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Studies Regarding Design and Optimization of Mechanisms Using Modern Techniques of CAD and CAE

The paper presents applications of modern techniques of CAD (Computer Aided Design) and CAE (Computer Aided Engineering) to design and optimize the mechanisms used in mechanical engineering. The use exemplification of these techniques was achieved by designing and optimizing parts of a drawing installation for horizontal continuous casting of metals. By applying these design methods and using finite element method at simulations on designed mechanisms results a number of advantages over traditional methods of drawing and design: speed in drawing, design and optimization of parts and mechanisms, kinematic analysis option, kinetostatic and dynamic through simulation, without requiring physical realization of the part or mechanism, the determination by finite element method of tension, elongations, travel and safety factor and the possibility of optimization for these sizes to ensure the mechanical strength of each piece separately. Achieving these studies was possible using SolidWorks 2009 software suite.

Keywords: *CAD, CAE, optimization, simulation, continuous casting*

1. Introduction

Exhibition development of computers and advanced software products led to a new way of graphical methods which are accused, mainly impreciseness. In the presence of CAD software (Computer Aided Design) these graphics methods, become accurate just as accurate as analytical methods, instead keeping the advantage of graphical methods to be simple and intuitive.

Using the design / computer-aided drawing is made precise geometric construction. Precision drawing and calculation which has established CAD software is very high. Because the possibilities of representation, in natural size of the vector quantities, the concept of scale disappears. The main advantages of CAD software which are recommended to be used in problem solving mechanisms are:

- Double precision drawing and calculation;
  - Almost unlimited possibilities to zoom in and entities made;
  - Coordinates of points can be entered using absolute Cartesian coordinate systems, absolute or relative polar coordinate;
- Realization of geometric construction, plane or space, however complicated;
- Precise determination of intersection points (INTersection), the middle of a line segment or arc (MIDpoint), centre of a circle or arc (CENter), the tangent point of a circle or arc with a straight (TANgent), the normal line on a line segment (PERpendicular), etc.;
- Listing display designs with linear dimensions sized entities or multiplied by a scale factor;
- Using files "script" drafting instructions may be transferred from one programming language (C, Turbo Pascal) in AutoCAD or other CAD programs. It can get so bi and three-dimensional graphics, the drawings of successive positions of mechanisms elements when the engine component, is occupying different positions. It also can be obtain the animation of plane and spatial mechanisms.

Thus, graphical methods are distinguished by their simplicity, which may become present and "analytical" using CAD software.

2. The design of mechanisms for continuous casting of metals

To exemplify the using of CAD and CAE (Computer Aided Engineering) techniques at design and optimization of mechanisms, it was proposed the realization of innovative mechanisms for withdrawing the continuous casting of metals.

Continuous casting of metals is a method of obtaining metal billets directly from molten metal in the form of yarn, round billets, blooms, etc. The method consists in introducing molten metal, which is in the pot to maintain, in a crystallizer cooled externally with water. Here there is the primary cooling metal followed by partial solidification of molten metal, the metal partially solidified taking shape of the crystallizer. The molten metal (inside the "wire"), under the metal-static pressure, leaves the crystallizer and it is subjected to a cooling for a complete solidification. Then, semi-finished is picked up a mechanism that helps withdraw of extraction. After extracting the semi-finished by the withdrawing mechanism, it is transferred through a roller bed to plant cutting which is cut to desired length. In figure 1 is presented horizontal continuous casting (HCC) plant and vertical continuous casting (VCC) plant in figure 2.

Continuous casting of metals is a process used more extensively on national plan, European, and world because it brings major advantages compared with traditional methods of obtaining metal blanks. Conventional casting followed by rolling the ingot moulds sequentially until the desired size, is a method of time and energy consuming, thus preferring continuous casting.

