Chapter

Reducing Clogs in Power Boiler Biomass Feeding System

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Abstract

With the constant increase in pulp and paper production, the demand for wood has been intensifying, and consequently, the availability of forest residues and bark for energy generation grows year after year. Seeking sustainability between forestry operations and the consumption of biomass, Klabin's paper production plant in Telêmaco Borba (Monte Alegre Unit) has been increasing the consumption of forestry residues and bark, and as a result of the particle size characteristic of these materials, occurrences of clogging of biomass transport screws became constant, reflecting in operational bottlenecks of the boiler. Seeking to solve this problem, the "Problem-Solving" methodology was used and actions were implemented in the screw that had the highest frequency of occurrences, based on the main idea of avoiding "empty spaces" and obstacles in the path of biomass. After the implementation of all items, a 75% reduction in the frequency of occurrences was obtained, reaching the objective proposed at the beginning of the work, showing that there are challenges in the pulp and paper industry that can be solved or reduced through quick solutions, cheap and effective.

Keywords: biomass, clogging, screw, boiler, residue, empty spaces

1. Introduction

The evolution of energy consumption, based on fossils, has led humanity towards an insecure and expensive energy matrix. This has led many countries to consider the need for profound changes, including an intensification of the use of other energy sources, especially renewable ones, including wood [1].

The energy use of forest biomass also promotes increased use of existing commercial forests, due to the possibility of using forest residues, which are generally left in the field after harvesting and constitute potential sources of energy; in addition, the energy use of forest residues can economically make forest management activities and silvicultural treatments feasible [2].

The main existing barriers to the greater use of renewable energies are of an economic nature. It is considered that one of the most important factors in the use of biomass as an energy input, regardless of the technique used, refers to the cost of harvesting and transporting this raw material [3].

Among the main biomasses lignocellulosic of agricultural and forestry origin, may include rice straw, rice husk, wheat straw, sorghum straw, corn husks, sugarcane bagasse, wood chips, branches and sawdust, grass, etc. In addition, this type of biomass is composed mainly of cellulose, hemicellulose, and lignin [4].

Nowadays, the integration between forest harvesting and pulp mills became closer, always seeking more yield and sustainability in the integrated production chain. Reducing the age of wood, increasing areas for planting and the proportion of total trees destined for the production of pulp keep pushing the consumption of waste generated, both in harvesting and in wood processing. For these residues, the most commonly used destination is burning in power boilers to compose the industrial energy matrix, for internal (or external) use, in addition to completing the wood cycle, completing the total use of the cultivated material.

With the frequent increase in paper production and demand for wood by the Monte Alegre Plant, the availability of this type of material for burning is constantly rising and, consequently, the consumption by power boilers (see **Figure 1**).

The valuation of forest residues for energy purposes supports some critical quality parameters that uniformity of composition is one of them. Since it is a mixed material, the ideal is to maintain the most uniform possible proportions between the various components of residual biomass (wood, bark, branches, thick roots, etc.). When it is just wood chips, it is very important to specify the contents of maximum bark and ash they may contain, in addition to the moisture content that is critical for energy performance [5].

As much as there are technological advances in the ways of harvesting and debarking, there are still several factors that hinder the consumption of forest residues and bark. The main one is based on the physical and granulometric quality of the material itself, which, residues (especially eucalyptus) and bark, have fibrous characteristics, forming the so-called "ribbons" or "strips."

At the Monte Alegre plant (Telêmaco Borba, Paraná, Brazil), there are two biomass-based power boilers to supply the steam demand for the plant. These boilers feature different operating technologies: bubbling fluidized bed (BFB) and

