PRODUCING PRECISE HIGH - PERFORMANCE CASTINGS FROM STAINLESS STEEL TURNINGS BY LOST- FOAM PROCESS.

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ABSTRACT

The reported technology provides deep refining of stainless steel turnings while melting. The turnings are melted in the layer of liquid flux. Oxidations processes are excluded. Metal yield ratio is extremely high. The capacity of the furnaces, which we use in our technology, may vary from 70 kg to 1000 kg. These furnaces are nearly unknown to Western specialists.

The novel technology and equipment for metal casting under mechanical pressure technology have worked out on the basis of the classical lost - foam process (LFP). The technology is successfully applied in Ukraine for production of high performance parts from stainless steels for chemical and food production.

Keywords: turnings, melting, lost, foam, pressure.

1. INTRODUCTION

In spite of the fact that Ukrainian producers are sophisticated in state-of-the-art technologies of recycling stainless steel turnings recently this problem has not been decided yet in the best way in our country. In the former time the major recycler of stainless steel turnings was plant “Dneprospetsstal”. The effective technology of the natural gas–oxygen refining of melt in converter was used there (1). Such melt was got in electric arc (EA) furnace by melt of the turnings. This cost effective approach cannot be used now due to the significant decreasing of the generated amount of stainless steel turnings. Though using furnaces of high capacity is irrational. In the same time the tolerance to the metal purity of castings significantly increased.

We apply method of electroslag crucible remelting (ESCR) process for the joint melting and refining of turnings. Earlier this process was applied mainly for producing high performance castings by chilling. It is described in details in book (2). Usually consumable electrodes were used as initial charge. Such process becomes expensive because of the necessity of manufacturing such consumable electrodes. Comparatively non-consumable graphite electrode in our technology substitutes for consumable one. The general principles of this approach are reported in papers (3, 4). Along with the possibility of using fine metal waste as charge material graphite electrode is suitable for temperature control. We can achieve the optimal temperature by regulating electric current conditions as well as by timing of heating. This feature is critical for our technology since the tight temperature control is one of the necessary conditions for effective casting of the melt.

In nowadays the application of the LFP takes more basic positions in manufacturing of castings. It is characterized by high technical and economical indexes of manufacturing ferrous and non-ferrous alloy castings for different applications. Comparative analysis of casting into the sand molds and LFP shows that applying the last one allows significant reducing of the consumption of basic and auxiliary materials, electric power, natural gas and labour-intensive operations.

2. MANUFACTURING HIGH PERFORMANCE CASTINGS FROM TURNINGS

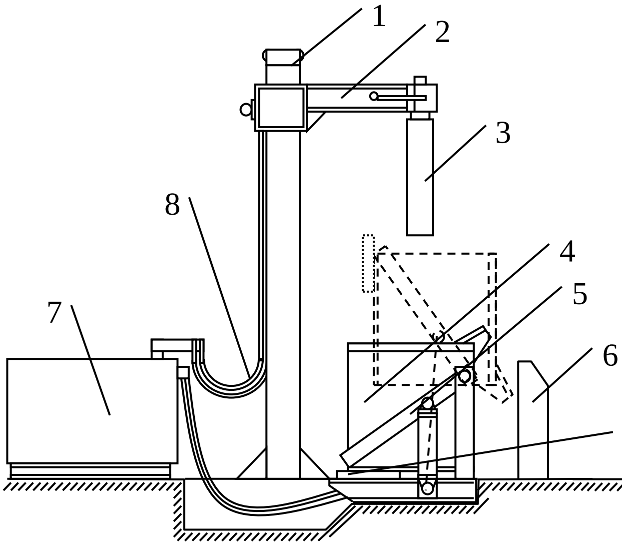
Though two processes: ESCR and LFP - after definite improvements should perfectly complement each other at stainless steel turnings recycling. We carried out a significant work in developing technology for one - stage manufacturing high performance castings from the turnings without intermediate stages.