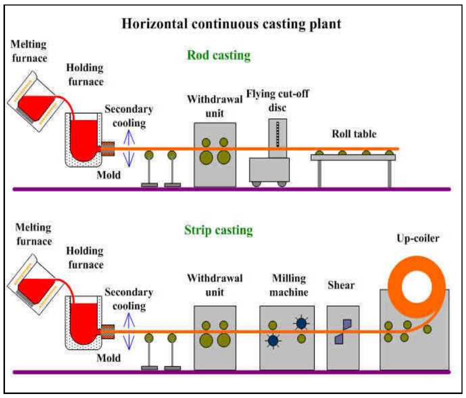

Figure 1 HCC installation [8]

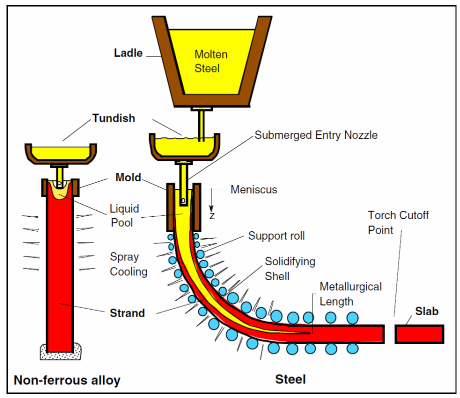

Figure 2 VCC installation [8]

Because of the above considerations, therefore follows that upgrading and optimization of continuous casting and drawing installations default to blanks, must be an intense and topical concern to experts in the field.

Modernization and optimization of continuous casting process should lead to:

- Increased productivity;
- Reducing consumption of consumables;
- Reducing energy consumption;
- Increasing the quality of their products;
- Diversifying the range of shapes and sizes of semi-products, can be obtained in continuous casting processes.

3. Innovative methods for continuous casting withdrawing

To remove the disadvantages that arise at the semi manufactured withdrawal, using rollers, at the horizontal and vertical continuous casting, the authors propose two new innovative methods, of withdrawal the semi manufactured. These two new methods are: withdrawal semi manufactured with withdrawing clamping jaws and withdrawal of the snails cylinder and are listed below.

3.1 Method of removal of the semi-finished using clamping jaws

The first proposed method is the withdrawing of semi manufactured with the help of adjustable horizontal clamping jaws. In this way the advance force is provided by rotational and translational movement of the clamping jaws; then contacts the blank and describe a translational motion providing the advance force and thus pulling profile. However, to take place the advance movement which is due the frictional forces between clamping jaws and semi manufactured combined with the force developed by the translational motion of the clamping jaws, is necessary to a normal force for pressing on the contact area between clamping jaws and semi manufactured (figure 1).

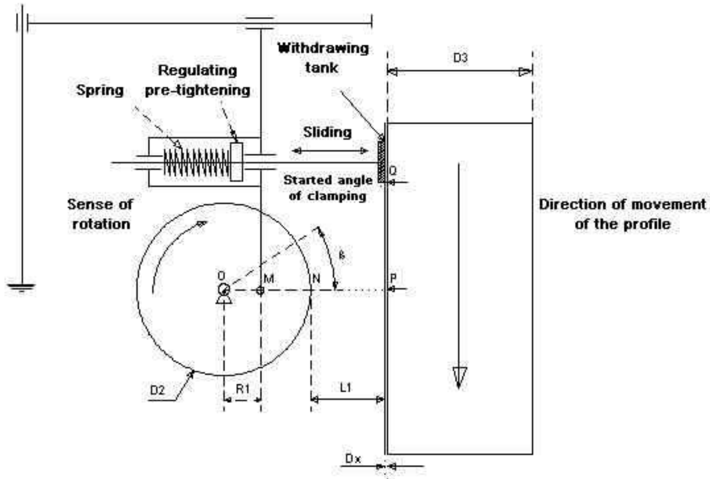

Figure 3 - Kinematics scheme of the system of withdrawal of clamping jaws

$$F_f=N\cdot\mu \qquad (1)$$

Where: F_f - is friction force;

N - normal force pressing the contact surface;

μ - coefficient of friction.

The normal pressing force N or the clamp force is ensured by the compression of two appropriately sized compression springs .Springs may be pre-stressed with a pre-tightening mechanism with nut and bolt.

$$N=F_e=2\cdot k_e\cdot x \qquad (2)$$

Clamping jaws withdrawing facility was designed using SolidWorks 2009 3D CAD software in and is shown in figure 4.