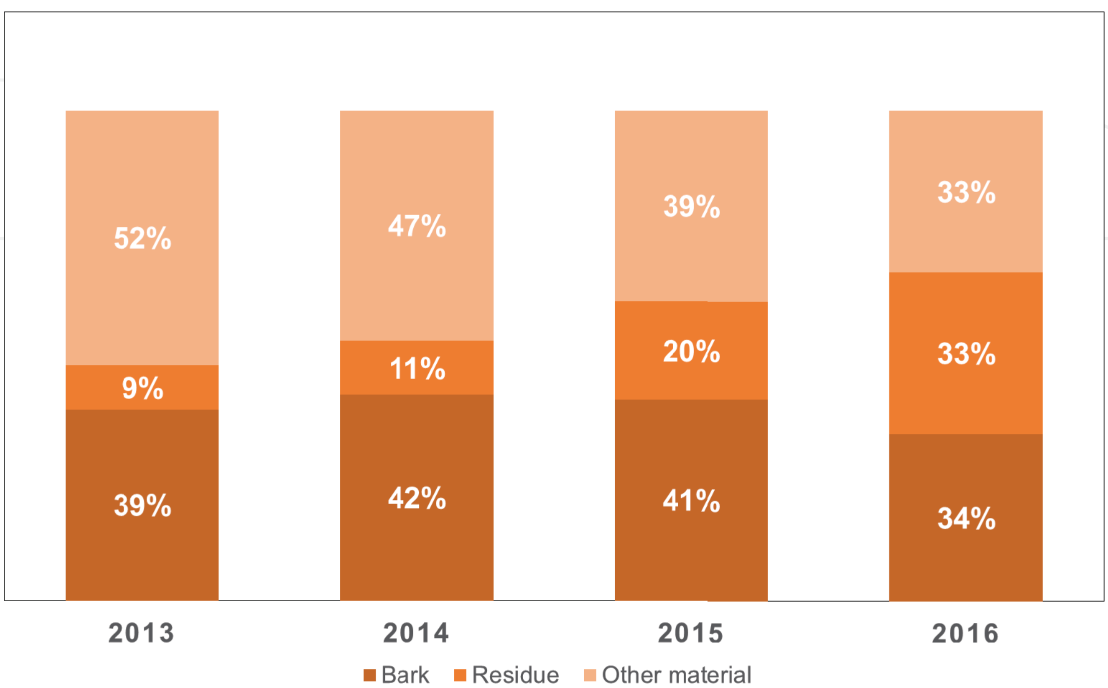

Figure 1.
Evolution in the composition of the total biomass consumed in Monte Alegre in the last four years.

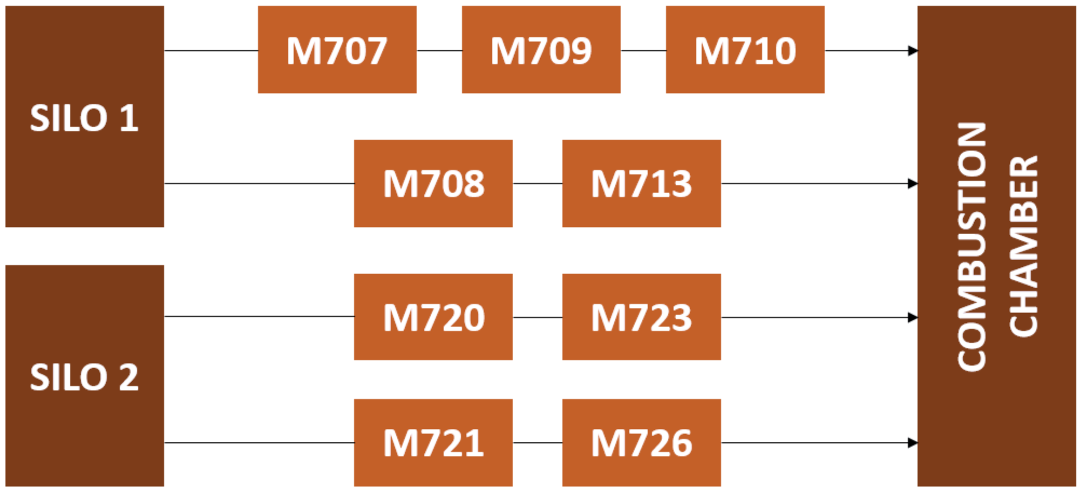

Figure 2.
Representative drawing of boiler feed system via biomass screws (adapted from Babcock Power España [6]).

circulating fluidized bed (CFB). In the CFB boiler, biomass is supplied to the power boiler and stored in two silos equipped with continuous level transmitters (weighing cells). Each biomass silo feeds two fuel lines and each silo is discharged by rotating devices with a drag arm and discharge screws. Each fuel line has a discharge screw, which transports the biomass to the metering screws and only in line 1 there is an additional transport screw [6]. **Figure 2** shows the representative design of the described system.

