Results of studies conducted in dissertation have been applied in Azerbaijan metallurgy industry, including in the production of fittings and other various rolling products used in construction structure at “Baku Steel Company” LLC and as well production of pipes used in oil and gas extraction. Application of developed production technologies allowed to acquire economic efficiency in the size of 1,0 million manats per year at “Baku Steel Company” LLC.

Application of research’s results. Scientific developments and technical solutions used in the dissertation targeted for energy saving resources and increasing of quality characteristics and exactness of the produced product have commonly been directed at creation of new technologies, ways, processes, methodologies, and units, plants. The results of this dissertation can be applied not only in metallurgical and machinery enterprises of the Republic of Azerbaijan, but also in corresponding enterprises of CIS states and other foreign states.

Approbation and application of the work. Materials of the dissertation reported and discussed in the following conferences and seminars, also liked.

International scientific-technical and scientific-practical conferences:

1.V International “Scientific – practical conference” “Modern problems of physics of metals” devoted to 80th anniversary of Pro. T.M. Panahov, Baku, 10 – 11 June, 2016.

2. “Problems of metallurgy and material studying ” II International conference, Baku, 2017, 28 – 30 November.

3. International conference of the week of metals in Moscow. Proceedings of conferences VNIIMETMASH, 2017, 2018.

4. Conference of the International Union of Metallurgical Equipment Manufacturers, city Moscow, 2018.

Republic scientific-technical conferences:

1. Scientific-technical conference on "Education - research - production mechanism setting", Baku, 2018, April 4-5.

2. Scientific seminars of Department "Metallurgy and metallurgical science" of ATU, 2017 – 2019.

3. Scientific seminar of Department "Technology of materials" of ATU, 2019.

4. Scientific seminar of Department "Material studying and machinery" ASOIU, 2019.

41 scientific works on dissertation work, including 1 monograph, 1 patent, 1 grant competition winner's materials, 24 articles, 14 abstracts and materials of conference materials were published. 7 out of 24 articles and 14 abstracts and materials of 14 conference reports, 1 co-author, 15 articles in 41 scientific works published in periodicals, included in the International Summary and Indexing Systems (databases) recommended by the Supreme Attestation Commission, on the results of national or international scientific events 21 works were published in the republic, 20 - abroad.

The results of the dissertation are reflected in the State Register of Scientific Research of Baku Steel Company LLC and Azerbaijan Technical University. The author participated in these reports as an executor.

The new construction and material of bimetal rolling mills used in rolling production has been used in the distribution of reinforcing steels and seamless pipe steels in Baku Steel Company LLC. As a result of the application of these shafts, the company achieves an economic benefit of 1.0 million manat per year.

Materials presented in dissertation work are used in bachelor's and master's degrees at Azerbaijan Technical University and Azerbaijan State University of Industry, in the implementation of course projects and course work, as well as graduation theses and master's dissertations.

Name of organization the dissertation work is performed.

The dissertation work has been carried out at the "Metallurgy and Metallurgical science" department of Azerbaijan Technical University.

Personal contribution of applicant in the conducted studies:

The applicant indicated the relevance of the research, the main purpose and objectives, to determine the directions of research and their implementation, theoretical research, the construction of physical models were solved independently and the results were processed, systematized and discussed. In general, the submitted dissertation is a complete scientific research work written by the applicant personally, covering a set of theoretical, scientific and practical provisions and results.

Common volume of dissertation with sign by noting the volume of structural units of dissertation in separate. The dissertation consists of an introduction, six chapters, a list of 258 references and appendices. The work is reflected in 304 pages of computer text, including 30 tables and 142 figures. The main part of the work consists of a total of 290,333 characters, 19708 characters at the entrance, 62938 in Chapter 1, 48678 in Chapter 2, 77620 in Chapter 3, 27472 in Chapter 4, 39143 in Chapter 5, 68612 in Chapter 6, and the total results are 9100 has a number of signs.

Degree of publishment: Main results of the dissertation obtained by the author and published in sufficiently full 41 articles and conference materials.

MAIN CONTENT OF THE WORK

In introduction actuality of dissertation work theme is reasoned and the degree of development is characterized, the goals and objectives of the research are clearly stated, research methods are described, the main provisions are defended, the scientific novelty of the research is determined, the theoretical and practical significance of the research is determined, the approbation and application, the name of the dissertation organization, the volume of structural divisions in sequence, the total volume of the dissertation is indicated by a sign.

In 1st Chapter analysis of available literature data made in electrosteelsmelting field.

Literature review in electrosteelsmelting field shows that leading firms engaging in this production pays their major attention to increase the quality of product by the application of effective methods of metalsmelting. Practice and experience of “Baku Steel Company” LLC (BSC) which is the flagman of Azerbaijani metallurgy is a dignified contribution to world metallurgy in this field.

Works done BSC in electrosteelsmelting field is based on the application of innovative technologies in the field. The company besides using metal wastes utilizes the metalized irons in metal charges. By using intermediate furnace- scoop in electrosmelting effectively applies purification, degassing of steel, and delivery processes of chemical composition to the necessary level.

In entire world ironized balls(DRI) are widely used as products of restoration of iron from direct ore. Raw material got by this way DRI and steel melted on its basis meet high demands of machinery. Demand on high quality steels remain more harshly. Metal obtained based on metal wastes in many times circulation has not got these qualities.

Sources of steel creaks-main material used in smelting of steel in the world and wastes are endangering. Thus, with this purpose use of alternative materials increasingly rises. This materials include metalized balls DRI and hot briquetted iron HBI.

The initial results of trial alloys conducted at steelsmelting factory of “Baku Steel Company” LLC show that use of ironized balls accounting 25-30% of its mass in the composition of charge materials not changing technological process of melting makes possible the production of steel and products responding to standard.

Role of melting process of electrosteelsmelting at modern development stage has been analyzed. Noted that increasing achievements of electrometallurgy, innovations in steel’s massive product occur in the hub of electrotechnics and metallurgy allowing the implementation of electrometallurgy. This, new scientific-technical developments and their implementation, is connected to the passage of creation of electroarc furnaces (EAF) and energy saving regymes

of smelting. Because these regimes are unseparated part of modern electrosteelsmelting technology.

Innovative solutions in electroarc furnace field consider energy technology nature of electrosmelting and directed into increasing of second tension of furnace transformers and sustainability of general resistance (impedence) and burning stability of arc in increased tensions and decreased working currents.

Principal opportunities of two schemes of steel casting studied and identified that it is possible to obtain this or other type sizes of ready rolling on ingot-finished rolling dispersed widely and/or continuous cast scheme.

But in the production of steel ingot continuous cast name compared to casting into metal cast has significant advantages:

- a) more homogenous for its chemical composition;
- b) productivity of useful product harshly rises;
- c) cost price of metallurgical reprocessing decreases (heating methods, blumes, machines making billets, mechanical and electrotechnical equipment cancelled).

Realization of other effective metallurgical technologies are very significant to increase steel quality in electrosteelsmelting. These includes electromagnetic mixing of steel in crystallizer, reprocessing with vibration and also steel degassing in cast scoop. Solution of these problems and other issues emerged in reprocessing of processes with pressure on the basis of innovative approach is main scientific-study direction of this dissertation.

In 2nd Chapter thermodynamical features of increasing efficiency of metallurgical processes in electrsteelsmelting have been analyzed. In steelsmelting calculation formulas of isobar-isothermal potential of the system described. System' thermodynamical assessment of elements including into the charge in separate not creating phase case has been made. In creation of some metals' oxydes changing of isobar-isothermal potentials have been described [39]¹.

