Comparative Study of Contact Stresses and Strains at Horizontal and Vertical Continuous Casting Using Conventional and Innovative Methods of Withdrawing Profiles

MARIUS TUFOI, ION VELA, CONSTANTIN MARTA, LENUTA SUCIU, IONEL ADELIN TUTA, CORNEL MITULETU
Center of Advenced Research Design and Technology CARDT
Eftimie Murgu University of Resita
Piata Traian Vuia 1-4, 320085, Resita
ROMANIA
m.tufoi@uem.ro, i.vela@uem.ro, c.marta@uem.ro, l.suciu@uem.ro, adelin.tuta@yahoo.com, c.mituletu@uem.ro http://www.cardt.uem.ro

Abstract: - This paper presents comparative study of contact stresses and strains at horizontal continuous casting and an innovative method of the half-finished products to horizontal continuous casting of metals. Withdrawal of half-finished products to continuous casting of metals is generally realized by using one or more pairs of metal rollers made of steel. The pairs of rollers are electromechanical and hydraulic driven. This method of half-finished products, although most prevalent, also presents drawbacks. The method proposed by the authors, using jaws firing concentrically oriented, with the half-finished product which is subject of the withdrawal operation.The proposed method is an innovative, and eliminates the hydraulic system of roller shrinkage on the profile, the necessary system in withdrawals roller case. In this way is ensure energy saving and improves facility efficiency and product quality. In terms of curvilinear wire vertical continuous casting, the authors propose the optimization of withdrawal cylinders. In vertical continuous casting withdrawal cylinders are generally used to withdraw several sizes and types of profiles. This is because vertical continuous casting applies only to the large semi-manufactured and change withdrawal cylinders for every size and shape of the semi-manufacturing is not economical. Thus, because the same cylinders are used to withdraw for several types and sizes of semi-manufactured products, slip and deformation may occur, which may affect product quality and reliability of vertical continuous casting. To overcome this problem, the authors propose optimization withdrawal cylinders. This optimization is done by machining the cylinder with more rays that adapts to different kinds of round shapes, but also may withdraw and blooms or billets.
Key-Words: - continuous casting, withdrawal, rollers, jaws, cylinder, advantages, FEM

1 Introduction

As method, continuous casting of metals is accomplished by introducing liquid metal with a well-defined temperature in a hollow form with internally water-cooled walls, called crystallized and discharge at the opposite end, of the solidified metal wire. To obtain the same product through continuous casting compared with traditional casting, the number of phases reduces the work over 50%, primarily by eliminating ingot handling, stripping, heating, and sometimes rolling them. Thus half-finished products through continuous cast (slabs, blooms, billets) are more economical in terms of manufacturing cost compared with conventional casting. Worldwide, continuous casting has been developed continuously, so that in developed countries like Japan, the share of continuously cast steel to be over 90%, while the average of continuously cast steel worldwide is 65%. Thus, consideration of possible solutions for improvement of the performance of continuous casting is a necessity, an economic and qualitative leap in the field of iron and steel production.

By applying the horizontal continuous casting process, molten lead has a horizontal route, requiring the evacuation of molten metal at the bottom and sides of the maintenance oven, where is attached the crystallizer. Figure 1 is a schematic diagram of horizontal continuous casting.

The process of continuous horizontal or vertical continuous casting, essentially consist in the direct transformation of liquid metal (liquid metal temperature must be at several points above liquidus point) into solid metal in a different, geometric shapes; bars, slabs, billets, wires, pipes.Horizontal position of the crystallizer put the stability problem of wire type liquid lubricant oil. Most convenient solution is self-lubricating. In this purpose resort to electro graphite, which in addition satisfies the imperatives imposed: high thermal conductivity, refractoriness, wear resistance, processing capacity to the desired shape. In both methods of casting,

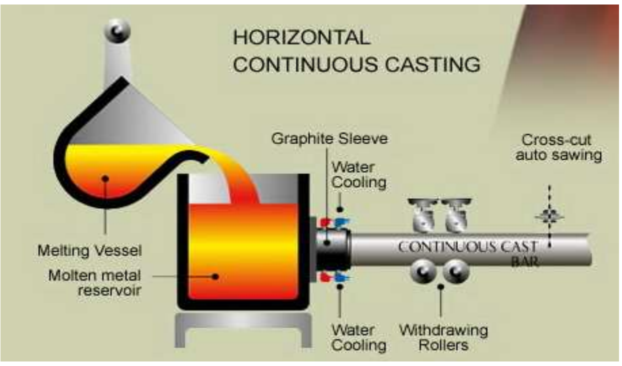

Fig.1

vertical and horizontal are used generally drawing system equipped with roller (or pair of rolls) perpendicular to either side of the drawn profile. One of the rollers is motor driven by an electric motor through a reducer.

The process of horizontal or vertical continuous casting, essentially consist in the direct transformation of liquid metal (liquid metal temperature must be with a few percentages higher than liquidus point) into solid metal in different geometric shapes; bars, slabs, billets, wires, pipes.

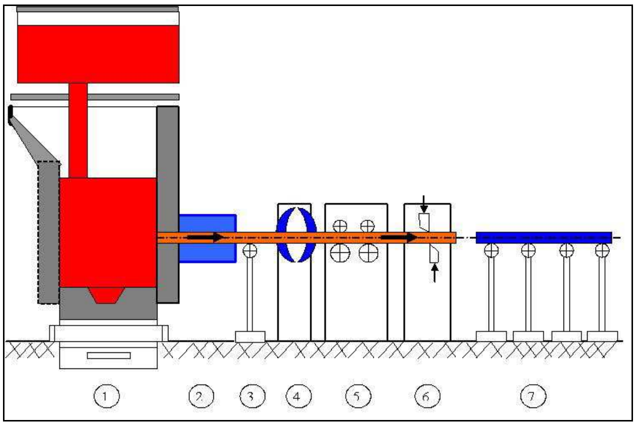

Fig. 2

The metal is molten in molten furnace (1) and is transferred in maintenance induction furnace (2). Here, the liquid metal under its own weight (metal-static pressure) flows into crystallizer (3) and is cooled with water and thus solidification is made.