One of the consequences of high waste consumption is the clogging and kinking that this type of material causes. In addition, the fibrous characteristic of this biomass makes the material's specific volume larger, causing the feed screws to work at increasingly higher speeds in order to maintain constant the biomass feed mass rate and, thus, increasing the possibility of entanglements. These factors, linked to the high rate of waste consumption, contributed to one of the power boilers starting to suffer from events of this nature in 2015, increasing the unavailability of the biomass transport screws.

This deviation from an abnormal operating condition brings several problems, which are as follows:

a. Unavailability of equipment – while clogged, the screw cannot be used to feed biomass;

b. Increase in power of other screws – with the clogged screw stopped, the other power lines proportionally assume the lost load and increase the operating speed, increasing the possibility of these other positions also clogging;

c. Punctual loss of steam generation – the delay between stopping the clogged screw and compensation for fuel oil causes a punctual loss of steam generation;

d. Risk of accidents – the unclogging process is manual and depends on human interaction with the equipment, which characterizes the activity as dangerous;

e. Material wear – unwanted equipment stops always bring risks of breakage and unnecessary peripheral efforts.

Therefore, the objective of the work was to reduce the occurrence of clogging, increasing the availability of equipment.

2. Methodology

The work followed the traditional problem-solving methodology, developed in seven main steps (as shown in **Figure 3**) based on the PDCA (plan-do-control-act) cycle. This method has been highlighted in the organizational environment as a management method for process improvement and problem-solving, being the basis of continuous improvement, and can be used in any type of organization, whether it is a private company, a nonprofit organization, or in a public sector. The PDCA is a method that manages the decision-making in order to improve an organization's activities, much explored in the pursuit of improved performance. This makes the PDCA very important and contributes significantly to the achievement of better results [7].

The PDCA in organizations obtains opposite results, with extensive and voluminous plans based on the procedures followed in step "P" of the cycle PDCA that determines where you want to go by imposing effective planning, achieving a way to the desired situation, in its implementation the practice of "D" bringing the uncertainty of carrying out an important activity, because through audits it is found a large number of activities outside your procedure, following step "C" identifying something that is not going as planned. Finally, step "A" is responsible for closing the PDCA cycle, so little practiced, but through convincing actions based on failures in the previous steps ensuring problems arising giving meaning to an improvement cycle continuous process of a given process [8].

The concept of the PDCA methodology does not consist only of implementation of strategic changes, but also organizes the successive improvements in circles, consisting of four phases as described in **Table 1** [9].

Adapted from Costa [9].

Problem-solving methodology seeks to objectively define and surround the problem analyzed, identify and mitigate the root causes of each type of failure mode