¹ Thermodynamic features of increasing the efficiency of metallurgical processes during electric steel melting. R.I.Karimov

Additives in steel with iron oxides and their interrelation schemes have been described. Some information about thermodynamics of reactions having very important significance in steel metallurgy has been interpreted. Here at the border with gas phase especially may be noted the oxidation of iron, without not strong oxidation of iron removal cases of some elements, opportunities of protection of metal bath components.

Analyzed and estimated purification processes by oxidizing in electrosteelmelting. Noted that carbon oxidation in purification in electroarc furnace is of importance significance. Decomposition of metal from CO-nun metal is one of intensive mixing factors of bath. In this case in bath cases of mass and heat composition, flotation of combinations in metal after charge smelting happens, achieved partial removal of hydrogen and nitrogen [38]².

Connection diagram of carbon and oxygen concentrations in metal bath in smelting in electric arc furnace described, calculation formula of appeared CO gas pressure has been given. Changing scheme of decomposition pressure of foreign pressure and CO has been graphically expressed. Mentioned that although kinetic interrelation difficulties of carbon in bath it is considered as the main element which regulates metal oxidation in smelting process and regulates oxidation opportunity in other elements of its internal volume .

Oxidation processes of slagforming components of electrometal bath has been analyzed. Formula identifying creation intensity of newly formed phase has been suggested. It is mentioned that creation intensity of new phase in homogenous fluid metal (oxidation products of slagforming components) is more higher than in carbon oxidation and CO creation. Analyzed and estimated oxidation processes of silicon and manganese and some information about thermodynamics of reactions happening on the border of their metal-slag.

Usually in electrosteelmelting chemical elements and also their oxides do not form separate phase, they are including into composi -

² Features of removal of Phosphorus and sulfur from Remelting stock during electric arc melting of Steel. R.I.Karimov

tion of metal and oxide solutions.

In these conditions it is possible to feature oxydation process with the following equation.

$$m[R] + n2O_2 = (R_m O_n); \quad \Delta G_3^0 = RT \ln(a_R^m \cdot P_{O_2}^{n/2} / a_{R_m O_n}) = RT \ln\left\{ [R]^m P_{O_2}^{n/2} / (R_m O_n) \right\} \quad (1)$$

ΔG_3^0 quantity differs from ΔG_1^0 quantity as only change quantity of isobar-isothermical potential of ΔG_{II} solution in slag of $R_m O_n$ oxide and $\Delta G_{,solution}$ in metal of R element: $\Delta G_3^0 = \Delta G_1^0 - \Delta G_I + \Delta G_{II}$.

Interrelation of additives in steel with iron oxides can be written in the formula below:

$$m(R) + n(FeO) = (R_m O_n) + nFe_m;$$

$$\Delta G_4^0 = RT \ln \frac{a_R^m a_{FeO}^n}{a_{R_m O_n}} \approx RT \ln \frac{[R]^m (FeO)^n}{(R_m O_n)} \quad (2)$$

Oxydation of metal additives can also happen under the impact of solved oxygen on the given formula:

$$m[R] + n[O] = (R_m O_n); \quad \Delta G_5^0 = RT \ln \frac{a^{\frac{m}{R}} a_0^n}{a_{R_m O_n}}; \quad (3)$$

as in previous cases in small concentrations of [R] and [O] and in $\gamma \approx 1$ possible to use the following equation.

$$\Delta G_5^0 \approx RT \ln \frac{[R]^m [O]^n}{(R_m O_n)}. \quad (4)$$

It may seem obvious by looking into equations for $\Delta G_3^0, \Delta G_4^0$ and ΔG_5^0 , negative amounts of these quantities not only identified with the ratio of nature of R element (in other words willing of R element to oxygen), but also the ratio of $O_{R_m O_n}$ assets of its oxide (or in oxidation products) in a_R element in metal and slag fluid. Thus, in a multi component solution, in a charge consisting of metal wastes, irons, cast iron, ferroalloys and slag formators applicable condition of a preferred element may change for the favor of the other element.

This can happen both because of temperature, and concentration changes.

Phosphorus removal reactions have been given in fluid metal bath and their equilibrium coefficients been assessed. Mentioned that in creation of phosphorus anhydride depending on concentration of SiO_2 in slag stratification state may happen in it. For this purpose stratification fields of slags to be drawn in different concentrations of SiO_2 special diagram has been displayed. In dependence of slag grounding distribution coefficient of phosphorus between metal and slag has been identified. Impact of this slag composition on this coefficient has been evaluated.

Speed of phosphorus removal is function of a number of variables in basic steel smelting processes :

$$V_p = f \left\{ [P], \frac{(\text{CaO})_a}{(\text{FeO})}, \frac{(\text{CaO})_a}{(\text{SiO})_2 + (\text{P}_2\text{O}_5)}, T_v, F \right\}, \quad (5)$$

here $(\text{CaO})_a$ – concentration of active CaO solved in slag alloy (including into solid phase, excluding still non assimilated to phase); T_v – bath temperature; F – interphase surface (slag – metal contact), it itself is function of mixing intensivity of metal and slag.

Of all mentioned variables correlation dependence of V_p smelting is so different for different equipment and methods that it becomes impossible setting of more precise general order.

Removal processes of sulphur from fluid been explored and imaginations in this field been enlarged. In $\text{FeS} - \text{MnS}$ alloys dependence graphics of share of sulphur communicated with manganese from concentration of manganese in different temperatures illustrated. Dependence graphics of grounding more than amount (FeO) of grounding of slag of distribution coefficient of sulphur between slag and metal in slags in different excess concentrations described. Dependence graphics of distribution coefficient of sulphur between slag and metal from the composition of

the slag presented. Functional dependence formula of desulphurization speed for electrosteelsmelting process has been described [38]³.

Main process identifying behaviour of sulphur in electroarc furnace is its distribution between metal and slag and passage to slag.

According to ion theory of slags' structure characterizing the real nature of process, distribution coefficient of sulphur between metal and relatively less grounded slag goes on the following reaction: $Fe_{m+}[S]=Fe^{2+}+S^{2-}$. In these conditions $n_s = (S^{2-})/[S] = K_s / (Fe^{2+})$, in a word, distribution coefficient of sulphur between metal and slag decreases with rise of ironed slag [35]⁴.

In highly grounded slags removal of sulphur from metal goes through the reaction of ion exchange: $[S]+O^{2-}=S^{2-}+[O]$. In this case distribution coefficient of sulphur organizes $n_s'' = (S^{2-})/[S] = K_s'' (O^{2-})/[O]$, in a word, volume of slag in relative to sulphur is featured by grounding of slag, (O^{2-}), but however distribution coefficient of sulphur decreases with increasing of metal oxydation.

In 3rd Chapter using hot briquetted irons(HBI) in electrosteelsmelting increasing of smelting intensivity has been explored. Using hot briquetted irons(HBI) depending on loading sequence of metal charge components to the furnace usable metal productivity has been determined. Obtained results show that metal productivity of steel alloy got from charges having hot briquetted irons(HBI) becomes approximate 1,5% less than metal productivity got from the used charge of full metal wastes. This is related with existence of non-metallic and/or other combinations in the same irons [34]⁵, [36]⁶.

³ Features of removal of Phosphorus and sulfur from Remelting stock during electric arc melting of Steel. R.İ.Karimov

⁴ An impact of the ladle lining on the refining of reinforced steel when blowing with powders. R.İ.Karimov, M.B.Babanlı, A.T.Bayramov

⁵ Improving steel melting intensity in the process of electro-smelting from waste and pellets (HBI). R.İ.Karimov

⁶ Использование металлизированного сырья при электросталеплавильном производстве. Р.И.Керимов, С.И.Шахов

Rule of loading of charge materials in a comparative form has been displayed in Table 1. Using from HBI chemical composition of alloy and mechanical features during rolling are presented in Table 2.