2.1. Melting stainless steel turnings:

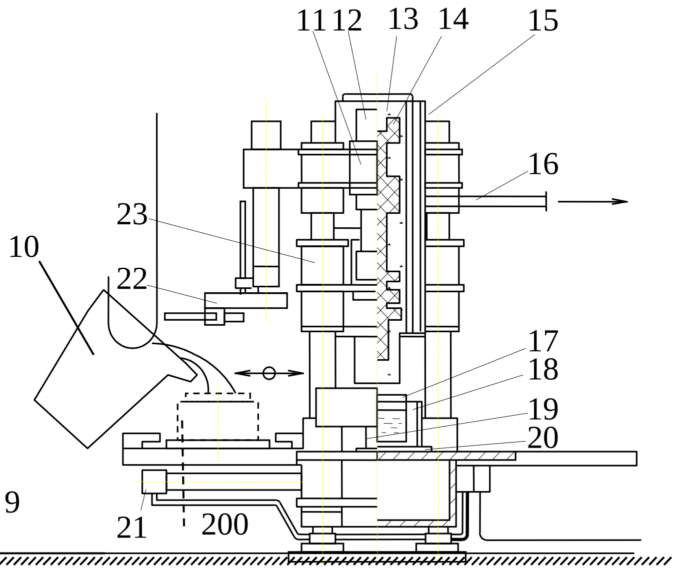
The preliminary condition of using the turnings in the one stage recycling process is their chemical homogeneity. Therefore, all turnings should be generated during processing the steel of definite grade. If not so, it is necessary to make the additional alloying of melt. That needs either application of expensive apparatus for express-analysis or remelting step for making additional alloying operation after the identification of steel chemical composition in laboratory.

The problem of carbon removal usually arises during recycling the stainless steel turnings. The carbon content in common Ni-containing stainless steel does not exceed 0.1 – 0.12%. The turnings are contaminated by oil after the mechanical processing of steel. The carbon from the oil gets into the metal during the melting. We applied the removal of oil before turnings melting. The separation of carbon from segregated phase seams to be easier than in the mutual phase due to thermodynamic considerations. We have proved this fact in the practice by turnings pretreatment. The carbon content in the melt produced from the pretreated turnings never exceeds the designated limits.

The standard 0.5-ton capacity furnace for ESCR is used for turnings melting (Figure 1(a)). However, 70-1000 kg capacity ESCR furnaces suitable for our process are manufactured in Ukraine. The graphite electrode is adjoined by the electrode carriage to the column. The melting runs in the ceramic crucible. The electric power is supplied from the pack via water-cooled cables. It is controlled with the help of the panel. The melting of flux is accomplished by the heat, which is released during the alternating electric current passing from the graphite electrode to the lower electrode through the flux. The turnings are melted during their submerging into the flux. Such mode of melting prevents the metal from the contact with air. Thus all of the components are not oxidized during the melting period. Since that nearly all metallic phase is reclaimed from the charged secondary raw materials.



a) ESCR furnace



b) Foundry device

Figure 1: Schematic drawings of manufacturing devices

1 – column
2 – electrode carriage
3 – graphite electrode
4 – crucible
5 – tilter
6 – control panel
7 – power pack
8 – water-cooled cables
9 - current supply of lower electrode

10 - ladle
11 - stationary traverse;
12 - hydrocylinders;
13 - quartz send;
14 - foam polystyrenic model;
15 - foundry container;
16 - vacuum supplier;
17 - punch;
18 - liquid metal;
19 - hydraulic fixing rods;
20- squeeze-metal-out chamber;
21 - turning table;
22 - positioner;
23 - traveling traverse.

As a result metal yield ratio progressed up to 98-99%. It is well known that significant metal losses occur while using common EA furnace for turnings recycling. Besides sulphur and non-metallic inclusions mainly oxides are simultaneously removed from metal by ESCR flux. After the finishing of melting, the crucible turns by the tilter and the metal is poured into the ladle. The electric power consumption of our melting process averages 1600-1800 kWh per ton of initial charge.