Solidification leads to obtaining semi –products whose cross section is identical with that of the crystallizer [1]. The semi-products are passed to intermediate support (4) and after through the intermediate cooling system (5) where is cooled and then transferred through the withdrawal system (6). After roller withdrawing the profile is evacuated to the cutting system (7) where it is cut at the intended lengh.

The widrawing of the strand (semi- product) is generally done with the help of pressing cylinder (roller). The pressing cylinder (rollers) can cause considerable deformations at the surface and the section of semi-product (profiles).

In the case of classical withdrawal system of continuous casting plants the rolls are electromagnetically actuated. Sequential or continuous rotational movement is coordinated by a step-by-step drive which, using a redactor-amplifier, forwards the movement to one or two pairs of rollers that provides the feed for semi-product [3].

The other roll is led through the withdrawn profile. Clamping force is provided by a hydraulic system.

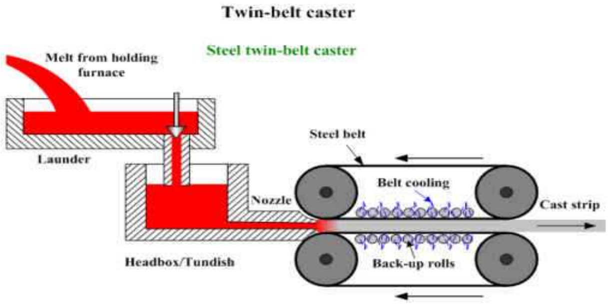

Fig. 3

Other methods of withdrawing the semi-manufactured with horizontal continuous casting are those which use instead drawing rollers, steel strip or glass fiber (fig.3). Another way of withdrawing at horizontal continuous casting uses withdrawing blocks (fig.3).

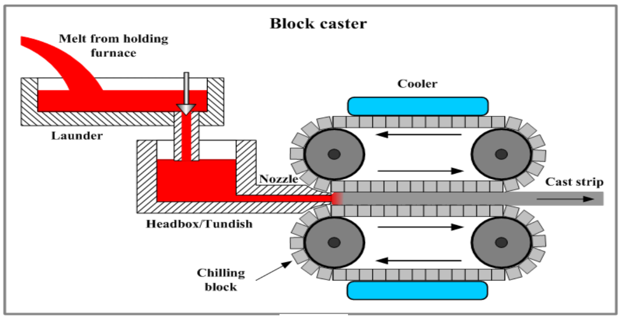

Fig. 4

Withdrawing methods described above, present some disadvantages, such as:
- Oversize of the ensemble motor-reducer;
-The need for a pneumatic or hydraulic system to ensure the clamping force on the profile.
-In case of withdrawing with metal strip or strips of fiberglass appear a rapid wear of these because of the high dynamic applications faced by and due to large thermal applications [2];

-Large size withdrawing system, with blocks and the need for additional facilities for cooling the blocks; -The need for rigorous controls of pneumatic or hydraulic system to avoid deformation withdrawing profile;

-The use in case of large sizes semi- manufactured of more pairs of rollers which need to be synchronized, resulting in a greater complexity of the drawing installation;

-Withdrawing rolls are grooved, which lead to visible traces on semi-manufactured affecting quality [4]. To remove these disadvantages of withdrawing methods developed so far, the author proposethe upgrading of horizontal continuous casting. This modernization refers to optimize withdrawing installation by replacing the classic roller withdrawing with jaws withdrawing, fig.5. and his section in fig.6

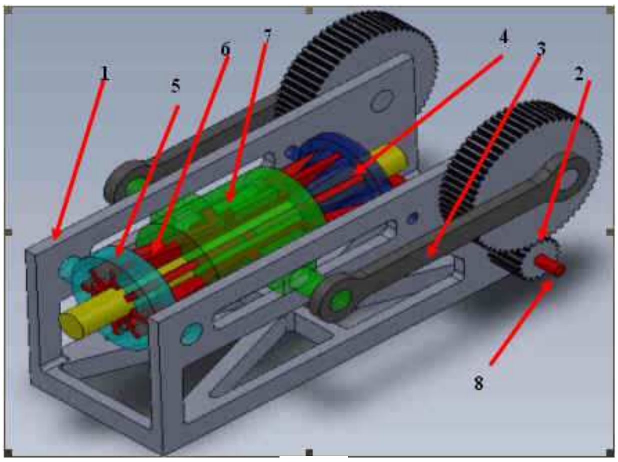

Fig. 5

3 Fundamental functioning of withdrawal system with jaws

The operating principle of the system is simple.

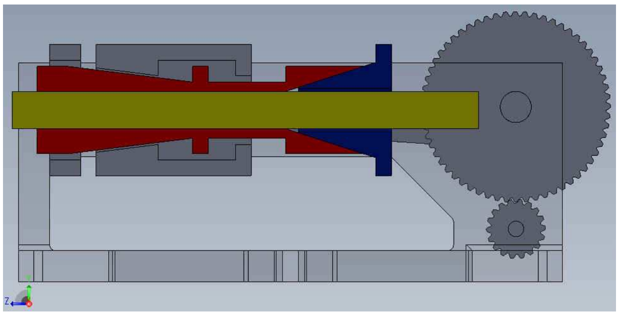
Fig. 6

It is based on a crank-type mechanism (3) which transmits the rotation of the drive gear (2) equipped with cylindrical gears which relies on the support fixture (1). Rotational motion, derived from the input shaft (8) is transformed into translational motion of reversible type, go-come, which applyed through-rods to the clamping ring release jaws (7) .

