Research to Optimize the Sustainability of Screw Conveyor System

Marius Mocanu[1,*], Ștefan Velicu[1], Cristian Ionel Păunescu[2], and Anișoara Corăbieru[3]

[1]Doctoral School of Industrial Engineering and Robotics, National University of Science and Technology POLITEHNICA, Bucharest, Romania
[2]CESTRIN SA, Bucharest, Romania
[3]Technical University "Gheorghe Asachi," Iasi, Romania
Email: contact@romocanu.ro (M.M.); velstefan@hotmail.com (S.V.); paunescu.cristian1996@gmail.com (C.I.P.); acorabieru@yahoo.com (A.C.)
*Corresponding author
Manuscript received January 14, 2025; revised April 2, 2025; accepted June 19, 2025.

***Abstract*—It is known that market economy generates products competition through constructive simplicities, low manufacturing costs/low usage prices, high sustainability, and low maintenance and compliance with EU environmental protection recommendations. The research paper presents the rewriting of the manufacturing technological process by replacing the classic technologies with sustainable ones. The purpose is to increase the hardness by metal deposition with quenching on the main components of a screw conveyor system for materials. For a transport system to become sustainable, it is necessary to improve the factors that increase performance and service life between two repairs. This can be performed using the laser technology, more environmentally friendly, and loading with electrode the clearance/breaking zone. Through deposition and cooling, this zone acquires a high hardness. The sustainable technological processes studied during the experimental investigation were applied to the active surfaces of the screw for special materials transport (semiwet screed, cement). They demonstrated a positive influence on the increase of active surfaces durability, diminution of costs and falling within the EU environmental recommendations.**

***Keywords*— surface hardened by LMD, deposition layer with quenching, sustainable technologies**

I. Introduction

At present, labor productivity must take into account the factors that govern the market economy. Technological equipment must face fierce competition in the market of similar products. In order to be able to generate a necessity of purchase, a piece of equipment must mainly meet the following conditions:

- To ensure intensive modes of operation;
- To be rigid;
- To be reliable;
- To have a good acquisition cost;
- Maintenance should involve little downtime and low costs;
- To ensure the safety of the operator during handling;
- High sustainability.

Among the most commonly used equipment that ensure the transport of materials horizontally, vertically or inclined, based on a discovery made by Archimedes, thousands of years ago, is the screw drive system (Fig. 1). This is currently found in many transport applications [1].

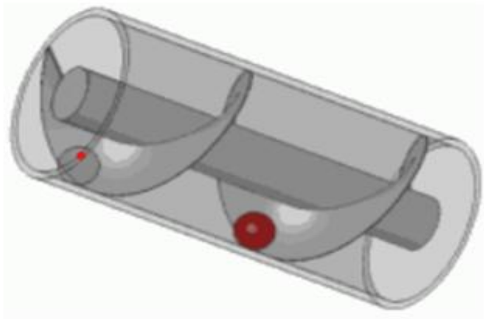


Fig. 1. Principle of screw conveyor.

Nowadays this principle is used very successfully as a conveyor for solids; it helps to eliminate the physical work of the employees in various fields of activity. Depending on the movement type of materials according to this principle, a wide range of configurations with special components was made for meeting market requirements (Fig. 2) [1].

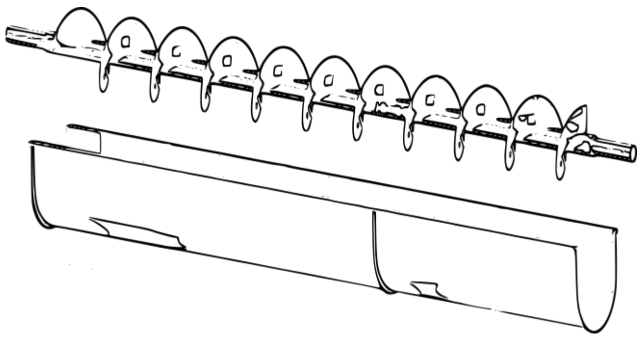


Fig. 2. Basic component of the conveyor.

The main component of the equipment is the helical element that moves by rotation the material which gets inside. The surface where this component is found can be open (Fig. 2) or closed (Fig. 3).

Fig. 3. Screw (auger) conveyor for materials.

DOI: 10.7763/IJET.2025.V17.1316

At the present moment, the market is filled with this type of mechanism, mainly used in the transport equipment. The life span of the equipment is influenced by the type of materials transported. This mechanism also entails a maintenance that often increases the operation costs and reduces the profit of a company [1].