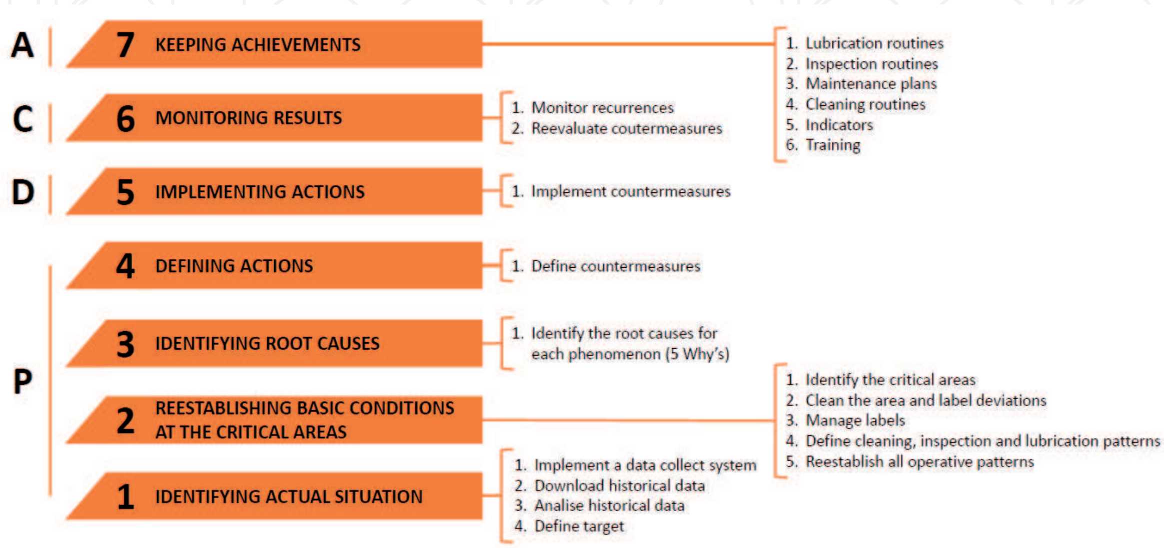

Figure 3.
Problem-solving road map (seven steps).

P	Plan – this phase starts from the preexistence of description and basic understanding of what is intended with the whole process. It consists of defining the necessary actions, sizing resources, conditions, identifying dependencies and implications, assigning responsibilities, and specifying the process for measuring performance and expected results. This phase is considered complete when a plan sufficiently detailed to support execution is proposed and approved for implementation. It is at this stage that the priority items for implementation are chosen.
D	Do – execution of the actions determined in the plan, from obtaining resources and conditions to the implementation of the measurement and control process. Its result is a set of systems, processes, equipment, or that which has been objectified in the plan, properly implemented, and in conditions to be operated and to produce the desired effects.
C	Control/Check – more than measuring, it implies ensuring that the process has been executed through careful observation of its planned performance in phase P. For this, monitoring and deviation reports are used, showing whether or not the established control parameters were met.
A	Act – in fact, more appropriately, this phase should be called "how to learn from mistakes and successes," as it is the practical use of the results of the process, good or bad, to be introjected in the culture and in the methods and systems of organization. Thus, in the previous phase (verify or control) two basic conclusions can follow—either everything went well or there were problems. In the first hypothesis, the more favorable process that was experimentally outlined in the planning and that was successful should be institutionalized and made a standard for the future. People need to be trained or educated to act in the way that worked, followed, in a new cycle, by the phases of planning, executing, verifying, and acting. This implies that the organization learns from what went right.

Table 1.
PDCA cycle steps.

and implement controls, so that there are no recurrences of the problems and that earnings are routinely maintained.

As a first step, the methodology provides for the definition of the focus areas of the work, since the biomass lines (four in total) contain nine screws and, through the work, the most critical position was highlighted.

Having chosen the focus area, possible problems related to the base condition of the equipment, maintenance, and lubrication routines, in addition to operating standards that, in some way, could be contributing to the problem observed were verified.

With the definition of the problem, the focus area and the guarantee of systemic maintenance and operating standards, the root causes of each failure mode that caused the stoppage of the biomass screw were investigated. Using the "5 Whys" quality tool, the reasons were broken down to the last level of knowledge, making it possible to define countermeasures to mitigate each failure mode. After the measures were implemented, the recurrence of problems was monitored and, if that happened, the analysis cycle was remade, with new countermeasures defined. Finally, the maintenance of the gains obtained was guaranteed through the systematization of controls.

3. Results

A large survey carried out over the year 2015 (see **Figure 4**) showed that position M710 was the main responsible for the blockages of the biomass system (35% of the total occurrences), being, therefore, the position chosen for the study and solution of the problem. **Figure 5** shows the simplified schematic drawing of the main components of the equipment in the M710 position.