This works the jaws which are focused on half-finished product and in the first phase creates a pressing force (clamping) on the half finished product followed by the advance force. On a sense of movement of the crank half-finished product clamp occurs and the advance movement of the jaws and default the half-finished product and the other sense is realized the released of the jaws from the half-finished product and their return to the open position. Jaws are resting permanently on the lower holder (4) and on the higher holder (5). Cycle resumes after a complete rotation (360 °) of the inlet shaft. Thus drawing speed is directly proportional to the inlet shaft angular velocity.

Next figures presents results of static finite element method study on the combination of two rolls withdrawing a semi-products round type. In this study we determined the variation of strain, stress and displacement, fig. 7, 8, 9, 10.

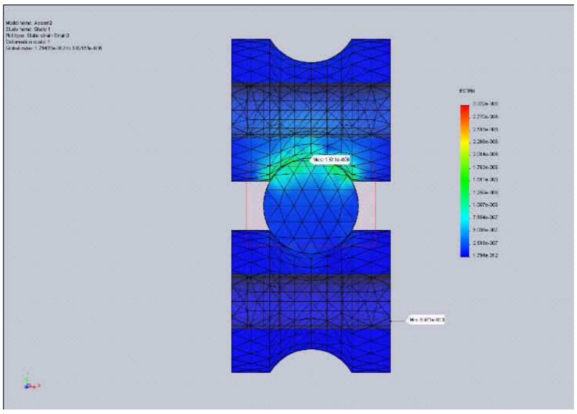
Fig. 7

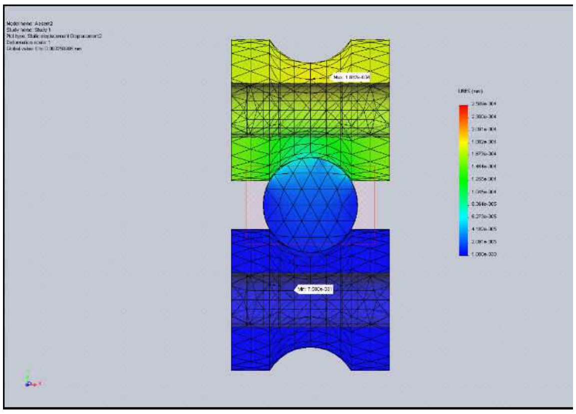
Fig. 8

Table 1 shows the values of tension, strain and displacement obtained by static simulations carried out with SolidWorks application, 2008 in terms of applying a force to raise the profile, Fs = 1000 N in the transverse direction, normal to the surface of contact between rollers and supplies. Same amount of force was applied to the study static jaws firing method.