II. Constructive Concepts Currently Used in the Material Transport System

Historically, the first generation of the concept of developing a technological system was the stone. At this moment, if the steps of a technological system components development are climbed, Fig. 10 would be probably exceeded. More exactly, this means the generation of smart materials, materials that incorporate environmentally friendly technology. The use of materials incorporating green technology corresponds to the value engineering desideratum: maximum sustainability, functionality with minimum maintenance and low expenses.

Nowadays, globalization in the sphere of industry must be perceived as the eco-motor of opportunities in a strong competition.

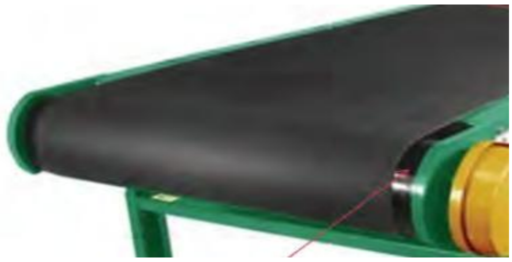
Commercial companies operating in the field of industrial engineering must continuously improve their manufacturing concepts. So, they have the availability of a fast and economically efficient reaction in the market of similar products where they operate.

These requirements must meet the unpredictable conditions and needs of the market. It is about changing the production volume at short intervals, maximizing quality and system sustainability, decreasing costs, using eco-technologies, using robotization to solve the lack of skilled labor. Thus, the current requirements of a material transport system must be related to market economic environment, through the following elements: simplicity, flexibility, reconfigurability, low maintenance costs, circular economy, pollution factors recommended by the EU requirements.

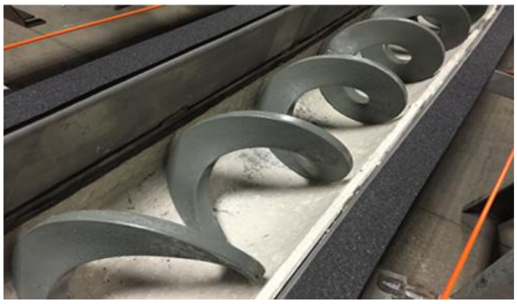
The specialized market offers several material transport systems. The most frequently used are the following: conveyor, belt conveyor, screw conveyor (auger conveyor) – Fig. 4 (a, b, c).

Among them, the screw conveyor is the most widely used bulk solids conveyor in the market. Many applications, but also a lot of chemical products, use this type of conveyor. This equipment has a special configuration. The active surfaces are coated with special materials to reduce friction and eliminate unpredictable incidents that could affect the proper operation. This fact contributes to the decrease of maintenance expenses [1].

(a)



(b)



(c)

Fig. 4. Material conveyors: (a) conveyor table; (b) conveyor belt; (c) screw conveyor.

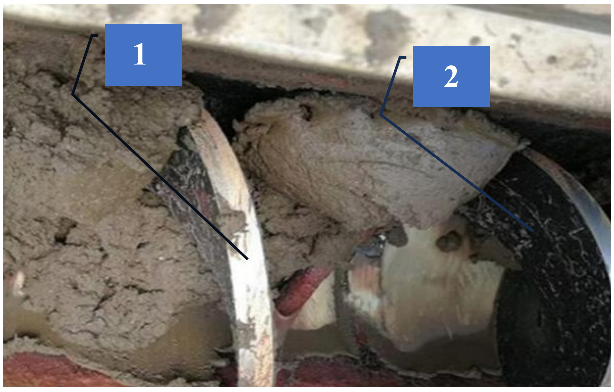
III. Requirements for the Implementation of the Sustainable Technology/Equipment Concept

The screw conveyor enters the sustainable area from the point of view of the studied eco-technological requirements, bringing economic and environmental benefits if the following conditions are met:

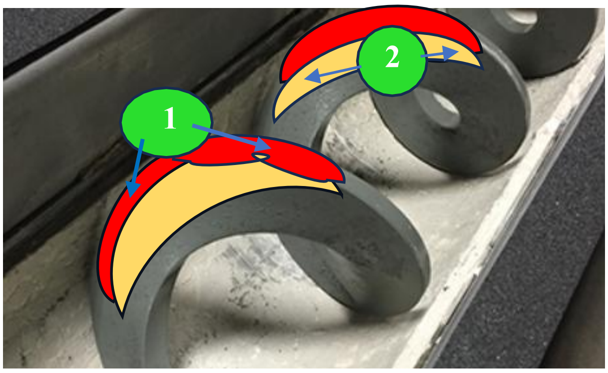
- Regarding the impact on the environment, the manufacturing technology of the equipment meets certain criteria, from the research and management of the construction process in which environmentally friendly technologies are used, up to the materials originating from the circular economy.
- From an economic point of view, the equipment sustainability means the transition from the classical model already known to a new concept. It involves green energy, materials recycling while maintaining the high quality of subassemblies by accepting innovative ways, rapid adaptation to changes requested by the EU etc.
- The screw conveyor configured as a result of applying environmentally friendly technologies (sustainable applications) has also a socially beneficial impact. It imposes high standards on how to introduce laser ecotechnology on the production line to be able to meet market demands.

IV. Research Concerning the Implementation of a Sustainable Technological Process in a Material Conveyor

The starting point of the research carried out was the problems reported by the users of the screw conveyor. Thus, corrosions of the active/passive components, sticking of the transported material on the work area, clogging/decreased capacity of transport were found out. These shortcomings were partly solved, with additional maintenance costs and equipment shutdown. Currently, technical solutions were provided through redesign. These solutions are based on classic technologies. They use more expensive materials obtained with polluting technologies, treatment of active surfaces with non-stick materials by applying technologies that release noxious substances, technological operations leaving fine powder (polishing of active surfaces), application of some elements for material dislocation (cutting teeth) through classic polluting technologies. The research paper remodels the manufacturing technology, parametrizing the critical points of the transport equipment, shown in Fig. 5.



(**a**)



(**b**)

Fig. 5. Parametrization of the auger critical points: (a) flow of material; (b) researched critical areas; (1) upper contact surface; (2) lateral contact surface.

At the same time, the influence of the transported material flow will be simulated. Based on the diagnosis obtained monitoring the researched active zones, the factors that lead to the slowing down/blocking of the transport system and to the wear of the contact area (surfaces (1) and (2) in Fig. 5) are analyzed. The concentrators of the mechanical stress that appears during the rotation movement are also monitored.

The following solution was considered to make the architecture of the system more efficient. Thus, a layer of wear-resistant material was deposited on the rotating element area of contact with the transported material.

Deposition technology, that is less polluting, can be applied (instead of surface polishing technology) generating a layer of small thickness. Materials deposited in the form of thin layer (Cr, Mo) are the key to technical progress, supporting sustainability. The thin layer is deposited using laser technology, injecting powder from the side through a metal tube (sizes from 40 to 90 µm.). The metal powder intersects the laser beam, heats, melts and fuses with the basic material of the auger side surface (Fig. 6) [2].

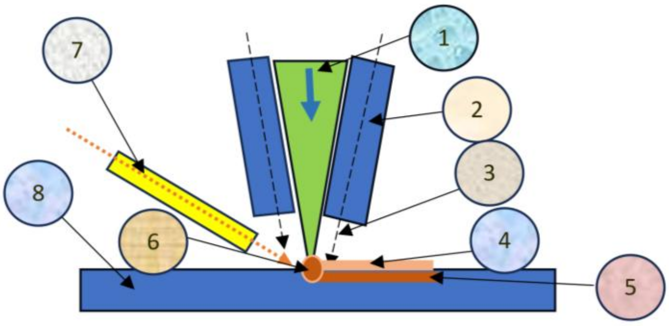


Fig. 6. Laser beam and side-injected powder deposition (1- laser beam, 2- optical focusing module, 3- coaxially supplied protection gas, 4- de-posited material, 5- thermal influence zone, 6- molten metal bath, 7- addition material and carrier gas, 8- basic material).

This technological process is recommended to create a metal coating by powder depositing. The side contact surface of the auger will have a high resistance to corrosion and will allow the transported material to slide due to minimal friction. The solidification of the deposited material is the main advantage of the laser depositing ecotechnology. This brings a fine metallic structure and superior properties to the surface subjected to the wear/seizure process [3, 4].

The deposition is carried out continuously on the surface of 1/3 of the auger width (Fig. 7).