Table 1

The sequence of loading charge to the furnace using hot briquetted iron (HBI) in a metallic charge

№	Melting №	Tub 1	Tub 2	Tub 3	Cast iron scrap	Hot briquetted iron (HBI)	Total furnace load (tons)	Yield of usable metal (tons)
1	85392	29,4	19,2	9,6	5,0	15,4	58,2	52,7
2	85393	29,0	20,4	8,7	5,3	15,3	58,1	52,5
3	85394	29,2	19,3	10,0	5,4	15,6	58,5	52,7
The sequence of loading charge to the furnace using from metallic charge								
№	Melting №	Tub 1	Tub 2	Tub 3	Cast iron scrap	Hot briquetted iron (HBI)	Total furnace load (tons)	Yield of usable metal (tons)
1	85628	22,0	16,8	11,4	8,2	–	58,4	56,1
2	85629	23,2	17,0	10,5	9,5	–	60,2	54,6
3	85630	22,6	16,8	11,2	9,0	–	59,6	52,4

Features of melting technological process consist of the followings [15]⁷:

- Loading of HBI must be done after fluid metal formation in smelting bath;
- Continuous loading of HBI must be consistent with power magnitude given to furnace;
- Stage of oxydation- decarbanozation with the stage of melting should be done on time;
- As the amount of sulphur and phosphorus is little and melting texnological process simplifies in charge.

⁷ Baku Steel Company MMC-də Elektrikqövs sobasında isti briketlənmiş (HBI) istifadə etməklə əritmə intensivliyinin artırılması və prosesin təhlili. R.İ.Kərimov, F.T.Quliyev

Characteristics of degassing process of steel in continuous casting process have been explored. Identified that if not enough steel degassing structural defects after crystallization occur, these defects reveal themselves as flockens and cracks in structure. Mentioned that it is possible to make degassing process with argon, nitrogen and even with compressed air. The highest results have been possible in degassing of fluid steel with argone. In this case it has been observed total amount of oxydes in steel to drop to 80% [36]⁸.

In steel continuous cast impacts of physical methods have been evaluated. For this purpose electromagnetic mixing of fluid and impact of vibration explored. For ball electromagnetic mixing of metal in crystallizer methodology and unit has been developed. According to this method arrow-like ward, arrow-like chemical non-homogeneity, dot-like non-homogeneity, sleeping depth of underpellet bubbles estimated [40]⁹.

Two experimental patterns of BEMM prepared (pic. 1). Before installation of BEMM on PFTM stand trials of electromagnetic mixerconducted for determination of rolling heating extent in different amounts of magnetic fields' induction of energetic parameters (pic.2) and phase current magnitude. Studies shown that charged magnetic wires of stator in normal power of current(420A) become in absorbed situation because of its rolling and not having screen between magnetic wires. Therefore when increasing current power of phase remarkable increase of induction of magnetic field does not happen. Changing of characteristics of magnetic fields of BEMM allows to clarify significantly the calculation methodics of electrodynamics of BEMM considering absorption extent of rolling discrecy and magnetic wire [37]¹⁰.

⁸Использование металлизированного сырья при электростале-плавильном производстве. Р.И.Керимов, С.И.Шахов.

⁹Усовершенствование встроенного электромагнитного перемешивания в кристаллизаторах блюмовых МНЛЗ. Керимов Р.И., Шахов С.И., Вдовин К.Н., Рогачиков Ю.М., Шахов Д.С.

¹⁰ Усовершенствование встроенного электромагнитного перемешивания в кристаллизаторах блюмовых МНЛЗ. Шахов С.И., Керимов Р.И.

Checking of BEMM we carried out in continuous casting of electrosteels marked like Cr3cn, 10cn and others at “Baku Steel Company” LLC.

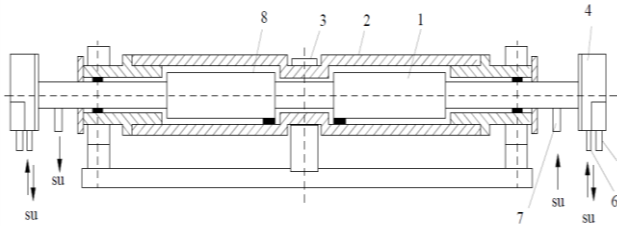
Table 2

Chemical composition and analysis of mechanical features of metal smelted from hot briquetted irons(HBI)

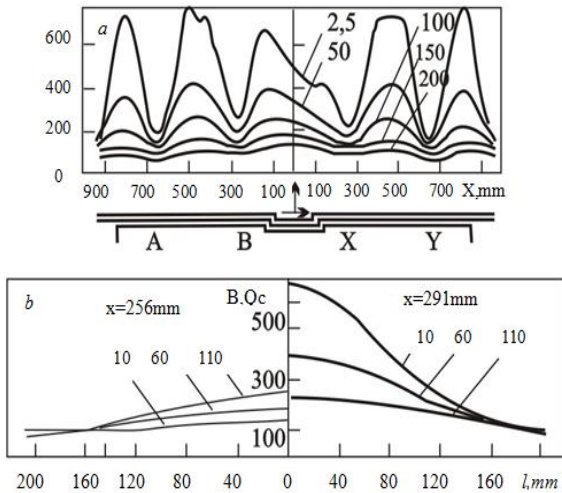
№	Smelting number	Chemical composition %								Mechanical features			Steel mark
		C	Mn	Si	P	S	Cr	Ni	Cu	Flowing extent (Rt), N/mm ²	Extent of solidness (Rm), N/mm ²	Relative extension, δ, %	
1	85392	0,20	0,67	0,22	0,017	0,014	0,08	0,06	0,09	545	630	22,1	A500
2	85393	0,2	0,68	0,25	0,016	0,011	0,06	0,05	0,07	550	645	21,8	A500
3	85394	0,2	0,65	0,21	0,015	0,012	0,08	0,07	0,09	535	640	22,0	A500
Chemical composition of metal smelted by using metallic charge and analysis of mechanical features													
№	Smelting number	Chemical composition %								Mechanical features			Steel mark
		C	Mn	Si	P	S	Cr	Ni	Cu	Flowing extent (Rt), N/mm ²	Extent of solidness (Rm), N/mm ²	Relative extension, δ, %	
1	85628	0,2	0,7	0,26	0,028	0,035	0,22	0,18	0,26	570	665	19,2	A500
2	85629	0,20	0,72	0,27	0,020	0,031	0,23	0,20	0,28	580	672	19,0	A500
3	85630	0,2	0,69	0,27	0,022	0,034	0,28	0,22	0,24	556	652	19,8	A500

When reprocessing steel under the effect of electromagnetic mixing unit in crystallizer in PFTM all indications determining the quality of continuous cast billets significantly become better [17]¹¹.