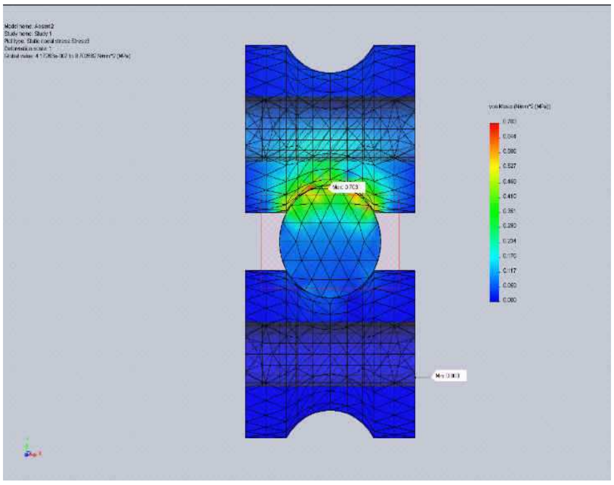

Fig. 9

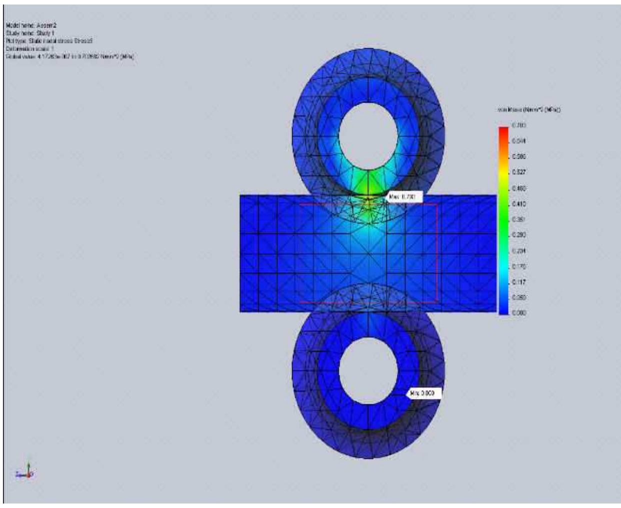

Fig. 10

Table 1

Fs=1000 N	Stress [N/mm^2]	Starin ESTRN	Displacement URES [mm]
ROLLERS WITHDRAWING	0.703	$3.022 \cdot 10^{-6}$	$2.509 \cdot 10^{-4}$
	0.586	$2.518 \cdot 10^{-6}$	$2.091 \cdot 10^{-4}$
	0.468	$1.511 \cdot 10^{-6}$	$1.673 \cdot 10^{-4}$
	0.351	$1.258 \cdot 10^{-6}$	$1.464 \cdot 10^{-4}$
	0.234	$7.554 \cdot 10^{-7}$	$8.364 \cdot 10^{-5}$
	0.176	$5.036 \cdot 10^{-7}$	$6.273 \cdot 10^{-5}$
	0.117	$2.518 \cdot 10^{-7}$	$4.182 \cdot 10^{-5}$
	0.059	$1.794 \cdot 10^{-9}$	$2.091 \cdot 10^{-5}$
JAWS WITHDRAWING	0.027	$1.076 \cdot 10^{-8}$	$6.710 \cdot 10^{-5}$
	0.022	$8.966 \cdot 10^{-8}$	$5.591 \cdot 10^{-5}$
	0.016	$6.272 \cdot 10^{-8}$	$4.473 \cdot 10^{-5}$
	0.011	$4.483 \cdot 10^{-8}$	$2.796 \cdot 10^{-5}$
	0.009	$3.586 \cdot 10^{-8}$	$2.237 \cdot 10^{-5}$
	0.007	$2.690 \cdot 10^{-8}$	$1.667 \cdot 10^{-5}$
	0.004	$1.793 \cdot 10^{-8}$	$1.118 \cdot 10^{-5}$
	0.002	$8.966 \cdot 10^{-9}$	$5.591 \cdot 10^{-6}$

By comparing the values obtained by finite element method is observed:
- The same power to raise the profile Fs = 1000 N tensions and elongations are much higher in method classic roller withdrawal than the proposed method of withdrawal of tanks;
- Contact surface between semi and tanks is higher than in case of withdrawal roller, which to cause less deformation of workpiece in the process of withdrawal;
- Less deformation due to lower tensions and elongations, and greater contact area increase quality semi retired.

Main advantages noticed after simulating and calculus are:
-reduced gauge of the semi-products withdrawal plant;
-the plant is efficient without the hydraulic and pneumatic assembly;
-withdrawal of various types and dimensions semi-products in a designed dimension range;
-the pre-holding system used at roller withdrawal can be excluded;
-less complex design which results in higher reliability;
-increased efficiency by reducing energy consumption;
-adaptability to profile’s shape by varying the number of jaws, up to 8 jaws can be mounted;
-singular rotational movement forwarded through the whole system;

Figures 11, 12, 13 presents results of static finite element method study on the combination of two jaws withdrawing a semi-products round type.

4 Optimizing withdrawal installation for vertical continuous casting

Vertical continuous casting is a method for obtaining semi-finished products of metal (steel, in general). As a method, vertical continuous casting liquid metal is made by introducing a well-defined temperature in a chamber cooled with water to interior walls, called mold and evacuation at the

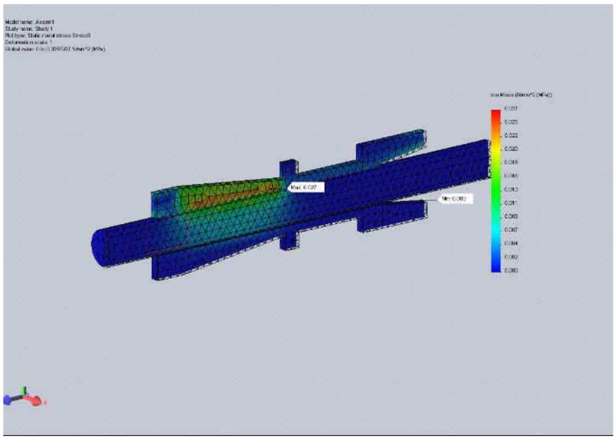

Fig. 11

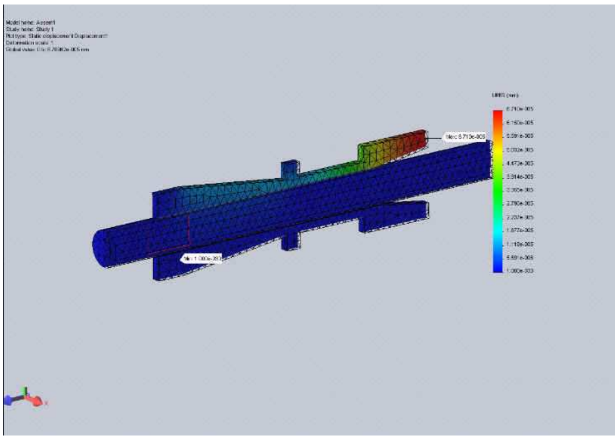

Fig.12

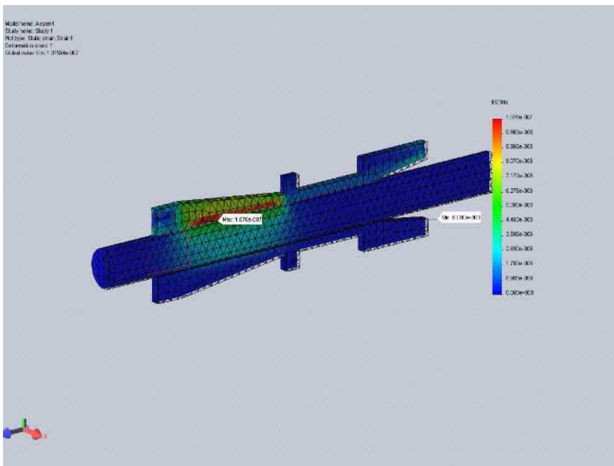

Fig. 13

opposite end of the "wire" of solidified metal. Crossing the mold takes place in continuous or intermittent motion (if horizontal shooting). Generated positive and constructive of mold very broad diversification of continuous casting processes. While they have specialized, leading to the following basic:

1. Crystallized casting down right;
2. Crystallized curved as an arc or ellipse arc;
3. Casting is made from top to bottom, and a movement of oscillation of mold.