Clamping jaws withdrawing system is operated from a single input shaft, trained in a rotation movement by a controlled induction motor, by the method of field orientation (vector control). The clamping jaws execute a rotation movement for an angle β, being mounted on an eccentric shaft.

$$\beta=2\pi-\alpha \qquad (3)$$

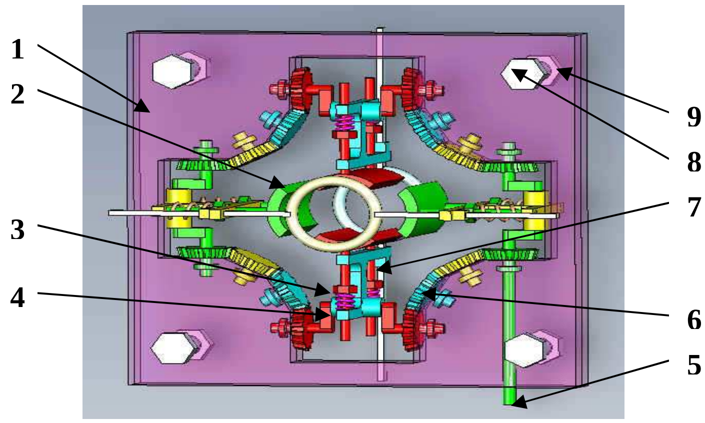

Figure 4 - 3D proposed model of the withdrawing installation with clamping jaws

Legend:
1 is semi-molds; 2-withdrawing clamping jaws; 3-springs; 4-cranshaft; 5-input shaft; 6-gears; 7-link elements; 8-screw for fixing semi-moulds; 9-nut for fixing semi-molds.

On the arc of a circle determined by the angle α, the clamping jaws describe a translational motion because after the contact with the semi manufactured, the jaw is fit on the profile and compresses the compression springs [3]. Compression springs ensure clamping force on the profile, and the rotation movement of the eccentric shaft through the mechanical moment created on the jaw, provides the advance force in necessary direction and purpose for semi manufactured withdrawal (see figure 5) .

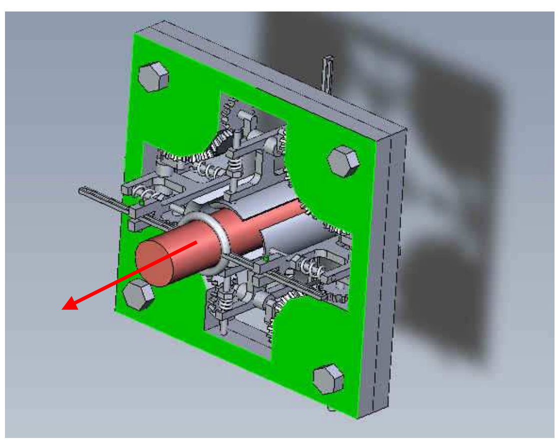

Figure 5 – Withdrawal of profiles with clamping jaws

The main advantages of the clamping jaws withdrawing system comparing with the classic rolls system are:

- Elimination of hydraulic or pneumatic system used to exercise the clamp force;
- Elimination of the speed reducer, through the command of asynchronously motor drive using the method with target field (vector control) which allows the direct obtaining of the necessary speed withdrawing system;
- Reducing the profile deformations that occur due to increased contact area between the clamping jaws and semi manufactured;
- Saving energy by eliminating the hydraulic system of collecting and replaced with coil springs for compression ;
- Reducing installation complexity and hence increase reliability.

The main disadvantage of the withdrawing system with clamping jaws is that does not allow the use of a withdrawing method for semi manufactured, continuously with constant speed [4,5].This system allows only the intermittent withdrawal because from time to time, no pair of clamping jaws is in contact with the semi manufactured.

3.2. Withdrawal method using snail cylinders withdrawing

The second method proposed replaces the classic withdrawing roller with cylinders snails. The system is composed of two cylinders snails, with longitudinal axes parallel to each other, and parallel to the longitudinal axis of symmetry of the semi-retired. The direction of rotation of a cylinder is opposite direction of rotation of the other cylinder (see figure 6).