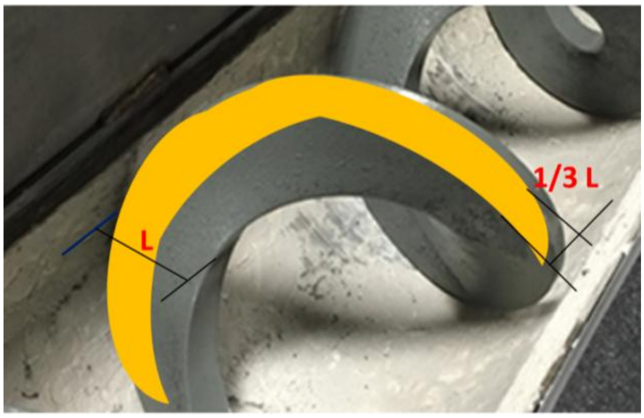


Fig. 7. Auger with metal deposition.

The thickness of the deposited layer depends on several parameters. Such parameters are the distance from which the spraying is done and the angle under which the material is deposited. Other parameter is the geometry (alignment of the surface planes of the part with the deposition head direction). Some of the variations that may occur due to the geometry can be reduced by rotations of the part on one or several axes during deposition.

When depositing thin films on helical surfaces, the process involves some complex geometric considerations. Formulas for this process should address parameters such as pitch (P), radius (R) and angle (θ) of the helix, as well as the thickness and evenness of the deposited film, here are some general considerations and formulas that may be relevant:

1. *Helical surface area*: The area of a helical surface can be calculated using geometric formulas specific to helix parameters, like pitch (P), radius (R) and angle (θ). For example, the surface area of a single helix round can be approximated using the formula for the lateral area of a cylinder:

$$A = 2\pi RP \quad (1)$$

Only 1/3 of this surface will be coated by laser beam and side-injected powder deposition.

2. *Volume of material deposited*: the volume of material deposited on the helical surface can be estimated according to the intended film thickness (T) and the calculated surface area (A). This can be expressed as:

$$V = AT/3 \quad (2)$$

3. *Deposition rate and time*: The deposition rate (R_d) of the thin film on the helical surface by laser beam and side-injected powder deposition can depend on factors such as temperature, material properties and process parameters. The deposition time (t) necessary for achieving the intended film thickness can then be calculated as:

$$t = V/Rd \quad (3)$$

4. *Evenness of deposition*: Achieving an even thickness of the film on the helical surface is essential. Formulas to predict film evenness may involve factors like powder injection angle, screw (substrate) rotation correlated with laser beam translation, also possible variations of powder flow distribution.

5. *Film stress and adhesion*: In the case of thin films deposited on helical surfaces, the considerations on film stress and adhesion are crucial for ensuring mechanical integrity and durability. Formulas for estimating film stress, such as the Stoney equation, and evaluating adhesion strength, like the critical load in tribology tests, may be relevant.

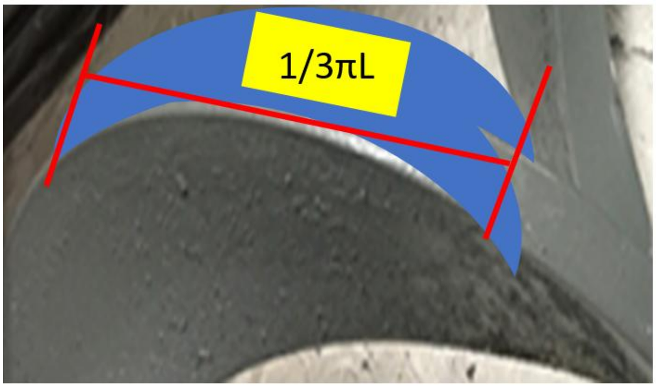


Fig. 8. Deposition by flux welding.

In order to eliminate concentrators from the contact area of the screw with the case, following the transported material deposits, additional material is applied by flux core welding on the edge of the screw, which acquires a high hardness through cooling (50–56 HRC) (Figs. 8, 9).

This type of technological ecoprocess is less polluting and the zones of new material deposition are smaller in area. (Fig. 8)

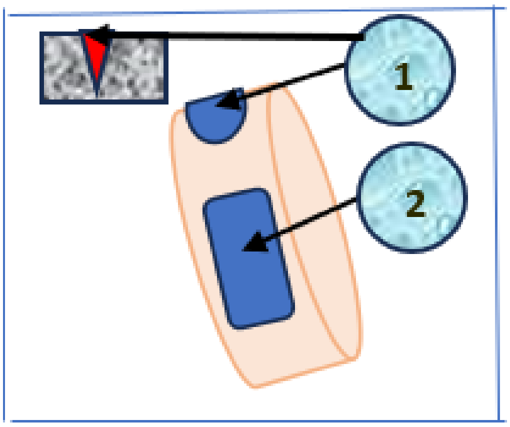


Fig. 9. Metal deposition on screw contact surface (1, 2 material deposited by flux welding).