Figure 14 and 15 is a schematic diagram of vertical continuous casting of metal.

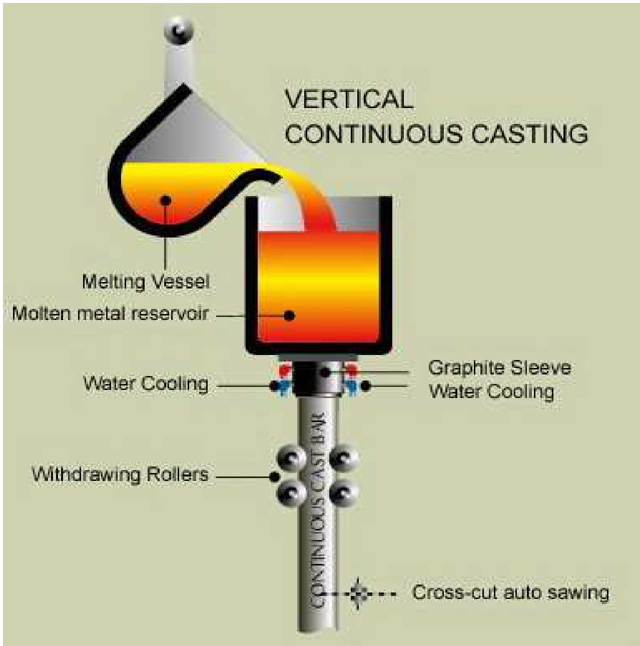

Fig. 14

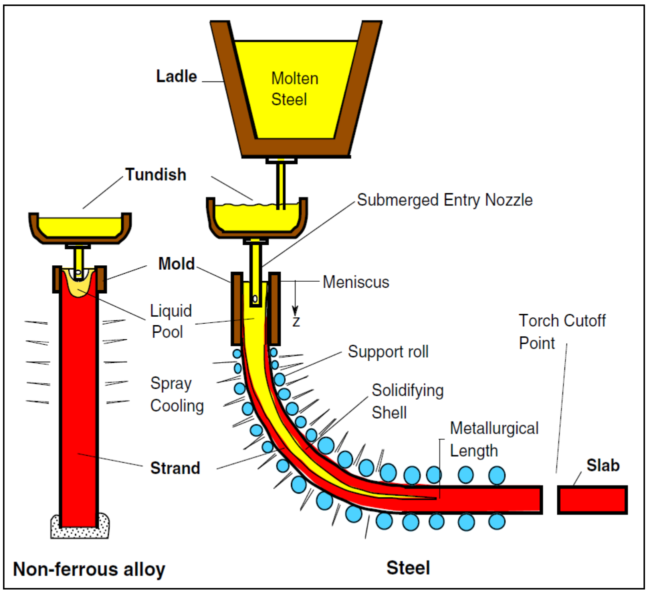

Fig. 15

In vertical continuous casting withdrawal cylinders are generally used to withdraw several sizes and types of profiles. This is because vertical continuous casting applies only to the large semi-manufactured and change withdrawal cylinders for every size and shape of the semi-manufacturing is not economical. Thus, because the same cylinders are used to withdraw for several types and sizes of semi-manufactured products, slip and deformation may occur, which may affect product quality and reliability of vertical continuous casting. To overcome this problem, the authors propose optimization withdrawal cylinders. This optimization is done by machining the cylinder with more rays that adapts to different kinds of round shapes, but also may withdraw and blooms or billets. In figure 16 is presented a installation for withdrawing blooms and round shapes at vertical continuous casting.

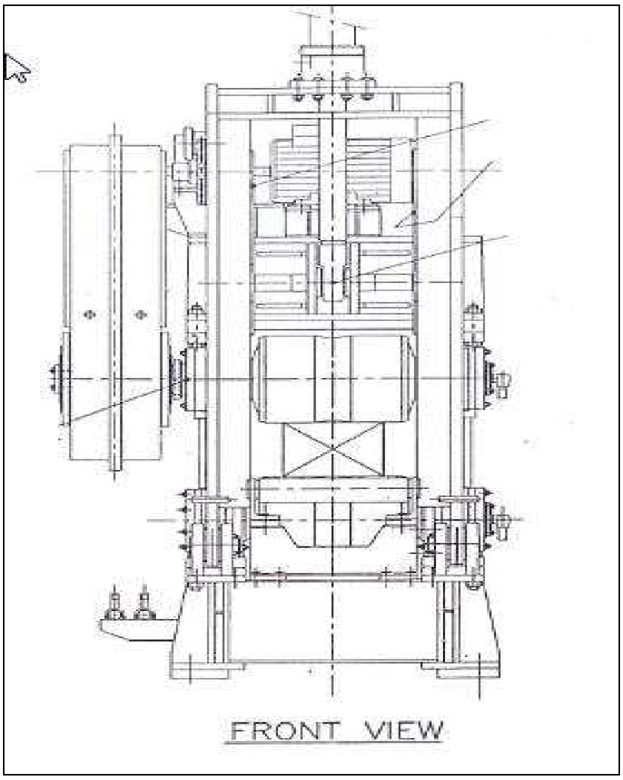

Fig. 16

With this facility may be withdrawn round profiles of 160 mm radius. For ray smaller or larger than the projected result in problems with maintaining the round shape semi-finished products. If you need to change the size of the blank, should be replaced by cylinders of withdrawal. This is neither practical nor economically and have the following drawbacks:

- stopping the continuous casting process to change cylinders withdrawal;
- high cost of each set of cylinders on hand, taking into account that there are four stands of each wire and can retreat there is also three to five threads simultaneously withdrawing;
- the maintenance and repair of a large number of withdrawal cylinders is also costly what invariably leads to increased production costs and low profitability.