¹¹ Fasiləsiz tökmə ilə Baku Steel Company MMC-də alınan boru pəstahlarından hazırlanan borularda yaranan qüsurlar və onların aradan qaldırılması yolları. R.İ.Rərimov, F.T.Quliyev A.A.Cəfərova



Picture 1. Intermediate sustainable ball electromagnetic mixer for PFTM: 1 – Stator of BEMM; 2 – pellet of bulwark ball; 3 – intermediate bulwark; 4 – clem hubs; 5 – inserter of rolling feeder; 6 – provision(implementation) of distilled water for cooling rolling; 7 – provision(implementation) of technical water for cooling ball pellet; 8 – rounded gap between stator and ball pellet



Picture 2. Experimental distribution curves of normal organizer of magnetic field induction (b) to width on the middle of reel at different distance (y – numbers in curves, mm) from the surface of ball in $f=4\text{Hz}$ and $J_f=450\text{A}$ and on the middle of teeth ($x=491\text{mm}$) along the length of BEMM (a)

For improving of quality of various billets in crystallizer electromagnetic mixer has been installed. Identified that effectiveness of electromagnetic mixing depends on movement speed of fluid alloy in crystallizer. In this case optimal speed of fluid should not be more than any minimum quantity, only if so condition allows non-metallic combinations to be collected on slag [33]¹².

Distribution of magnetic induction in side cut of crystallizer has been explored. Noted that increase of magnetic field induction along the width of arc is closely related with the existence of significant distribution. For this purpose speeds of fluid alloy flows have been calculated [33]¹³.

In the application of electromagnetic mixing thickness surface layer being clean from non-metallic combinations 2 times rose approximately in comparison to the billets not passing this reprocession. At the same time 1,5÷2 times undershell bubbles amount and score, also maximal diameter of bubbles and their maximal sleeping depth 1,5 – 2 times reduced; except it amount of surface bubbles increased 2,0÷2,5 times. Therefore, in billets's heating before rolling surface bubble practically fully disappeared together with burning.

To reprocess the steel with vibration in crystallizer of PFTM unit's scheme has been developed. Identified that 25-63% increasing of crystallization speed in metal crystallization, compression of central zone of billet happens and liquation decreases significantly [25]¹⁴, [31]¹⁵.

¹² Улучшение качества сортовых заготовок путем применения электромагнитного перемешивания металла. . R.İ.Rərimov, A.T.Bayramov

¹³ Улучшение качества сортовых заготовок путем применения электромагнитного перемешивания металла. . R.İ.Rərimov, A.T.Bayramov

¹⁴ Kristallaşdırıcıda elektropoladların titrəyişlə emalı. R.İ.Rərimov

¹⁵ Опыт внедрения физических методов при внепечной обработке электростали. Р.И.Керимов

Determined that reprocessing of steel with vibration does not reveal itself in the distribution of oxyde and nitride combinations. However the effect of vibration in steel shows itself apparently in changing of the character of sulphid phase. So in comparison of metal not reprocessed with vibration decrease of amount of layer-like sulphides in experimental metal is observed and share of linear sulphid combinations consisting of separate globules [13]¹⁶, [17]¹⁷.

Large layer-like sulphids in vibration of crystallized metal are willing to be dispersed and turning into beard like lines. Determined that by the way of vibration tiny globular share of sulphids in steel reprocessing is becoming less (<2mkm) and in the result of their assumed coalensation share of bulker combinations (2 – 4mkm) rise. Particularly in central zone of billet in steel absorption with gas reduces; amount of oxygen and hydrogen correspondingly reduces among 10 – 20 and 14 – 29% [25]¹⁸.

The most efficient deoxygenization way of metal in terms of technology and economy is complex delivery unit of steel. With this purpose special methodics and unit has been developed to conduct aluminium and ferroalloys' implementation process with deoxygenizing- alloying firms (DAF). For the purpose the most effective construction of deoxygenizing- alloying firms (DAF) and metal's deoxygenizing technology in scoop in steel complex delivery unit (SCDU) has been offered. Totally utilization of DAF's used construction and technology allowed unpleasant product of dispersed metal to decrease from 1,1 to 0,4%.

Application of DAF allowed to the significant reduction of consumption of aluminium in deoxygenizing of steel, rise of assimilation of aluminium in SCDU unit, decrease of contamination

¹⁶ Azkarbonlu və azlegirlənmiş karbonlu poladların sulfid daxilölmələrin deformasiyası və onlara yayama temperaturunun təsirinin tədqiqi. . R.İ.Rərimov ,M.Ç.Hüseynov, F.T.Quliyev, Ə.İ.Həmidova

¹⁷ Fasiləsiz tökmə ilə Baku Steel Company MMC-də alınan boru pəstah-larından hazırlanan borularda yaranan qüsurlar və onların aradan qaldırılma yolları. R.İ.Rərimov, A. A.Cəfərova, F.T.Quliyev.

¹⁸ Kristallaşdırıcıda elektro-poladların titrəyişlə emalı. R.İ.Kərimov.

in oxide combinations, reduction of dispersed metal's defectiveness, significant rise of flexibility and solidity indications of steel.

In PFTM cooling system explored and algorithm determining cooling ability of ingot has been set. Analytical models of cooling regimes with water and water-air system suggested. It has been noted that temperature of surface of cooling ingot is close to linear distribution and from solidness temperature from crystallizer in the exit of billet changes until the temperature of the surface. Calculation parameters of thickness of crystallizer's pellet and billet's length have been identified[32]¹⁹.

Defects in pipe billets obtained with continuous casting and their prevention ways have been analyzed. It has been determined that in the production of pipes with continuous casting, cast process should be conducted in a closed state with the presence of electromagnetic mixing.

Results' analysis during the inspection of couplings prepared from pipes [18]²⁰:

1. Metal pattern cut off from coupling, however the number of alloy nömrəsi A1062 became cast billets with open contour, mark of steel is 45-dir;

2. Couplings made from such steels should be exposed to absolute thermic reprocesson – tabreduction process. Because internal structure of this composed steels remains tense;

3. Creation of central liquation because of not fully completion of carbon liquation appeared in structure and sitting gap depending on speed of start and end temperatures' speeds of crystallization during casting and height of billet;

4. Due to violation of relation in the result of growing granules in the border of the same liquation and sitting gap, non-regular arrangement of crystals internal tensions happen. When pipe disperses as a result of attaching internal tension in wall part of pipe large

¹⁹ Fasiləsiz tökmə maşınlarında pəstahları soyutma sisteminin tədqiqi. R.İ.Kərimov

²⁰ Исследование качества разрушенной муфты обсадной трубы, изготовленной в "Baku Steel Company". Р.И.Керимов, А.А.Джафарова

granulated structure is forming and it allows the violation of relation among them[29]²¹;

5. One of the other main reasons of creation of this defect is metal casting with open contour;

6. Obviously seems from schliff of pattern made from cut coupling that internal cracks have emerged in tension appearing parts (in the ending part of the pattern);

7. Study of eroded (in 3% solution of H₂NO acid in alcohol) and non-eroded microstructure of schliff got from the same pattern confirmed the majority of ferrite structure. And thus this directly causes to carbon liquation;

8. Referring to the result implemented in two different spectrometers it is possible to say that chemical composition of the same A1062 alloy is different. Mainly differentiation of carbon amount noted, because after rolling as a result of burning in thermic furnace it is possible the reduction of carbon. However otherwise its increasing is observed;

9. To provide more qualitative casting of pipe billets in PFTM unit utilization of electromagnetic mixturer can help reducing these defects to 2-3 times;

10. Control should be done over full solution of materials given during the reprocessing of metal in furnace-scoop. For this, mixing of fluid metal with physical ways should be made. With that purpose using from magnetic mixturer can be more effective.

In 4th Chapter structure and features of fitting and pipe steels obtained by application of active degassing in ball electric magnetic mixer and casting scoop. Logical scheme of finished billets design has been compiled and calculation formulas given. In different fields of billets difference in the sizes of first austenite zone constitutes up to 5-6 scores and this difference is eliminated by normalization.

New technologies of pipes production have been developed in continuous cast billets. For preparation of unsewed pipes utilization of continuous cast billets in pipe productions formed and experimental data acquired (table 3).