Traditional ESCR process includes the operation of melting consumable electrode of the same composition as manufactured casting. The limited possibility of temperature adjustment is available for a smelter. The application of comparatively non-consumable graphite electrode in our technology gives a possibility to overheat a melt to the needed temperatures. It is critical positive feature for using produced molten steel in foundry technologies. Earlier only casting into chill mold accompanied ESCR process. We successfully have implemented combination of ESCR and LFP.

2.2. Casting under mechanical pressure by the LFP:

It is well known that LFP differs from the traditional methods of casting by the presence of model in the mold during the pouring process. That fact has tight positive influence on the quality of casting (5). Main parameters of hydrodynamics and heat & mass transfer during the casting by the LFP under controlled mechanical pressure have been found out by the researches and experiments, made in Physico-Technological Institute of Metals and Alloys (PTIMA) of National Academy of Science of Ukraine (5-9). As the result, technological process has been developed on the basis of the summarized scientific knowledge about hydrodynamic filling of the mold with the LF in it, gas conditions and the mechanisms of formation of the castings during the application of mechanical pressure. The novel device is used for this purpose. It provides the controlled mechanical pressure during metal feeling of LF blocks as well as pressing metal at the period of its crystallization and solidification.

This device mainly differs from devices, which are used for the pressure-die casting process. This approach brings about a significant expanding the field of applying the LFP for the production of high performance castings from ferrous and non-ferrous alloys with complex geometrical shapes. It also leads to significant increase in the speed of metal filling the mold and to lowering the requirements to the properties of LF and antiburning coatings. It also causes increasing the effectiveness of feeding by liquid metal the solidifying castings and lowering the temperature of pouring by 30-70 ^{0}C. These statements provide significant advantages of pouring by the LFP at mechanical pressure in comparison with common pouring by the same process. They give the possibility to provide the improving of quality and the elongating service life of castings. The preciseness and roughness of the surface of cast parts achieve the level, which is the characteristic of castings produced by more expensive by the lost-wax process (6).

2.3. 2.3. Novel equipment for manufacturing of high performance castings:

So, a new type of casting devices for producing stainless steel castings by the LFP by pouring and crystallizing the metal under the mechanical pressure has been developed in PTIMA. It differs from the one (5), applied earlier for the LFP by the presence of devices for the superposition on the liquid metal of controlled mechanical pressure. The devices of rotor and rotor-conveyer type have been developed for the organization of the high capacity manufacturing of castings. All their technological operations are made in the foundry container during its non-stop transportation. The principal scheme of the typical device for applying the mechanical pressure to the liquid metal is shown on the Figure 1 (b).

Metal in portions is poured into the squeeze-metal-out chamber, lined by the refractory. The chamber is coaxially set by the turning table to the foundry container, where the foam polystyrenic model is molded into the quartz sand. The coated punch covers the squeeze-metal-out chamber by the positiotner. The vacuum supplier is automatically joined to the foundry container. It is stationary fixed by the hydraulic fixing rods. Then container and squeeze-metal-out chamber move toward each other. At the same time the metal is forced out at the designated speed into the operating space of mold by this counter movement. The movement is accomplished by two hydrocylinders located on the stationary traverse. The automatically operated system designates its speed. After pouring the metal into the form the movement of the traveling traverse is continued. This movement provides the feeding of solidifying casting by remainders of liquid metal from the squeeze-metal-out chamber. Thus, the metal is crystallized under mechanical pressure. Then traveling traverse makes reverse movement. On this basis the number of types of casting machines has been created. Its productivity is up to 50 containers per hour. The mechanical pressure varies from 100 to 250 MPa. The pressure in the squeeze-metal-out chamber is changed from 0.1 to 10.0 MPa. This technological process is so called GAMODAR-process.

The pilot rotor-conveyer line (Figure 2) has been developed for the production of castings from the ferrous and non-ferrous alloys by the GAMODAR-process. Its productivity varies from 250 to 500 containers per hour. The manufactured castings weigh up to 50 kg. Pouring device is used for liquid metal supplying from the ESCR furnace. The device works as continuous or cyclical supplier of liquid metal in portions into the squeeze-metal-out chambers of units for applying the mechanical pressure to the liquid metal (see Figure 1 (b)).