To remove these drawbacks occurring in vertical continuous casting withdrawing due to cylinders, the authors propose the development of withdrawal cylinders which have turned more transverse axis ray depending on the types of round profiles required beneficiaries. Also, this type of withdrawal cylinders can provide both withdrawal profiles as well rounded square shape profiles. Advantages of these solutions using withdrawal cylinders with multiple transverse axis rays have several advantages:

- Eliminate the time required to change cylinders withdrawal;
- Possibility of extending the range of profiles depending on their dimensions withdrawn;
- Increase productivity.

In figure 17, are shown schematically withdrawal cylinders, for a vertical continuous casting plant for round profiles of 180 mm diameter as well as blooms.

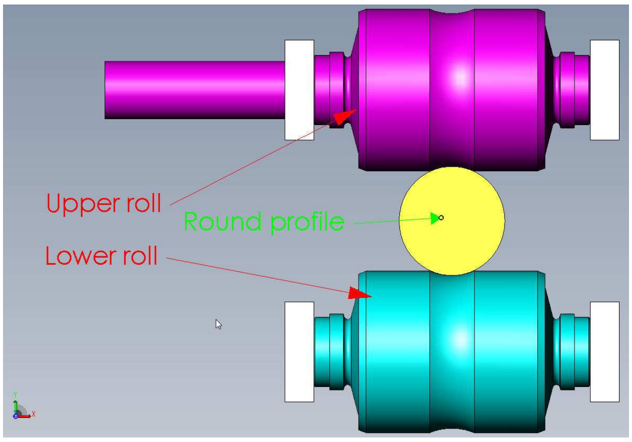

Fig. 17

For this facility to withdraw the cylinders were made simulations using finite element method. To use a static simulation with higher loading on the cylinder follow the prompts that appear on the round profile used as a model of semi-finished product.
Table 2 shows the material properties at static simulation and mesh information in Table 3. Table 4 presents the results from the static simulation round profile, i.e. stress values, strain and displacement.

Table 2

No.	Body Name	Material	Mass	Volume
1	SolidBody 1(Boss-Extrude1)	Copper	561.219 kg	0.0630584 m^3
2	SolidBody 1(SurfaceCut1)	AISI 1020 Steel, Cold Rolled	599.135 kg	0.076129 m^3
3	SolidBody 1(Chamfer2)	AISI 1020 Steel, Cold Rolled	685.39 kg	0.0870889 m^3
4	SolidBody 1(Boss-Extrude4)	AISI 1045 Steel, cold drawn	29.0805 kg	0.00370452 m^3
5	SolidBody 1(Boss-Extrude2)	AISI 1045 Steel, cold drawn	29.0805 kg	0.00370452 m^3
6	SolidBody 1(Boss-Extrude5)	AISI 1045 Steel, cold drawn	29.0805 kg	0.00370452 m^3
7	SolidBody 1(Boss-Extrude6)	AISI 1045 Steel, cold drawn	29.0805 kg	0.00370452 m^3

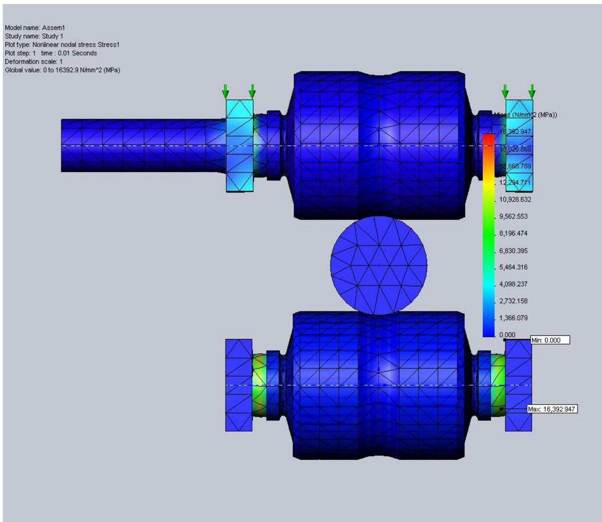

Fig. 18

Table 3

Mesh Type:	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	62.242 mm
Tolerance:	3.1121 mm
Quality:	High
Number of elements:	12301
Number of nodes:	20067
Time to complete mesh(hh;mm;ss):	00:00:08
Computer name:	Z

Table 4

Name	Type	Min	Location	Max	Location
Stress1	VON: von Mises Stress at Step No: 1(0.01Sec)	0 N/mm^2 (MPa) Node: 18214	(370 mm, -810 mm, -130 mm)	16392.9 N/mm^2 (MPa) Node: 7079	(359.817 mm, -747.217 mm, 46.0217 mm)
Displacement1	URES: Resultant Displacement at Step No: 1(0.01Sec)	0 mm Node: 3278	(370 mm, -749.282 mm, -40 mm)	7.01165 mm Node: 11165	(-227.608 mm, -6.59076 mm, -209.925 mm)
Strain1	ESTRN: Equivalent Strain at Step No: 1(0.01Sec)	0 Element: 11372	(379.75 mm, -563 mm, -117 mm)	0.0751548 Element: 4269	(-359.334 mm, -603.533 mm, -31.3732 mm)