²¹ Qoruyucu qazma boru poladlarında yaranan qüsurların təhlili. R.İ.Kərimov

Production of highly solid digging pipes with sourced locks has been assimilated on the basis of production studies. Used rolling technology increased the productivity of useful pipes from 75 to 83% (with number) [26]²².

Table 3

Main technical parameters before and after modernization of PFTM-2 of “Baku Steel Company” LLC

Parameter	Before modernization	After modernization
Weight of smelting, T	25	25
Basa radius of PFTM, mm	6000	6005 (6000–130x130mm)
Amount of flows, piece.	2	2
Cycle of smelting, min.	55 – 60	55 – 60
PFT layering dots amount	2	2
Cutting of billets, mm	110x110, 130x130	Ø130, Ø170, Ø190 və Ø220, 130x130
Casting marks of steel	Ordinary less carboned	Pipe less carboned, alloyed
Casting method	With open jet	With close and open və jet
Storage method of metal level in crystallizer	Manual	Automatic
Type of feeder of storage method of metal level in crystallizer	–	Electromagnetic (NPP “Technoap”)
Nominal volume of Promchalov (PK), T	3,9	6,0
Nominal level of metal in P/K, mm	500	600
Water consumption in crystallizer, l/min	1300	1300÷2200

PFTM-2 reconstruction has been realized at “Baku Steel Company” LLC for organization of industrial production of pipe billets with continuous casting in the country. Compared to obtaining new PFTM based on innovative approaches reconstruction of such

²² Fasiləsiz tökülmiş boru pəstahların kompleks istehsal texnologiyasının təkmilləşdirilməsi. R.İ.Kərimov

machines reduces capital expenses invested in obtaining rounded pipe billets 3 – 5 times[11]²³.

In the result of works in various PFTM-2 with base radius R6m production of rounded pipe billets having the diameter Ø130, Ø170, Ø190 and Ø220mm have been assimilated within the condition of “Baku Steel Company” LLC. In the result of conducted studies reconstruction concept had been developed for production of continuous casting pipes of active available PFTM in enterprises [9]²⁴, [8]²⁵.

Problem mostly met by specialists has been “cold” (with plate) braid of intermediate scoop. Before casting this “cold” braid not allowing the first heating requires its extra heating before giving metal to cast. For heating of heatproof metal cast this problem has been solved successfully after application of special designs developed by “Baku Steel Company” LLC and specialists of “VNIIMETMAŞ”.

In reconstructed PFTM–2 for assimilation of casting of round billets serial casting of rounded billets with “open jet” was conducted on 2 January – February 2016. After casting of billets with Ø220mm maximum diameter in such a format on getting rounded billets latest doubts have been eliminated from production opportunities in PFTM-2 [11]²⁶.

In PFTM–2 with “open jet” Ø130, Ø170, Ø190 and Ø220mm diametered and as well with “close jet” Ø170, Ø190 and Ø220mm diametered billets are luckily casted. In casting with “close jet” the

²³ Реконструкция сортово МНЛЗ-2 завода «Baku Steel Company» с целью производства круглых трубных заготовок. Р.И.Керимов, С.И.Шахов.

²⁴ Модернизация действующей сортовой МНЛЗ завода «Baku Steel Company» с целью производства круглых трубных заготовок. С.И.Шахов, А.С.Смоляков, Р.И.Керимов

²⁵ Модернизация действующей сортовой МНЛЗ завода «Baku Steel Company» с целью производства круглых трубных заготовок. С.И.Шахов, Р.И.Керимов

²⁶ Реконструкция сортовой МНЛЗ-2 завода «Baku Steel Company» с целью производства круглых трубных заготовок. С.И.Шахов, Р.И.Керимов

casting from steelcasting scoop to intermediate scoop metal mirror had been carried out via protective pipe with protection of purifying and heatisolating mixtures (pic. 3) [8]²⁷.

In intermediate scoop-cystallizing field casting has been carried out by loading glasses protecting mirror of metal with specially elected crumb. Significant defects of microstructure and billets' surface having the casting diameters of $\varnothing 170$, $\varnothing 190$ and $\varnothing 220$ mm with protection of jet after examination at refrigerator and factory laboratory.

Detection of separate defects in microstructures of continuous cast billets is mainly connected with compulsory extreme healing of metal in intermediate scoop. Now at "Baku Steel Company" LLC this problem has been solved. Except this in correspondence with casting speed on PFTM-2 autoatores have been installed to automatically maintain cooling intensivity of billets [14]²⁸.

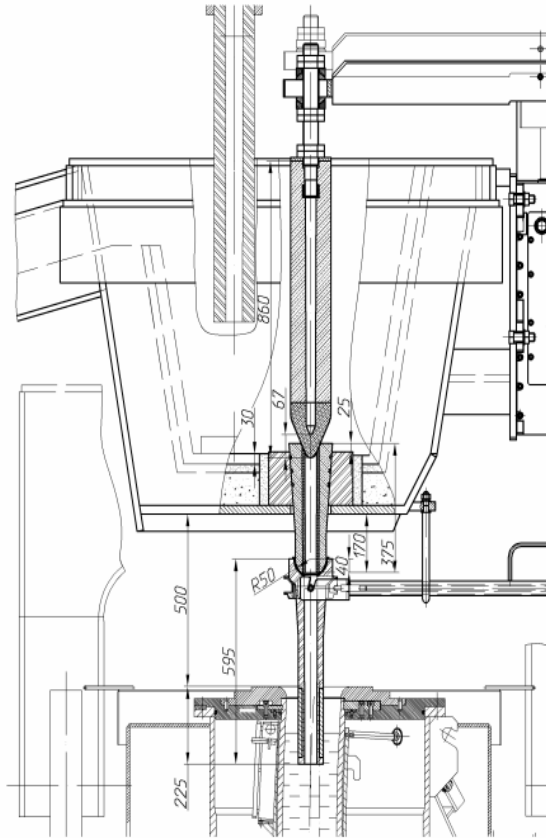
Especially should be noted that implemenatiton of this work never could become possible to realize without high qualification of crew of "Baku Steel Company" LLC and professional reaeraches made by us. All problems evoked during the work process have luckily been solved in a minimum period.

Conducted studies show that purposeability of construction of PFTM and available machine' reconstruction should be solved by the way of concise studying of capital expenditures and providing the reliable work of equipment. "VNİİMETMAŞIN" experience allows to confirm that reconstruction of available PFTM shouldd be evidently solved in that case that, in comparison to getting new yeni PFTM it could reduce capital expenditures 3-5 times [1]²⁹.

²⁷Модернизация действующей сортовой МНЛЗ завода «Baku Steel Company» с целью производства круглых трубных заготовок. С.И.Шахов, Р.И.Керимов

²⁸ Fasiləsiz tökmə ilə Baku Steel Company MMC-də alınan boru pəstahlarından hazırlanan borularda yaranan qüsurlar və onların aradan qaldırılması yolları. R.İ.Kərimov, F.T.Quliyev

²⁹ Modernization of Baku Steel Company metallurgical plant section CBCM for producing round pipe billets. A.S.Smolyakov, S.I.Shakhov.



Picture 3. Scheme of metal feeding in PFTM-2 to cast with “Closed scoop”

In 5th Chapter quality indications of couplings used for interconnection of protective pipes applied in oil and gas extraction have been compared. It has been determined that chemical composition of metal of the produced couplings fully meets the requirement of ГOCT 1050 – 2013, composition of metal the requirements of ГOCT 632 – 80 for the amount of sulphur and phosphorus, and all the parameters of hollows opened in the coupling the requirements of ГOCT 632 – 80.