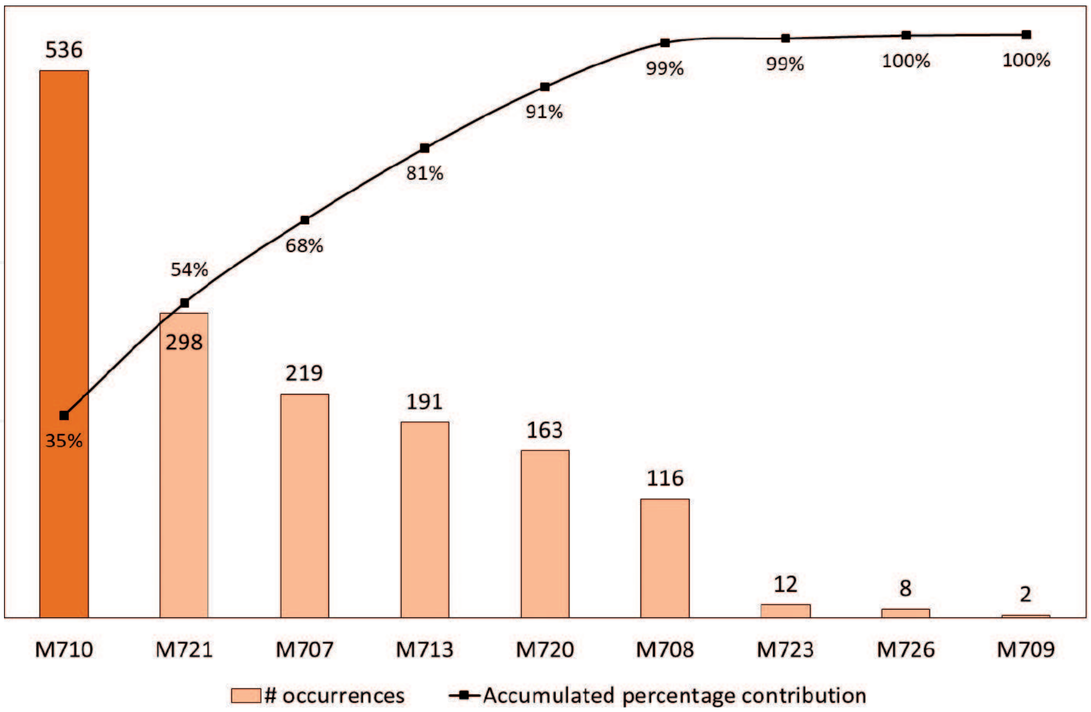

Figure 4.
Number of cloggs per position in 2015.

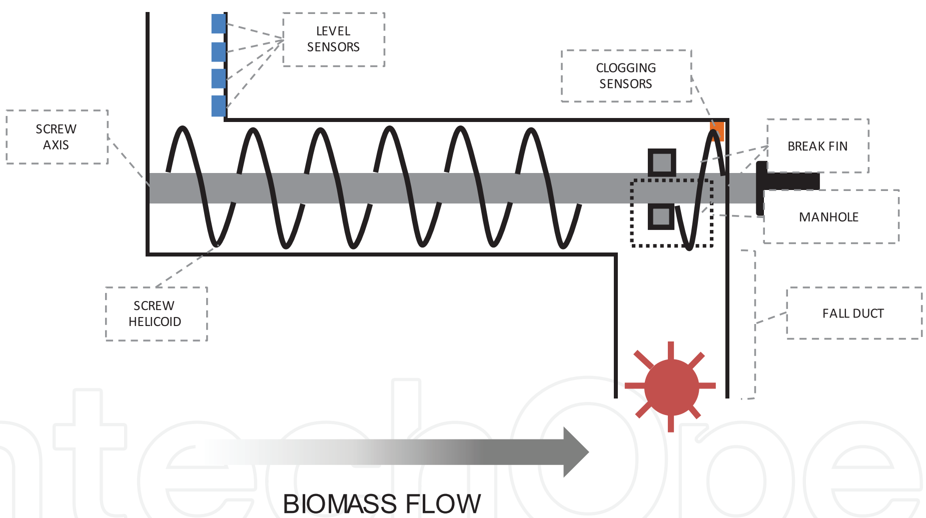

Figure 5.
Schematic drawing of the M710 thread and main items.