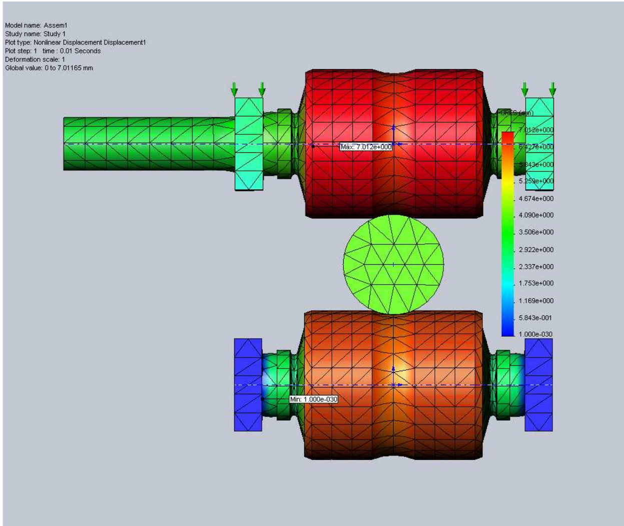

Fig. 19

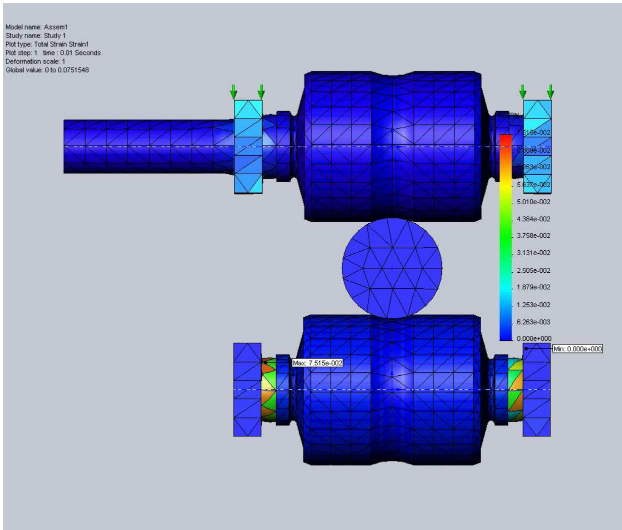

Fig. 20

In Figures 18, 19 and 20 are the results file for mechanical stress on the semi-finished products when using cylinders with a single radius.
Figure 21 shows the optimized withdrawal cylinders which have been processed with more cross radius. The dimensions of the radius are made: R90, R125, R14 and R175 for the corresponding diameters of the semi-manufactured products of Ø180, Ø 250, Ø 280 and Ø 350 mm. Most of beams will be created with Sheet Metal and Weldments module from SolidWorks [6], [9], [10], [11]. [12].
Withdrawals of these cylinders built with multiple radius that are consistent with semi-manufactured diameters were performed simulations identical to those described above. Note that:
- Increase surface contact between cylinders and semi-manufactured as per size of the profile there is a corresponding radius executed per cylinder;
- Due to greater contact surface stress of materials are reduced.

Table 5

Mesh Type:	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	On
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	18.084 mm
Tolerance:	0.90422 mm
Quality:	High
Number of elements:	259244
Number of nodes:	372153
Time to complete mesh(hh;mm;ss):	00:01:16
Computer name:	Z

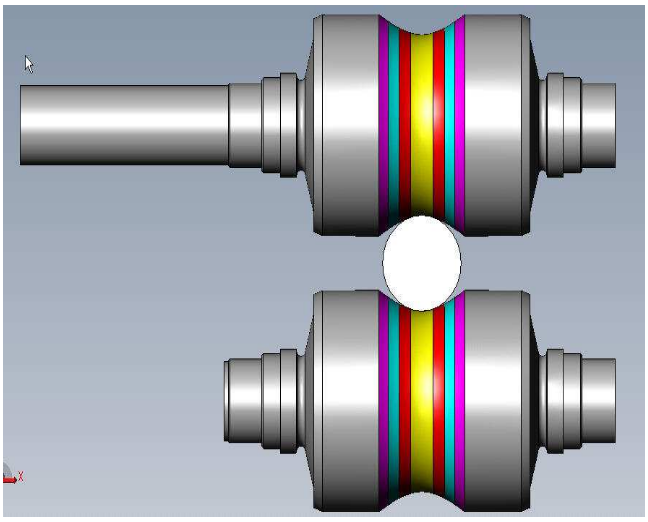

Fig. 21

In geometrically and material non-linear FEM solution, the Euler method was applied based on proportional loading in combination with the Newton-Raphson method [7].

Table 6

Name	Type	Min	Location	Max	Location
Displacement2	URES: Resultant Displacement	0 mm Node: 8002	(45.5 mm, -182.756 mm, 500 mm)	5.23751 mm Node: 331196	(-930.049 mm, 69.6359 mm, 4.33384 mm)
Stress2	VON: von Mises Stress	6.3042e-008 N/mm^2 (MPa) Node: 175015	(-913.218 mm, -63.472 mm, -22.6871 mm)	7127.37 N/mm^2 (MPa) Node: 313622	(35.0301 mm, -186.595 mm, -5.52217 mm)
Strain2	ESTRN: Equivalent Strain	2.71081e-013 Node: 175015	(-913.218 mm, -63.472 mm, -22.6871 mm)	0.0306477 Node: 313622	(35.0301 mm, -186.595 mm, -5.52217 mm)