During the work process crack occurred along the height in coupling and it has been destroyed. Its study of macro and microstructure detected to be “rolling dimple”- metallurgical defect in coupling. Existence of “rolling dimple” and dispersement along the height of coupling requires the solution of two factors.

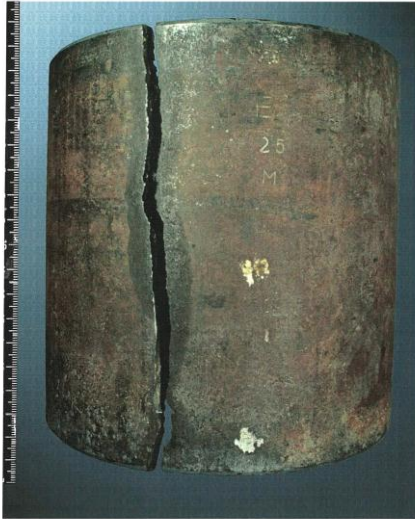
Firstly, there is need to develop new rolling shafts for improving pipes’ rolling process.

Secondly, by thermic strengthening of coupling billets there is need to improve structure and features.

In one of skulls of the dispersed coupling with the length of 190mm presented to the study exists E25M kleymo in external surface at the distance of 35 mm. In pipe exists whole along crack. Whole crack has weakly curved character and disperses throughout alongside(height) direction (picture 4 and 5). Edges of crack along the whole length ~5mm separated, because of it, depicted diameter of the dispersed coupling accounts for 190mm. Profile of cracks’ edges fully exactly repeated on a practical basis. Breaks of response surfaces in whole length of the crack are perpendicularly dispersed on a practical basis to the external surface of coupling, so this is typical for weak shuttle. Cheuron picture on the surface of the crack shows that lengthwise weak crack developed from the side of working combination from the opposite top to marking.

From the field of hearth of assumed the creation of weak crack rolling dimple with opening defect depth metallurgical character ~3mm found. At the distance till 40mm from the edge of crack tracks of rolling dimple in external surface of coupling. In accordance to the requirements of ГOCT632 – 80.P.22 “at external and internal surface of pipe and couplings whip, ward, rolling dimple, layer-like cracks and sand tracks...” must not become. At flats of macrotemplates two lengthwise cut at the distance of ~50mm from edge of this long crack detected several rolling dimples located under sharp angles to the external surface of coupling.

For the first time at “Baku Steel Company” LLC newly constructed bimetallic shaft for rolling pipe and fitting billets offered and patent of the Azerbaijan Republic acquired for its material



Picture 4. Coupling of protective pipe $\text{Ø}168 \times 8,9\text{mm}$ with whole lengthwise cracks



Picture 5. Dispersing of coupling of protective pipe $\text{Ø}168 \times 8,9\text{mm}$ with whole lengthwise crack

(invention document i20170045) [24]³⁰, [16]³¹, [10]³². Developed the technology of preparation of core of bimetallic shaft (nucleus part) from less-carbon steel, and working part from highly solid cast iron. Working surface of bimetallic shaft consisting of martensite+ unsolved carbides+ spherical graphite after tabbing and tabreduction has 48 – 52HRC solidness. Nuclear of the shaft keeps its flexibility, and has high working ability in different changing loads (pic. 6 and 7).

Strengthening technology of various sized coupling billets developed and assimilated. This technology expresses induction heating of billets, cooling in water and tabreduction. Real and characteric cooling curves installed in tabbing unit on coupling billets. New construction to give tabreduced billets from furnace offered, so this, made the work of unit better and unloading of coupling billets [24]³³, [39]³⁴.

Application of new technology of thermic strengthening of coupling billets allow to form the following structure and features:

- beynite with one-by-one in the size of 4-5 scores fields of granule throughout all thickness of martensite and wall in acarbon steels: $\sigma_m=1420-1441\text{MPa}$; $\sigma_{ax}=1142-1146\text{MPa}$; $\delta=4-6\%$, $\psi=23\div 26,2\%$.
- Martensite at the extent of 5-6 scores of austenite score in less alloyed steels: $\sigma_m=2000-2010\text{MPa}$, $\sigma_{ax}=1630-1730\text{MPa}$, $\delta=8-9\%$, $\varphi=27,5-29,5\%$.

In the study of tabbing process it has been identified that quantities of cooling intensivity of external and internal sprayers are close to each other and pretty high. Analysis of real cooling alloys of coupling showed that average ccooling speed in temperature interval

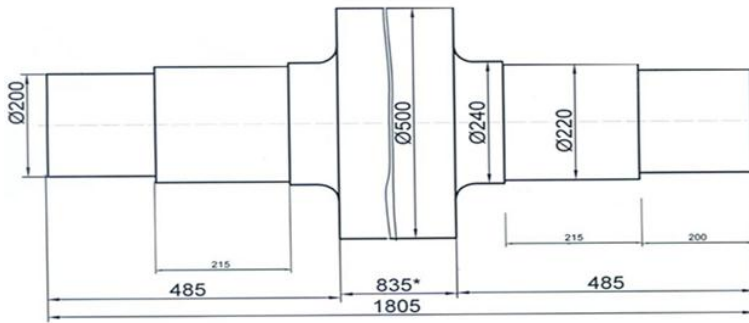
³⁰ İnnovativ yanaşma əsasında yeni yayma vallarının işlənməsi. R.İ.Kərimov

³¹ Yayma istehsalında istifadə olunan bimetallik valların termiki emal rejiminin işlənməsi. R.İ.Kərimov, S.N.Namazov, F.T.Quliyev

³² Bimetallik yayma valın işçi hissəsi üçün çuqun. İxtira sənədi

³³ Azərbaycan Respublikasının Prezidenti yanında Elmin İnkişafı Fondu Qrant Layihələri müsabiqəsi. “ELM-TƏHSİL İNTEQRASIYASI” Fundamental və tətbiqi xarakterli elmi-tədqiqat layihələri müsabiqəsi EİF/MQM/Elm-Təhsil-1-2016-1(26)

³⁴ Qoruyucu boruların mufta pəstahlarının termiki möh-kəmləndirmə texnologiyasının işlənməsi. R.İ.Kərimov

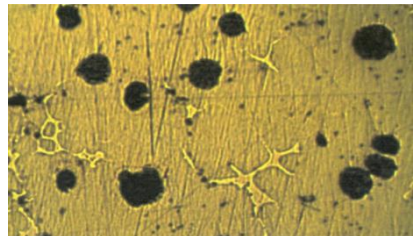
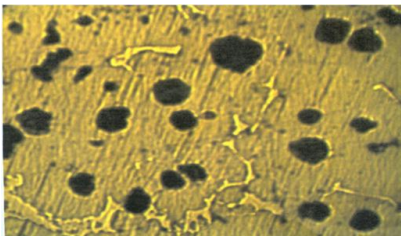


a)

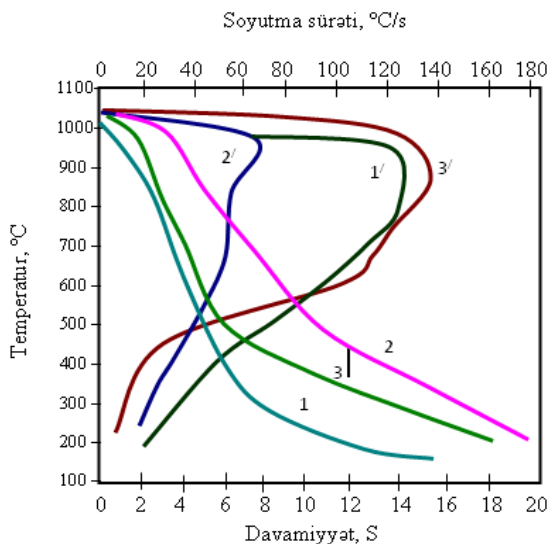


b)

Picture 6. Bimetallic shaft: sizes (a) and common view (b)



Picture 7. Microstructure of barrel part of bimetallic shaft, x500



Picture 8. Real (1 – 3) and characteristic cooling curves 1' - 3' of shaft billet sized 166×17mm in tabbing unit: 1, 1' - external surface (3,5mm distance); 2, 2' - middle of wall thickness; 3, 3' - internal surface (3,5mm distance)

until 850 - 400°C (pic. 8) makes up for external and internal surfaces correspondingly 100 and 82°C/s, but for the middle of wall thickness 50°C/s. Referring to characteristic cooling curves maximum cooling speed at 800 – 900°C temperatures interval, correspondingly for external and internal 154 and 142°C/s, and for the middle of wall thickness this indication is equal to 77°C/s in 900 – 1000°C .