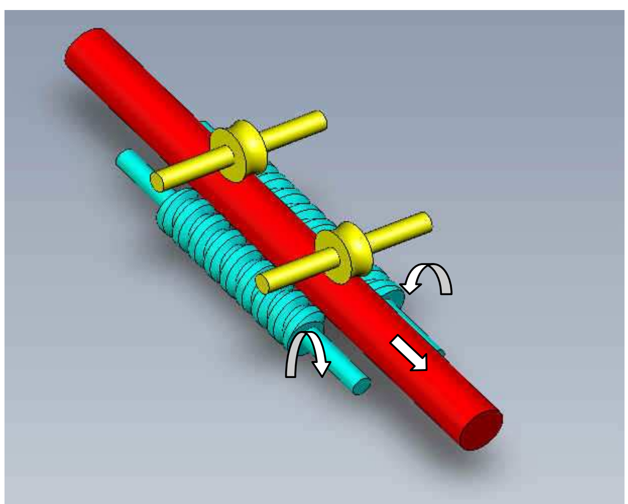

Figure 6 – Withdrawing method with snail cylinders

The cylinders are carry-forward from an induction motor through a gear with cylindrical gear wheels. The clamp force on the profile is provided by the roller perpendicular to the semi manufactured. Rolls have and guiding role and maintaining of the semi manufactured on the desired trajectory during the advance movement of semi manufactured. Advance movement appears due to the frictional forces exerted between snails cylinders trained in rotating movement and profile. This advance movement has a parallel direction with the cylinders axes, and the meaning is given by the worm movement of the thread cylinders. Friction force composed with the clamp force created by the rollers, have a resulting in a useful force along the axis of cylinders which leads to the withdrawal of semi manufactured. Clamping force required is created by a gravitational mechanism equipped with counterweights and operates on the principle of the lever. It acts on the profile through the rollers. The value of the clamp force is adjustable according to semi manufactured sizes by moving the counterweight along the semi-manufactured switches (see figure 7).

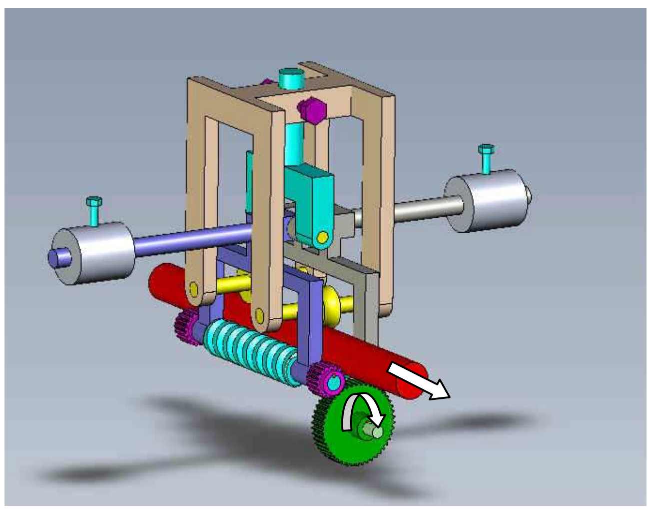

Figure 7 – 3D proposed model of the withdrawing installation with snail cylinders

The main advantages of the withdrawal system with cylinders compared with the classic roller system are referred to the system of withdrawal of clamping jaws. In addition other benefits to retirement system with clamping jaws are:

- elimination of compression spring necessary to raising the clamp force of the clamping jaws on the profile, it is using a gravity mechanism;
- the possibility of utilization of the withdrawing method with steady speed and intermittent withdrawing method (see figure 8);
- the possibility of adding of a second redundant drive system with gear for the worm cylinders: it is to take the training withdrawing cylinders in case

of failure of the first drive system; the second drive system is attached symmetrically about the vertical axis cylinders in the opposite end of the first system, the control part of the two gearing systems is achieved by a simple electronic circuit, equipped with motion sensors.