The line is equipped by two general technological rotors such as rotor for pouring and crystallization of metal under pressure and rotor for loading containers. These two rotors are connected together by the transporting conveyers, by the rotor for setting loaded container on the filling rotor, and by the rotor for removing the poured containers, and setting them on the transporting rotor. Operations for setting up models, vibro-packing of sand, mounting cover on container by transporting rotor are made on the rotors for loading containers. Then loaded container is forwarded on transporting conveyer. Two auxiliary rotors forward loaded containers from storages to transporting conveyer if needed. The line is supplied by sand regeneration device, by the catalytic re-burning reactor for exhaust gas, and by the system for vacuum treatment.

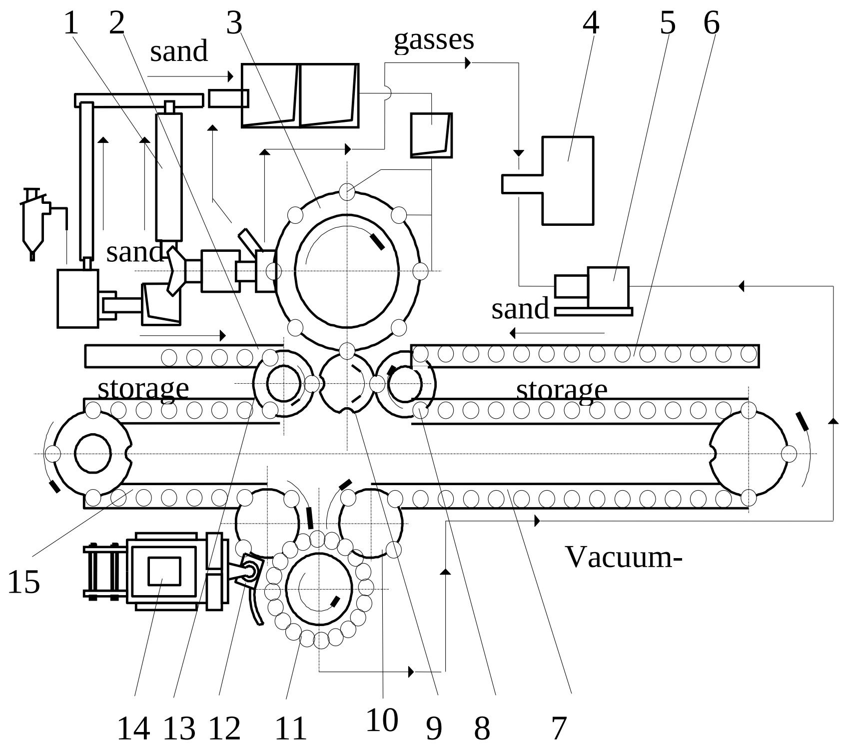


Figure 2: Scheme of rotor-conveyer line for manufacturing castings by using GAMODAR-process (productivity is 250-500 containers/hour)

1 - sand regeneration device;
2, 6 - storages;
3 – rotor for loading containers;
4 - catalytic re-burning reactor of waste gases;
5 – system for vacuum generation in the container during the pouring;
7, 15 - transporting conveyers;
8, 13 - auxiliary rotors;
9, 10- transporting rotors;
11 – rotor for pouring and crystallization of metal under pressure;
12 – rotor for setting loaded container on the rotor 11;
14 – pouring device;

2.4. Environmental protection:

The composition of the products of the LF decomposing in the mold at the different melting temperatures has been investigated for developing the system of environmental protection. Two periods of the thermal destruction of polystyrenic model have been revealed. The first one goes on during pouring into the mold, and the second one runs during solidifying and cooling of the casting in the mold. These periods are characterized by the coefficient of gasification n = Qr/Qo, where Qr and Qo are the volumes of gasses, which are extracted during the first period and during the complete thermal destruction of polystyrene correspondingly. As the result of researches it has been found out that the n varies within limits of 0.2-0.6 during the casting of alloys at the temperature range 600-1600 ^{0}C. So it has been concluded that 40-80% of the products of thermal destruction are condensed on the grains of the molding material. It follows that along with hazardous gasses purification the sand purification from the condensate of the products of LF destruction is needed.