In tabreduction furnace in the study of heating process of coupling billets we detected the difference between feeders and other devices measuring temperature in furnace on regions. Also until reaching maximum temperature of coupling billet difference between furnace and coupling billet has been till 20 – 25°C, then temperature adjusted. Storage duration in tabreduction temperature is regulated

through only replacement frequency of furnace conveyer (70 – 184mm/min) and 7 – 84 min., also possible [2]³⁵.

In 6th Chapter classification of defects to be emerged in continuous casting billets forming through electrosteelsmelting process developed, their reasons analyzed and preventive ways noted. In accordance with the applied classification defects of continuous casting billets have been grouped as below [21]³⁶:

- geometrical defects of billet form;
- defects of billet tops;
- surface defects;
- internal defects;
- washing of crystallized pellet in continuous casting billets.

Geometrical defects of billet form are expressed with changing of separate fields' sizes of its perimeter and reveal themselves with creation of cracks. There are many different causes forming these defects, which include, non-homogenous cooling, non-equal transmission of heating in crystallizer, unequal re-cooling, high speed of casting and others. Majority of these defects can be corrected in the next reprocession [19]³⁷.

Defects of tops of billet damage their commodity view of this billet, and these lead to emergence of different defects in products in rolling process. These defects are also called cutting defects. These defects are not of metallurgical character, and mostly happen in the result of violation of regymes of cutting machines with gas, low cleaning of oxygen taking part in the cutting and so on. Prevention of defects is made by cutting off [20]³⁸.

Surface defects of billets are divided into 2-“hot” (crystallization) and “cold” cracks. Crystallization cracks do not cut the allows of

³⁵ Qoruyucu boruların mufta pəstahlarının termiki möh-kəmləndirmə texnologiyasının işlənməsi. R.İ.Kərimov

³⁶ Fasiləsiz tökmə ilə alınan boru pəstahlarında yaranan qüsurlar və onların aradan qaldırılma yolları. R.İ.Kərimov

³⁷ Fasiləsiz tökmə pəstahları. (Qüsurları və onların aradan qaldırılma tədbirləri).R.İ.Kərimov, F.T.Quliyev

³⁸ Fasiləsiz tökmə pəstahlarında yaranan daxili qüsurların təhlili. A.T.Məmmədov, R.İ.Kərimov, F.T.Quliyev

dendrites, only walls of dendrites and endings of cracks are rich in liquators. Nonetheless cold cracks otherwise cut the same arrows. A lot of technological factors and quality factors of casting steel impact on creation of hot cracks. In most cases utilization of unquality SSUs (Steel Smelting Units) in crystallizer, extreme cooling in re-cooling zone (RCZ), high temperature and big conical of crystallizer form these cracks [21]³⁹.

The most horrible defects in billets are internal ones, because they are in most cases emerge out in final reprocessing processes-rolling, mechanical reprocessions and etc,. Classification of internal defects has been displayed on the basis of the following clauses: according to development scope, reasons of creation, directiveness, location, extent of length. Concomitantly in accordance with every conclusion forms of cracks have been classified after determination. It has been defined that main reasons of creation of these defects are violation of parameters of metallurgical technology [22]⁴⁰.

The most serious defects appeared in billets are non-metallic combinations located in metal. Their types have been shown and their cleaning ways from composition of steel applied. Non-metallic combinations's classification have been shown as following: linear oxides, dot oxides, weak silicates, deformed silicates, sulphids, nitrides and linear carbonitrides, dot nitrides, linear nitrides. Causes leading to these defects are violation of metallurgical and casting technologies and non-obeyance to the cleaning of charge materials. [27]⁴¹.

Main problem of continuous casting of various billets is washing with crstallized pellets of metal. There are 4 types of washing of metal pellet identified: cooling, hanging(hanger), slag and starting (in release of flow). It is possible to identify cooling washings on "gap" (empty billet) on billets. Hanging washing happens under crysallizer.

³⁹ Fasiləsiz tökmə pəstahlarında səth qüsurlarının yaranma səbəbləri. R.İ.Kərimov, F.T.Quliyev, A.A.Cəfərova

⁴⁰ Fasiləsiz tökmə pəstahlarının həndəsi qüsurları və onların yaranmasəbəbləri. R.İ.Kərimov, F.T.Quliyev, A.A.Cəfərova, N.R.Məmmədli

⁴¹ Ovuntuların üfurməklə çalovda poladın kükürdsüzləşmə prosesinin kinetikasının tədqiqi. R.İ.Kərimov, A.T.Bayramov

Hanging washings is sticking of crystallizing pellet onto the surface of cooled casing [14]⁴². Washings on “Slags” mostly occurs as a result of not observing to optimal ratio of [Mn]:[Si] in fluid steel. Starting washings usually occurs in first seconds (15 – 25sec.) of casting after the release of metal flow. Place of this washing is under crystallizer [30]⁴³, [28]⁴⁴.

GENERAL RESULTS

1. For production of various and pipe billets metallurgy technology of electrosteelsmelting process has been developed. Available imaginations about thereotical-technological basics of electrosteelsmelting have been improved and became precise. Thermodynamical parameters of increasing efficiency of metallurgical processes in electrosteelsmelting defined and their impact on the process assessed. By oxidizing in electrosteelsmelting processes of metal purification analyzed. In oxidation of slagforming components of electrosteel bath equation of formation intensivity of new phases has been shown.

2. Removal reactions of phosphorus and sulphur in electrometal bath have been analyzed, and equilibrium coefficients of the reactions have been evaluated. Defined that depending on the concentration of SiO₂ in charge stratification state could occur. Therefore chart has been made up reflecting stratification fields of slags in different concentrations of SiO₂.

3. Depending on manganese concentration in alloys of FeS – MnS graphics illustrated, analyzed and imaginations in this field enlarged. Distribution coefficient of sulphur between charge and metal has been

⁴² Fasiləsiz tökmə ilə Baku Steel Company MMC-də alınan boru pəstahlarından hazırlanan borularda yaranan qüsurlar və onların aradan qaldırılması yolları. R.İ.Kərimov, F.T.Quliyev

⁴³ Ovuntuları üfürməklə çalovda poladın kükürdsüzləşmə prosesinin termodinamikasının təhlili. R.İ.Kərimov, M.B.Babanlı, A.T.Bayramov

⁴⁴ Metal ovuntuları üfürməklə poladın çalovda oksigensizləşdirilməsi. R.İ.Kərimov, M.B.Babanlı, A.T.Bayramov

evaluated in dependence of slag priority.