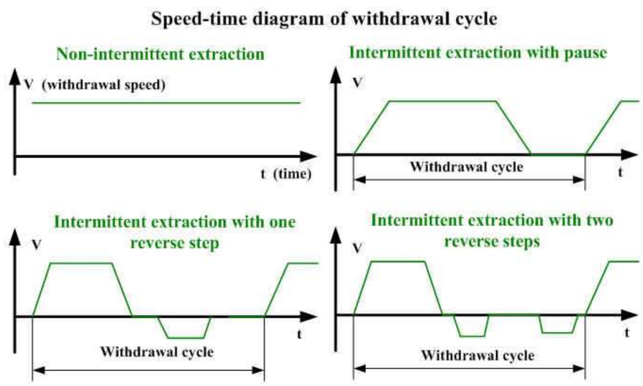

Figure 8 – Speed diagram of withdrawal cycle

3.3 Determination of the contact pressure on the surface profile at withdrawing with clamping jaws

To determine the pressure exercised on the semi manufactured at withdrawings with clamping jaws, was used finite element method calculation. This determination is necessary to verify whether the semi manufactured withdrawn by this method, with clamping jaws is deformed by emerging applications [6,7,8].
Input data necessary for calculation were chosen for the withdrawal of a semi-manufactured round profile Ø = 120 mm diameter of steel. Are known:

-Elastic modulus 2.1• 10^{11} N/m^2

-Poisson's ratio 0.28 NA

-Mass density 7700 kg/m^3

-Yield strength 6.2042 • 10^{8} N/m^2

In table 1 is presents forces (load and restraints) allocated for dynamic study for stress with von Mises criterion.

Table 1 – Load and restraint for dynamic study

Load	
Load1 <Dynamic solicitation_B>	on 4 Face(s) apply normal force 10 N using uniform distribution
Load2 <Dynamic solicitation_B>	on 1 Face(s) apply force 250 N normal to reference plane with respect to selected reference Front Plane using uniform distribution
Restraint1 < Dynamic solicitation _B>	on 1 Face(s) immovable (no translation).

COSMOSXpress design analysis results are based on linear static analysis and the material is assumed isotropic. Linear static analysis assumes that:
1) the material behaviour is linear complying with Hooke's law;
2) induced displacements are adequately small to ignore changes in stiffness due to loading;
3) loads are applied slowly in order to ignore dynamic effects.

The calculation will show whether the chosen method is valid. It must be determined the stress exercised on the semi-manufactured and if it exceeds the amount allowed for steel grade chosen, figure 9,10,11,12.

