Control of the work, elements and modelling of the bucket elevators in modern software packages

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Abstract. Bucket elevators is the most commonly used device for the transport of bulk, granular materials, from lower to higher levels. This role of the bucket elevators has been achieved thanks to its advantages, such as low power consumption, large capacities, high reliability and low maintenance costs. This paper is based on theoretical and practical analysis of the operation of the bucket elevators. The basic elements of the bucket elevators are presented in this paper, analyzing their advantages and disadvantages in practical application. The possibilities of electronic control of the bucket elevators operation as a basis for preventive maintenance are examined. The possibilities of modelling in modern software packages, individual elements of bucket elevators, primarily connecting elements, are presented. Considering that all the standards and recommendations from the practice, related to the use of bucket elevators, are covered by the analysis of the work and elements of the bucket elevators, this paper can serve as a guide in the selection and design of bucket elevators.

1. Introduction
In industrial plants, bucket elevators have been in use for more than a hundred years, and are used to transport grain and powder materials. The first bucket elevators were made of wood, and the drive was carried out through the transmission of flat belts. Today, the bucket elevators have a rubber belt or chain (one or two) as pulling elements, buckets of metal or plastic as supporting elements and a metal support structure covered with sheet steel with galvanized or painted surface protection. There are also bucket elevators for the transport of piece material, but they are rarely applicable and are not the subject of this work.

The use of these conveyors ensures lower energy consumption and a lower percentage of fracture of the transported material compared to other types of conveyors. Bucket elevators with belt as a pulling element in relation to the elevators with chains are characterized by a steady, silent operation, may apply higher speed, lower their weight, dimensions and price. Bucket elevators with chain are used for larger tensile forces in the pulling element, as well as at higher heights of the conveyor - over 50 meters.

The economic advantages of the bucket elevators are energy efficiency, long service life, low maintenance costs and high flexibility of the system. The technical advantages of the bucket elevators are high reliability of the system, relatively high safety of the device, slight damage to the transported material, minimal maintenance and quiet operation. Thanks to all of these advantages, the wide
application of this type of conveyor is understandable and can be predicted that in the future will have a significant place in industrial systems.

Self-supporting bucket elevators, Figure 1, are stable structures and anchoring is done using a rope. Given that rope control and handling is left to employees, this system has proven to be impractical and unsafe because periodic inspections are performed only at the beginning, while control after a while is generally neglected, which in many cases led to the overturning of the bucket elevator. Supporting bucket elevators are placed in the stack and are attached to it, or are connected to another object or other part of the equipment, Figure 2.

2. The control and safety devices at bucket elevators

The interruption of the operation of the bucket elevator is most often due to the transverse displacement and falling of the belt from the drum and its jamming, the appearance of a foreign body in the bucket elevator, or a combination of insufficient tension and overload. Due to the stopping of the movement of the belt, and the continuation of movement and rotation of the drive drum, slipping occurs, and after a while occurs heating, ignition and ultimately cracking of the belt. In order to prevent this it is necessary to monitor and compare the speed of the drive and tension drums, as well as belt speed. With the same goal, it is necessary to carry out continuous monitoring of the position of the belt. If values exceed the permitted limits of any of the monitored parameters, the belt should be automatically stopped with a warning on the control panel. Figure 3 shows safety and control devices, i.e. sensors, which allow full control of bucket elevator operation, [1].

Based on the above, on the bucket elevators, it would be necessary to control the speed of the belt, control the speed of the drive and tension drum, check the position of the tape, monitoring the flow of material and control the temperature of the bearings on the drums (or sprockets). In order to enable continuous monitoring and comparison of all the above parameters, it is necessary to connect all control and safety devices to the control unit, which would later be connected to the serial communication system monitoring, [2]. Figure 4 shows the WATCH DOG control unit.

Drive drum speed sensors and belt speed sensors are used to measure the speed of the drum rotation and belt speed. In this way, it is possible to detect the eventual occurrence of a slipping of the belt, which is manifested as the appearance of a difference in the speeds of the belt and the drive drum. Similarly, controlling the speed of the drive and tension drum can detect slipping of the belt.
Two variants of the drum speed sensors are most commonly used: inductive sensor, Figure 5a, and rotary encoder, Figure 5b.

The belt alignment sensor plays a role in monitoring the position of the axis of the belt, which should be normal in relation to the axis of the drive drum and pass through the middle of the drum. In the case that the belt transversely moved, and that the axis of the belt moves from the middle of the drive drum, it is necessary to turn off the drive to prevent the belt from falling, firing and cracking likely. For the control of the belt position are mainly used capacitive sensors, which are connected in pairs in two variants, in-line and in parallel depending on whether plastic or metal buckets, Figure 6 and Figure 7. [3]
Figure 5. Speed sensors: inductive sensor (a) and rotary encoder (b).