The initial analysis of the work on the position defined as the focus aimed to identify external factors that could contribute to the clogging being recurrent or severe. Some indicators such as average precipitation, average steam generation load, and possible operational variations between groups or work shifts did not show influence with the occurrences. As already known, the particle size quality of biomass was a point of attention, but not directly addressed, as the actions for this topic are medium and long term.

Through the "5 Whys," it was possible to observe that the biggest challenges of the M710 position were the "empty spaces" and the obstructions present in the path taken by the biomass. The actions focused on solving these root causes were:

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3.1 Manhole readjustment

The manhole present in the screw fall duct was misaligned with the fall wall profile. This misalignment generated an "empty space" inside the pipeline, serving as support for the deposition of biomass, which, over time, totally obstructed the transverse profile of the pipeline, causing clogging. Thus, the simple solution was to fill the empty space with metallic material, welded to the manhole, which would eliminate the space and keep the walls of the entire duct in the same profile, as shown in **Figure 6**.

3.2 Clog sensor stem improvements

The M710 screw clogging sensor is simply a rod with tabs that when rotated by the build-up of biomass, triggers a physical sensor that stops the thread. During the observations, it was evidenced that the rod was very close to the biomass level of the screw itself, causing the material to pass over the rod, and not under, as it should be. In this way, the rod, in addition to not being activated as it should, served as a barrier for the free fall of biomass, being a major clogging point. By increasing the height of the stem by approximately 21 cm, it was possible to observe that the transported biomass returned to normal flow, eliminating an accumulation point.

3.3 Modification of the thread shaft fin

Widely known as "break-mount," the fin located at the end of the biomass screw is intended to push the material down the pipeline, avoiding agglomerations and possible clogging. During the work, it was observed that the angle between the face of the fin and the axis of the screw has a great influence on its performance, and originally, the fin had its face towards the beginning of the screw. With this configuration and direction of rotation of the thread, the fin did not push the material down, but back into the thread, in the opposite direction to the natural flow of transport.

The position of the fin was changed (according to **Figure 7**) so that it pushed the material in the same transport direction. With this new configuration, the fin, in addition to helping to transport the material, prevents the biomass from being trapped at the beginning of the drop duct.

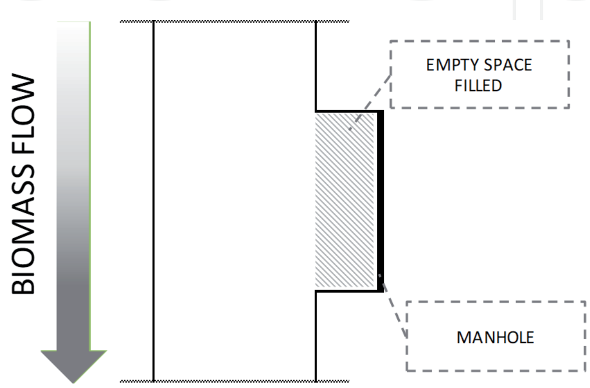

Figure 6.
Adequacy of the manhole of the biomass pipeline.

Figure 7.
Thread shaft fin position before (left) and after (right).