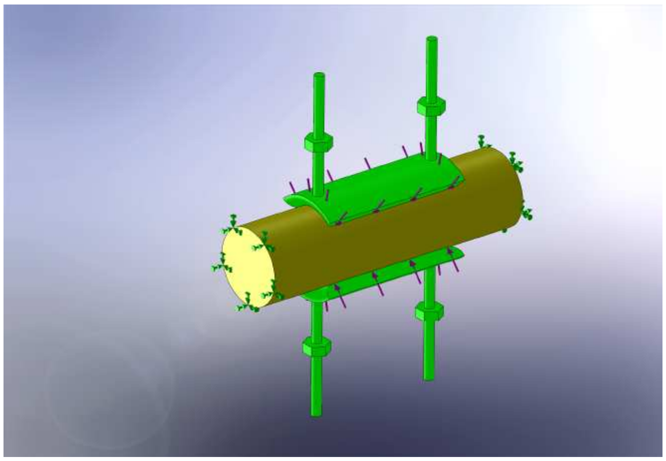

Figure 9 – Force application for dynamic study

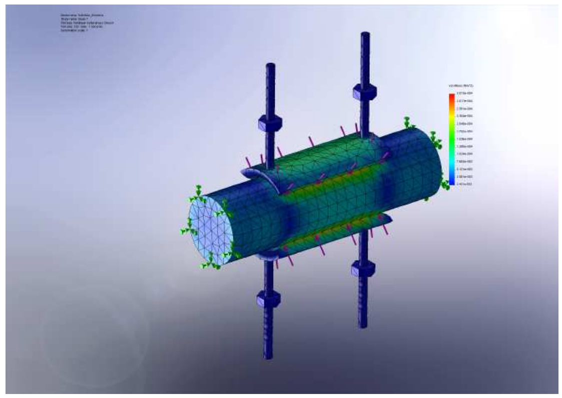

Figure 10 – Stress results with mesh

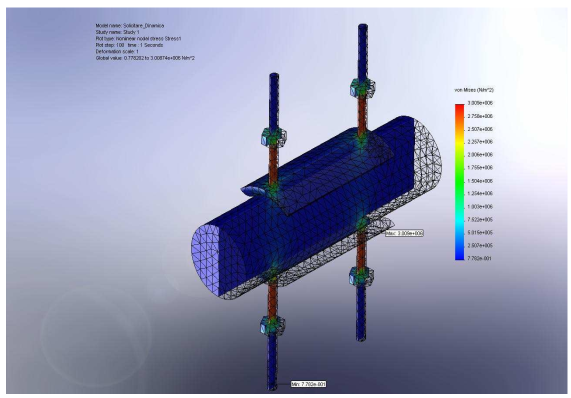

Figure 11 – von Mises stress results with mesh, in section

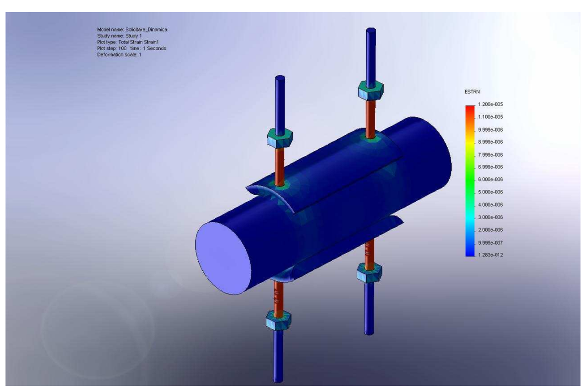

Figure 12 – Strain results

Sizing clamping jaws meet required mechanical application, and profile application is withdrawn within the limit of deformation.

4. Conclusions

Upgrading existing systems of withdrawing horizontal continuous casting and drawing building new systems for new projects are a concern of great interest in current metallurgy. The methods proposed by the authors are new, mechanically and constructive simple, and bring a number of advantages over traditional method of withdrawal with roller. Future research will focus on the practically realization of systems of withdrawal described above and their implementation in current practice. In the first stage will be execute the withdrawal systems, at reduced scale, for static and dynamic testing, followed by physical models, at real scale and making determinations of mechanical strength, reliability and wear behaviour. This new withdrawing system ensures the modernization of withdrawing installation to horizontal continuous casting with the following advantages. - Simplified construction requiring a simple rotating at the entrance of the mechanism; simple electric drive; low gauge; lack of hydraulic or pneumatic system; large contact area between clamping jaws and semi–product ensure preservation of the semi-product dimensional characteristics; easy maintenance; higher reliability, energy savings, by eliminating the hydraulic installation, the clamping force being provided by springs or gravitational mechanism. Future research will focus on development of experimental models and laboratory testing facilities for withdrawal. After experimental validation, the two methods of withdrawal will proceed to their implementation in metallurgical industry. Design, optimization and realization of mechanical parts for continuous casting of metals is an area of great current due to the increased importance that this method of obtaining metal blanks is becoming more used to traditional methods of casting. Studies and research required for upgrading and improving these facilities. Using modern methods and techniques of CAD, CAM and CAE bring a number of advantages over traditional methods of design. Among these advantages are:

- Design is fast, shorter time compared to traditional methods;
- Reducing time and costs, the optimization of assemblies in terms of design and safety factor;
- Achieve rapid prototyping using CAM methods and processing on CNC machines;
- Reduce the massive cost of design, optimization and manufacturing;
- Make time reduced of drawings and the possibility of rapid processing of parts on conventional machine tools, or CNC machines.

The future research and studies of the authors will focus on comparing the various applications of CAD, CAE and CAM on the market, in order to choose the most competitive and fast in terms of initial cost, installation and speed of the work. All solid designs and simulations were conducted using the Solid Works 2009 application. They are models made by the authors at the "Eftimie Murgu" University of Resita to achieve doctoral thesis for the main author. Studies will have been published in specialized publications, and dissemination will have been made by creating Web pages useful for a rapid transmission of results by experts in the field.

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