The effective methods of these products elimination during the production of castings by the LFP were worked out. The main condition of environmental control is the purification of the exhaust gas. A number of types of devices for thermo-catalytic re-burning were developed for the exhaust gas purification. The operating of such devices is based on the heating of the exhaust gasses up to 200-400^{0}C and passing them through the layer of the catalyst. The scheme of gas purification device is shown on the Figure 3. It consists of the catalytic chamber, thermal chamber and the burner.

The second main condition of environmental control is the regeneration of molding materials. The repeated usage of molding materials for many times leads to the accumulation of harmful substances in the sand. It was found out that using the same sand repeatedly for over 10-15 times leads to maximizing the composition of polystyrenic condensate up to unrestricted levels of 0.3-0.5%.

The number of the types of devices for the regeneration of molding materials has been developed (Figure 4). Such typical device consists of regeneration furnace, double zone sand cooler and recuperator. The bunker feeder supplies the contaminated sand into the regeneration furnace at the designated speed. The polystyrenic condensate burning-out takes place there. The joint supply of heat carrier and oxidizer is made through the gas-distributing grate into the regeneration furnace. Then the regenerate is passed into the sand cooler equipped by water-cooling tubular heat exchangers and ventilator for mixing of sand. The sand is cooled down to 40-60^{0}C there and is discharged from the lowest zone of the cooler. Ventilator delivers air into the recuperator. There it is heated up to 400-450^{0}C by the exhaust gas and comes into the burner. The exhaust gas from the recuperator is mixed with the air from the cooler and goes into the dust-collecting system.

2.5. Application of technology:

The technology is rationally used for manufacturing the main high performance parts of spherical taps weighing from 0.1 to 4 kg, locking elements of dosage devices weighing from 0.5 to 40 kg, and other parts used in the food and chemical productions

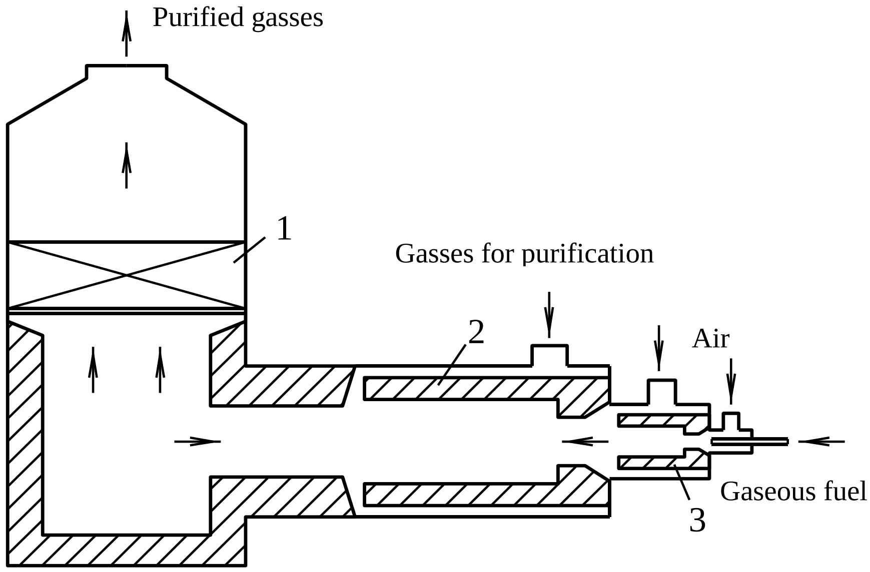


Figure 3: Thermo-catalytic gas re-burning device

1 – catalytic chamber; 2 – thermal chamber; 3 – torch.