4. Physical effect methods on the quality of steel in electrosteelsmelting, as well electromagnetic mixing, reposition with vibration researched and available conclusions clarified. Also utilizing hot briquetted irons (HBI) with metal wastes in certain proportions metal smelting intensivity's rise have been achieved. Researches shown that metal productivity after charge having HBI in composition become approximately 1,5% less than metal productivity aroused from full metal wastes. This is related for HBI to be dirtier relatively with non-metallic combinations. [7]⁴⁵.

5. Degassing process of fluid steel in continuous casting process has been studied. When degassing is not enough emergence of structural defects in steel has been observed. Determined that in degassing of fluid metal with argon the amount of oxides in steel can decrease to 80%.

Methodology and unit for mixing of rolling electromagnetics (MREM) has been offered in fluid metal crystallizer. Application of this unit brings to reduction and full absence of arrow-like ward, arrow-like chemical non-homogeneity, dot non-homogeneity, bubbles in billets.

6. To reprocess fluid metal with vibration in PFTM crystallizer, scheme of unit has been displayed. Application of this unit brings to increasing of metal crystallization speed to 25 – 63%, compression of central zone of billet and significant decreasing of liquation. Identified that reposition with vibration affects not seriously to distribution of oxide and nitride combinations in steel, however reflects itself in changing character of sulphid phase, in a result, layer-like sulphids in steel dispersed, and they turn into linear form. Concomitantly in reposition with vibration the amount of oxygen and hydrogen reduces correspondingly among 10÷20 and 14 – 29% [4]⁴⁶.

⁴⁵ Реконструкция сортовой МНЛЗ-2 завода Vaku Steel Company с целью производства круглых трубных заготовок Керимов Р.И., Кулиев Ф.Т., Шахов С.И.

⁴⁶ Участие ВНИИМЕТМАШ в реконструкции действующих сортовых блюмовых МНЛЗ с целью литья круглых заготовок для нужд трубной промышленности и транспорта. Шахов С.И., Соляков А.С., Рогачиков Ю.М., Керимов Р.И.

7. On PFTM algorithm of cooling system of ingot had been compiled. Analytic models of cooling regimes with water and water-air system offered and determined surface temperature of cooling ingot to be close to linear distribution. Defects appeared in pipe billets with continuous casting and their prevention ways had been analyzed. It was identified that in this case casting process should be conducted in a close condition with involvement of electromagnet mixer. [5]⁴⁷, [6]⁴⁸

8. New technologies of production of pipes in continuous casting billets have been developed. Developed rolling technology of highly solid digging pipes with sourced locks on the basis of studies led to productivity of useful pipes to increase from 75% to 83%. For the production of pipe billets with continuous casting at “Baku Steel Company” LLC PFTM – 2 machine reconstruction done, and this, compared to acquiring new PFTM, allows to decrease capital expenses to 3 – 5 times. [23]⁴⁹

9. Quality of couplings of protective digging pipes studied, appeared defects in this case analyzed. It had been determined that chemical composition of couplings’ metal fully respond to the requirements of the standard. But in work process, crack happened alongside its height in the coupling. According to metallographic researches occurrence of this crack due to the existence of metallurgical fault-“rolling dimple” had been confirmed. These researches actualized to take measures in two directions in order to prevent crack creation in the coupling: 1) development of new rolling couplings and 2) thermic strengthening of metal of coupling billets.

⁴⁷ Реконструкция действующей сортовой МНЛЗ Baku Steel Company с целью литья круглых заготовок для нужд трубной промышленности. Шахов С.И., Смоляков А.С., Егармин Е.В., Керимов Р.И.

⁴⁸ Модернизация сортовых и блюмовых машин непрерывного литья стали с целью расширения сортамента отливаемых заготовок, улучшения их качества и увеличения производства. Смоляков А.С., Шахов С.И., Цымбак И.Ф., Рафиев О.Ю., Керимов Р.И.

⁴⁹ Модернизация действующей сортовой МНЛЗ завода «Baku Steel Company» с целью производства круглых трубных заготовок. С.И.Шахов, А.С.Смоляков, Р.И.Керимов.

10. Bimetallic coupling for rolling pipe and fitting billets has been offered for the first time at “Baku Steel Company” LLC and its innovation becoming verified by the Committee of Meterology, Standartization and Patent of the Azerbaijan Republic , patent has been given to coupling material. Nucleus of offered bimetallic coupling is made from steel 20 having soft viscous core, and the working part of highly strong cast-iron having martensite matrixes. In result by induction heating after tabulation and stratification solidity of working surface of coupling changes around 48–52 HRC. But the core part keeps its working ability in pulsating and changeable loads not changing viscous (soft) structure.

11. With the purpose of improving of coupling billets’s structure and increase their solidness features their thermic strengthening technology has been developed. This technology reflects in itself heating of couplings with induction current, cooling in water and high-temperature resistance. To continue the process special automatic thermic strengthening line has been installed in pipe rolling factory. New technology of thermic strengthening of coupling billets provided the formation of martensite structure in low-carbon and less alloyed steels. Together with high solidity characteristics ($\sigma_m, \sigma_{0,2}$), flexibility characteristics of steel (δ, ψ) has also been kept.

12. Defects of continuous casting billets produced in the condition of “Baku Steel Company” LLC had been detected, their creation reasons analyzed and ways to prevent them had been given. For this purpose classification of defects possible to appear developed. It is offered to classify them as shows below:

- geometrical defects of billet form;
- defects of billet tops;
- surface defects;
- internal defects;
- washing of crystallized pellet from billet.

13. Geometrical defects of billet form are expressed with changing of separate fields’ sizes of its perimeter and reveal themselves with creation of cracks. It has been identified for main reasons emerging these defects to be metallurgical reasons. Defects of tops of billet damage their commodity view especially in pipe billets,

as result other defects are detected. These defects are not of metallurgical character, and mostly happen in the result of violation of regymes of cutting machines with gas.

14. Surface defects of billets consist of “hot” (crystallization) and “cold” cracks. Crystallization cracks do not cut the allows of dendrites, nonetheless cold cracks otherwise cut the same arrows. A lot of technological factors and quality factors of casting steel impact on creation of hot cracks.

The most horrible defects in billets are internal ones, they are regarded as final finished but unpleasant product because of mainly emergence in last reprocession. Classification of internal defects has been displayed on the basis of the following clauses: according to development scope, reasons of creation, directiveness, location, extent of length.

15. The most serious defects appeared in billets are non-metallic combinations located in metal structure. Their classification have been shown as following: linear oxides, dot oxides, weak silicates, deformed silicates, sulphids, nitrides and linear carbonitrides, dot nitrides, linear nitrides. Causes leading to these defects are violation of metallurgical and casting technologies and non-obeyance to the cleaning of charge materials.

16. Main problem of continuous casting of various billets is its washing via crystallized pellets of metal. There are 4 types of washing identified: cooling, hanging(hanger), slag and starting (in release of flow). These illustrated types of washing had been analyzed, emerging causes detected and their measures to prevent had been developed.

17. Electrosteelsmelting, reprocession-production technologies with pressure developed within the condition of “Baku Steel Company” LLC provided to get new and more qualitative various and pipe billets and these technologies have been applied successfully. Conducted studies confirmed to be more stable and low-sounded through using metal waste and HBI mixed charge of electrosteelsmelting. Chosen power consumption and technological regyme provide high intensivity of metal heating, heating-physical stability of arc heating and reliable work of power regulator.

Application of developed production technologies allowed to acquire economic efficiency in the size of 1,0 million manats per year at “Baku Steel Comany” LLC.

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