Figure 6. Belt alignment sensors for metal buckets (inductive sensors) [1].

Figure 7. Belt alignment sensors for plastic buckets (inductive sensors) [1].
The material flow sensor is used to monitor the presence of material in the gravity slider through which the material is transported after unloading from the buckets in the head of the bucket elevator. In case the gravitational slider is filled with material and there is a complete interruption of the flow of material in it, it is necessary to switch off the bucket elevator, because due to the accumulation of transported material, first in the head, and then in other bucket elevator parts, would cause damage and breakdown. As a material flow sensor, the capacitive sensor is most often used, Figure 8. [4]

Bearing temperature is a key indicator of bearing health. Temperature sensors can be used to monitor temperature on a wide range of industrial machinery including conveyors, bucket elevators, motors, gearboxes, … The bearing temperature sensors designed to screw directly into an existing grease zerk fitting on a bearing housing, Figure 9. Each sensor is fitted with a grease nipple to allow lubrication of the bearing without the need for removal of the sensor. [1]

Figure 8. Capacitive material flow sensor [4].

Figure 9. Bearing temperature sensors.

3. Modeling of the bucket elevators in modern software packages
Modeling is called the formation of certain objects, using computers and computer graphics. Computer models are used for the formation of working documentation, for the technological production of parts and for engineering analysis.

At the beginning, it is necessary to analyze the geometry of the element that is to be modeled, in order to select the fastest and easiest way in which this geometry can be obtained. This element analysis can significantly shorten the drawing process and improve the end result. Depending on the type and shape of the element, in software Autodesk Inventor Professional, the modeling is done in the sheet metal and part design modules, [5]. By choosing a given module, the basic settings are made according to the design method. Since thin plates are present on the bucket elevator, in this paper will be something more to say about the module sheet metal.

By using the sheet metal module, the development of complex sheet surfaces is achieved in one move, which are made significant savings both in terms of working hours and by the accuracy and reliability. After forming the desired drawing in the plane, it comes out of the drawing mode in the plane (sketching). Then it returns to the 3D view, where operations are performed with formed sketches, and operations on formed bodies. Some of the basic operations in the module sheet metal are the following.

By using command face, based on the drawing, flat plate are obtained. On these plates, as well as on all other models made in the sheet metal module it is possible to perform all operations as well as in the part design module. To add a sheet metal surface on the already formed parts used command flange. It is most commonly used for making smaller stiffeners. Modeling of flat surfaces of straight edges, which are processed exclusively by bending in the press, is done using the contour flange command.

Loftedflange is a command for modeling transition elements. It is very often applied in the modeling of bucket elevator elements. In the command window, the number of bending lines can be adjusted. With the increase in the number of bending lines, a more accurate shape of the circle is obtained.

Command contourroll is used in the visualization and obtaining developed measures for bending hot-rolled profiles. The command hemm is intended for bending the ends of tin plates. Bending is done
with the aim of getting stiffening or avoiding sharp edges. The `bend` command serves to connect two independent tin surfaces. The command is applied when modeling parts in assemblies.

In modeling, the first formed by individual elements, which are then assembled into sub-assemblies, in order to finally generate the final assembly. Figure 10 shows the model of the folding box of the bucket elevator, which is formed in the software `Autodesk Inventor Professional`. The folding box is mounted in the bucket elevator head and serves to guide the conveyed material after unloading.

![Figure 10. Folding box assembly.](image)

### 4. Conclusion

A bucket elevator is a frequently used conveyor for the vertical transport of granular and powdery materials. The structure is closed, which ensures hermeticity, but due to the accumulation of dust that is intensely occurring, it represents a device in which ignition and explosion can occur. Also, unwanted occurrences may occur, such as transverse displacement and falling of the belt from the drum, slipping the belt on the drive drum, and so on. In order to avoid all this, it is necessary to place different sensors on certain positions on a bucket elevator in order to control the work and prevent the occurrence of damage by timely action. Different sensors and switches allow smooth running of the bucket elevator and protects it from damages. Monitoring listed parameters can prompt routine maintenance procedures such as greasing or predicting when rebuilds are necessary. Application of modern software, such as `Autodesk Inventor Professional`, allows for faster design, modification, analysis, formulation of technical documentation and, finally, the production of bucket elevators.

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