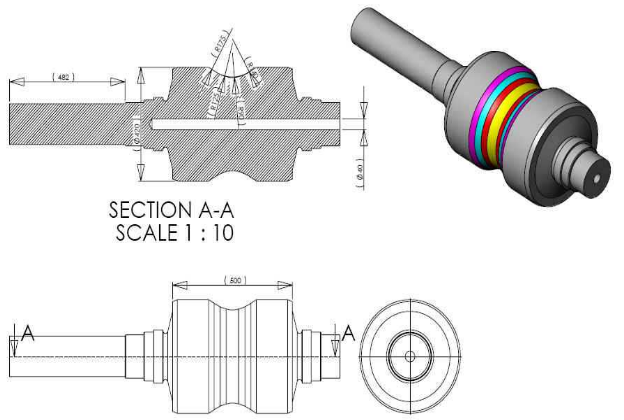

Fig. 22

Figure 21 shows the multi-radius cylinders withdrawal. On the basis of solids created with SolidWorks 2010 has made a study similar to that described above. Apply the same constraints and demands on the same round profiles studied were determined mechanical stress elongation (strain) and displacement. These determinations were made by applying the finite element method. In Tables 5 and 6 are given information on meshing and simulation results. Note that stress levels are lower than previous simulation. The conclusion that arises is that the withdrawal cylinders using multiple beam profiles correlated with the size advantages are obtained:

- Lower deformation profiles withdrawn;
- Less wear on the cylinders;
- Obtaining geometrical shape how profiles closer to the mold

Figure 22 shows design execution of withdrawal cylinders with multiple ray and figures 23, 24, 25 present results of stress, strain and displacement obtained after simulation.

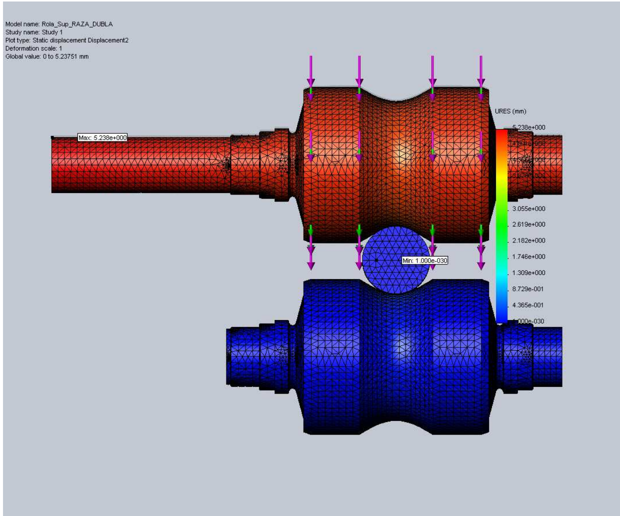

Fig. 23

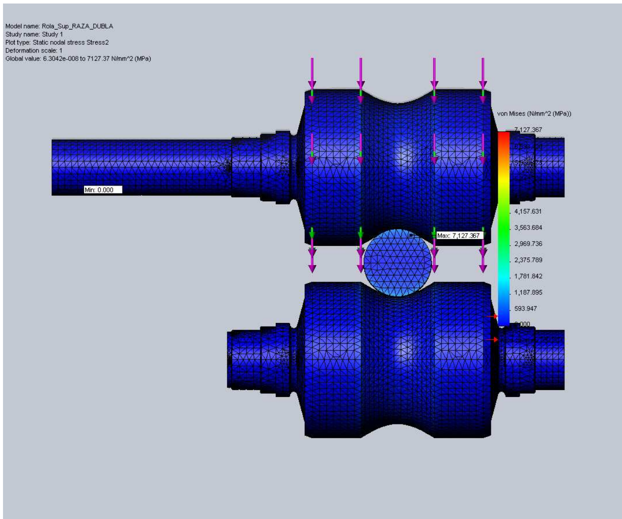

Fig. 24

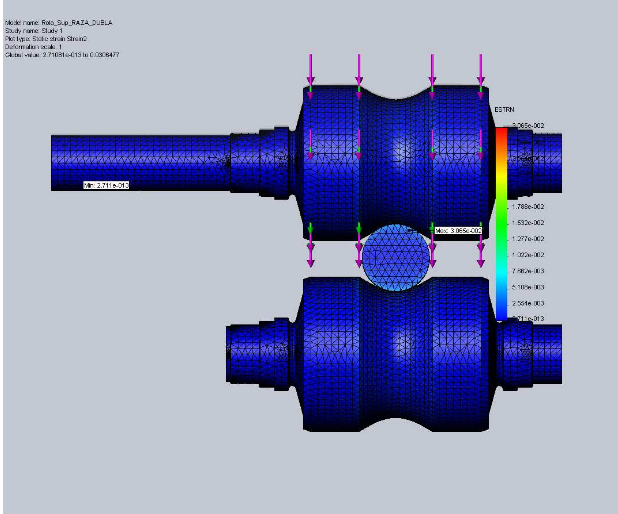

Fig. 25

5 Conclusion

Given the importance of continuous casting of metals in the steel and metallurgical general flow, is required to modernize and optimize existing continuous casting plant to increase product quality and reduce energy consumption. Withdrawing method of the semi-manufactured proposed by authors, will be practic realised on a smaller scale to validate the principle and then to be implemented in the profile industry. Shall have regard to future research on the achievement of modernization and improvements to existing facilities and the development of new mechanical systems for withdrawing horizontal continuous casting and improve vertical continuous casting instalations. The mechanism for withdrawing half-finished product, at horizontal continuous casting with withdrawing jaws, is a new, innovative, which introduces several advantages over traditional roller retirement system. He is in line with current trends to reduce manufacturing costs by lowering energy consumption and increase reliability of mechanical systems from composition of mechanical drive systems. The system was designed and the simulations were performed by the modern techniques and current area (CAD, CAE, CAM) for choosing an optimal solution in terms of design and dimensional. Future researches are aimed at practically realization of the proposed scheme, its validation by experimental way, and introduction of production systems of metal semi-finished products, already on the market.

Acknowledgement

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Romanian Ministry of Labour, Family and Social Protection through the Financial Agreement POSDRU/6/1.5/S/16.

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