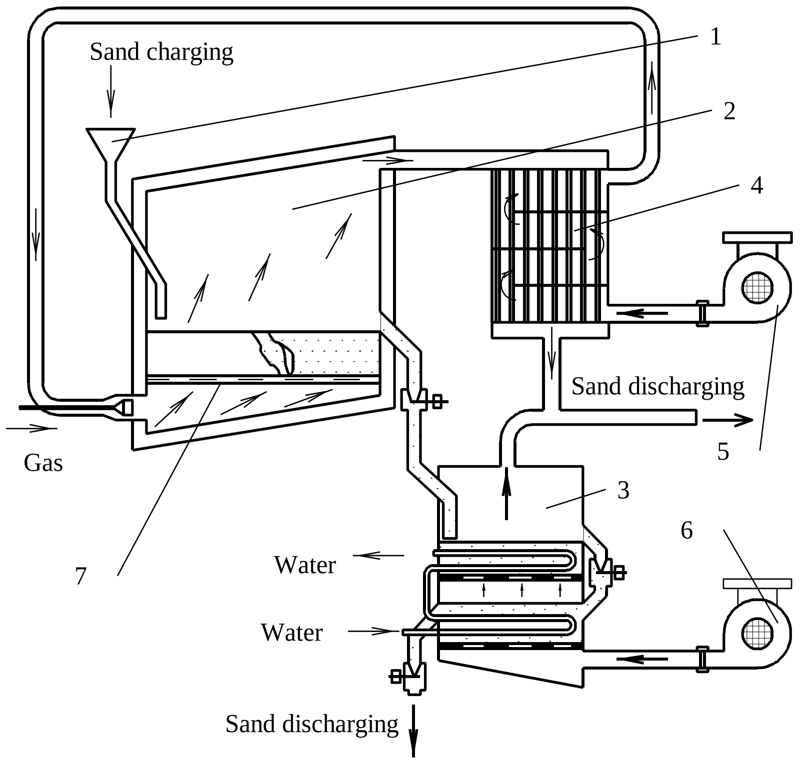


Figure 4: Sand regeneration device

1 – bunker feeder
2 - regeneration furnace
3 – cooler
4 - recuperator
5 – ventilator of regeneration furnace
6 – ventilator of cooler
7 – gas-distributing grate

They are massive stainless steel parts of complex configuration, which must meet very tight requirements to the quality of the surface and the layer, adjoining to the casting skin. Hydrodencity and homogeneity of castings are also very important properties. Earlier these parts were manufactured by the method of welding of two or three wrought sections.

Such parts are tested under the pressure of not less than 0.8-1.0 MPa. They also operate most of the time in the aggressive environments under high pressures as well as at elevated temperatures. Therefore, these requirements lead to the necessity of using the stainless steel of extra-high purity. Metallographic examinations showed that the content of non-metallic inclusions in metal produced by ESCR process is lower than the same indices of metal produced by other methods including electron-beam melting in vacuum. All properties of cast parts correspond to the properties of the parts produced from wrought steel. As the result the significant cost saving is obtained since cheap stainless steel turnings are used instead of expensive wrought stainless steel. It also becomes possible to increase the service life of the parts. Since casting approach allows eliminating joint welds in part, which are the most vulnerable for disruption places of alloy.

3. CONCLUSIONS

The technology of manufacturing the stainless steel castings has been worked out and introduced into practice in Ukraine. This process allows using the unlimited amounts of stainless steel turnings in the charge. The turnings pretreating along with deep refinement of melt by flux leads to the production of highly purified alloy. It corresponds to the requirements of high performance castings. The metal yield ratio averages from 98 to 99%. The produced liquid alloy serves for foundry purposes.

The applied method of pouring the metal under the mechanical pressure allows attaining needed quality of castings. It gives the possibility to change the wrought steel on the cast one at the production of parts, operating at the aggressive environments, elevated temperatures and high pressures. The usage of LFP allows organizing cost-effective production of different high performance castings of complex configuration. The special measures have been applied for developing environmentally sound technology. Such technology may be applied for recycling other ferrous and non-ferrous alloy turnings.

4. ACKNOWLEDGEMENTS

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