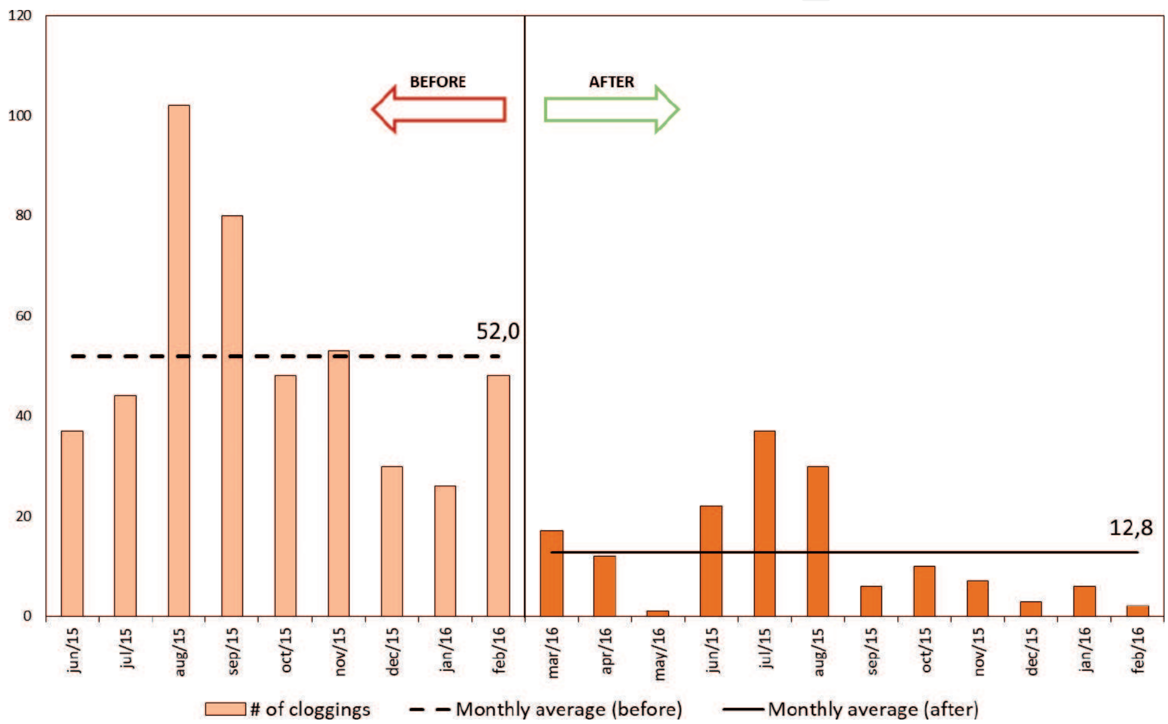

Figure 8.
Evolution of the number of cloggs of the M710 screw.

3.4 Changing the operating logic

Another important point dealt with in the work was the reactive actions taken after clogging that could prevent new occurrences or reduce the man–machine interaction in the thread unclogging process.

When the screw stops due to clogging (when the sensor is activated), an automatic operating logic was created to rotate the screw in the opposite direction to normal operation, for a few seconds and at low speed. The purpose of this sequence was to loosen any material that might be trapped above the drop duct or sensor rod. With reverse movement, the biomass detaches and falls, freeing the material duct and avoiding the need for human intervention in the machine. With the development of this logic, most of the clogging was resolved soon after the occurrence (sensor activation) and, thus, the machine availability increased significantly, while the human-machine interaction reduced.

In addition to these actions, others of lesser impact were also applied to contribute to solving other voices of the problem. The result of all the actions together can be seen in **Figure 8**, where the monthly average number of occurrences of clogs dropped 75% after the implementations. Consequently, the frequency of unclogging interventions dropped from 1.7 times a day to less than 0.5.

It is known that eliminating this type of occurrence is practically impossible for this position, since, due to the structural shape and distribution of the boiler support points, the M710 thread is the one that receives material in a different direction from the natural flow, where the entire biomass line is tortuous.

However, the actions developed were of low cost and did not require the boiler to be stopped, thus configuring a good option for solving this type of problem. In addition, any of the actions can be extended to other positions of the threads in the boiler, making it possible to drastically reduce problems related to clogging.

4. Conclusions

Using a well-known methodology, it is concluded that the actions actually attacked the root causes that promoted plugging in the biomass system, especially in position M710. The great gain of the work was the low cost and agility in carrying out the proposed actions, surpassing expectations regarding the return that was thought to be possible to achieve. Therefore, the work reached the proposed objective of reducing the occurrences in the power boiler through simple and easy-to-apply solutions, showing that, in general, there are opportunities for solving problems that involve low cost and high return.

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