The deposited material enters the channel made by mechanical machining operation; the depth is 2 mm (± 0.1 mm). There is no need for mechanical machining operations after welding deposition. In this context, the remodeling of the contact area enhances the performance of the equipment. A better performance is obtained by improving the quality of transport active surface and of break edges made for detaching the deposited material [5]. Tables 1 and 2 list the technical characteristics of the deposited material.

Table 1. Typical weld metal composition

[wt. - %]	C	Cr	Mn	Mo	Ti	Si	Fe
Min.		6.0	1	2			
Max.	0.35	7.5	1.5	2.5	+	0.7	Bal.

Positions: all except PD, PE and PG
Redrying: 300–320°C/2h

Table 2. Dimension

Φ[mm]	Length [mm]	Welding current [A]
2.5	350	80–120
3.25	350	100–160
4.0	450	160–220
5.0	450	190–260

The coated surface must not exceed ½ of the length of the auger circumference. This length will be divided into three equal zones (they have the role of teeth for detaching the material).

The composition of the deposited material ensures a good hardening of the auger active parts. Especially the high content of Cr and Mo gives an increased durability through the chemical compounds that are formed, wear resistance and the hardening that takes place during the cooling process. The chemical compounds based on Cr and Mo obtained during the micro-alloying process followed by rapid cooling underlie the hardening of the auger active parts [6].

V. Conclusions

In conclusion, sustainability is becoming more and more a mandatory course of action as the negative impact of the changes in the market is accentuated at an ever more alert pace. Although there are still some obstacles, especially related to sometimes higher costs or even prejudices, the advantages of sustainable technologies/equipment/systems could pave the way to a cleaner future. This research work, carried out in the laboratories of the Măgurele Research Platform by a multi-professional team (technologists, metallurgist, economist), identified the possibility of updating the making of an auger intended for certain materials, bringing into discussion/analysis/research less polluting manufacturing technologies. The layers deposited by means of the researched ecotechnologies ensure the durability of the auger, wear resistance and high reliability of the material conveyor. The determining factor in the achievement of the research goal is the ecotechnology, Ecotechnologies are used for the application of carbides and chemical compounds based on Cr and Mo obtained in the surface layer of the active parts through micro alloys in liquid phase, followed by the accelerated cooling of the deposited layer, as well as the material deposited on the front side. Large economic companies could modify their manufacturing practices for the benefit of the environment. This analysis was also presented by the Governor of the BNR at the Conference with the theme: Development - from planning to stability and sustainability.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

MM carried out the optimization of the parts and tests, collected data and wrote the paper; SV conducted the research and analyzed the data; CIP carried out the studies for the economic impact and sustainability and provided the technical documentation and translation services; AC conceived and designed the analysis and contributed to the research plan of the work; all authors had approved the final version.

References

[1] Wamgroup. 2024. [Online]. Available: https://wamgroup.ro/ro-RO/WAMRO/Family/398/Separatoare-Solide-Lichide-cu-Snec accessed in 12.02.2024.

[2] M. A. Mahmood, D. Chioibasu, A. Ur Rehman, S. Mihai, and A. C. Popescu, "Post-processing techniques to enhance the quality of metallic parts produced by additive manufacturing," *Metals*, vol. 12, no. 77, 2022, https://doi.org/10.3390/met12010077.

[3] D. Bardac, Şt. Velicu, S. Pălălău, and C. Rânea, *Tool Hardening Technologies*, (in Romanian) Didactics and Pedagogy Publishing House, Bucharest, 1997.

[4] Trumpf. 2024. [Online]. Available: https://www.trumpf.com/ro_RO/solutii/aplicatii/sudura-cu-laser/incarcare-prin-sudura/, accessed in 12.02.2024

[5] A. Corabieru, S. Velicu, P. Corabieru, and M. Sohaciu, "Research on metal parts hardening by superficial alloying," *Revista de Chimie*, vol. 70, no. 2, pp. 470–474, 2019.

[6] C. Ruset, E. Grigore, T. Gläser, and S. Bausch, "Combined treatments-A way to improve surface performances," *Journal of Optoelectronics and Advanced Materials*, 2007.

[7] P. A. Vetter, T. Engel, and J. Fontaine, "Laser cladding: The relevant parameters for process control," *Laser Materials Processing: Industrial and Microelectronics Applications*, SPIE, vol. 2207, pp. 452–462, 1994.