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FULLY AUTOMATED PORTAL SCRAPER

POTPUNO AUTOMATIZOVANI PORTALNI STRUGAČ

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ABSTRACT

Portal scraper is machine widely used for bulk material supply of industrial facilities. Its performance is usually highly dependable on the ability of human operators since it relies on manual operation for some of its most sensitive functions. Fully automated portal scrapers with appropriate solutions for critical operation situations can significantly contribute to increasing the reliability of bulk material supply to the production process. Because of that, the analysis of portal scraper functionality and recognition of the main points of concern for its proper operation are presented in the paper as a base for the development of fully automated control solution. The time critical operations were identified and appropriate algorithms were developed for the reduction of time spent in unproductive motion.

Key words: *portal scraper, automated, bulk material.*

REZIME

Portalni strugač je mašina koja ima široku upotrebu u industrijskim postrojenjima. Koristi se kod skladištenja i snabdevanja postrojenja rasutim materijalom. Materijal se obično skladišti u dve gomile koje su poredane u liniju. Dok se jedna gomila formira sa druge se izuzima materijal i transportuje prema liniji za proizvodnju. Pored snabdevanja proizvodne linije rasutim materijalom, važna uloga portalnog strugača nalazi se i u mešanju i homogenizaciji rasutog materijala. Performanse portalnog strugača su obično značajno zavisne od sposobnost operatera posto se za izvođenje nekih od najkritičnijih funkcija oslanja na ručno upravljanje. Potpuno automatizovan portalni strugač sa odgovarajućim rešenjima za situacije u kojima se izvode kritične operacije može značajno da doprinese povećanju pouzdanosti snabdevanja procesa proizvodnje rasutim materijalom. Zbog toga, analiza funkcionalnosti portalnog strugača i uočene glavne tačke koje utiču na kvalitet njegovog rada su predstavljeni u ovom radu kao osnova za razvoj potpuno automatizovanog sistema za upravljanje. Na osnovu analize zaključeno je da su glavne tačke koje utiču na kvalitet rada vremenski kritične operacije, posebno u situacijama kada se vrši oblikovanje sveže gomile sa materijalom, i održavanje odgovarajućeg protoka materijala sa gomile na pokretnu traku i dalje u proizvodnju. Definisan je algoritam za određivanje putanje koju portalni strugač treba da sledi tokom rada da bi se miniminiziralo vreme potrošeno u neproduktivnom kretanju tokom formiranja nove gomile. Takođe predložen je način za održavanje odgovarajućeg protoka materijala sa gomile na pokretnu traku na osnovu regulacije struje motora koji služi kao pogon lanca strugača.

Ključne reči: *portalni strugač, automatizacija, rasuti materijal.*

INTRODUCTION

The portal scraper is machine normally used in a production line in bulk material buffer store. The store operates with stockpiles placed in line. While building up one pile, another pile is being reclaimed. Aside from being used for providing supply of bulk material to production line, the significant role of a portal scraper is in blending and homogenization of bulk material (*Fischer, 1981*), (*Wolpers, 1995*). It is therefore important that the stockpile is reclaimed in such a way that the reclaimed material represents a mixture of a great number of layers and therefore evens out chemical variations in the material stacked (*Gy, 1981*), (*Petersen, 1994*), (*Petersen, 2004*). Portal scrapers are used for a broad range of bulk materials like urea, ammonium nitrates, coal, limestone, marl, gypsum, iron ores, etc., and are by far the most commonly selected type of reclaimer (*McTurk, 1995*). The material provided by a portal scraper is fed into the production line in various industrial processes. Its proper functionality and reliability can have a significant influence on the production rate and the stability of production process (*Wöhlbier, 1977*). Since the portal scraper is used for providing the continuous flow of material to production, the strict procedure has to be defined and complied in order to minimize every time loss during operation. Most commercial portal scrapers operate in the way that is significantly influenced by human operators and only parts of its functionality are automated. The full automatic operation of a portal scraper is certainly a way of providing a reliable system that has the assigned reaction in every situation. In order to develop an automatic operation of a portal scraper its functionality needs to be analyzed in detail and appropriate solutions for every functional characteristic need to be developed.

MATERIAL AND METHOD

In order to make it possible to build one pile while the other pile is being reclaimed a portal scraper and accompanying system for building up the pile are completely separated. There are two constructions widely used for building a pile. In the first construction material enters the store on a rubber belt conveyor running along one side of the store and it is discharged onto a stacker jib which is raised and lowered in order to reduce dust emission. In the second construction for building a pile, stacking is done by using a tripper car supported by a frame structure above the pile.

The portal scraper travels on rails along the store. It consists of a portal frame with scraper chain system. The material is reclaimed by the scraper chain system and in a constant flow transported onto an outgoing rubber belt conveyor. The portal scraper usually has a primary and secondary scraper chain working on either side of the pile while the portal moves along the pile. While the primary chain is used for scraping the material to conveyer belt, the secondary chain is used to throw the material from its side of the pile onto primary chain so that it can transport it to conveyer belt.

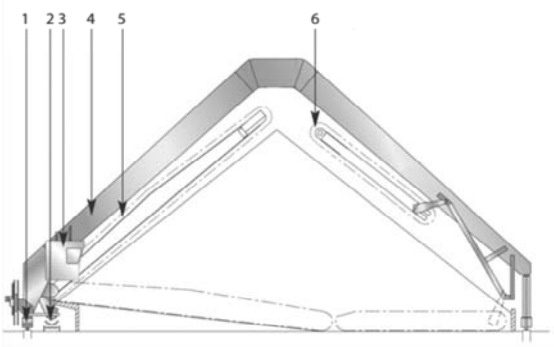

Fig. 1. Portal scraper main components

Shaping the pile

When the material is reclaimed from the freshly formed pile it takes significant amount of time until the flow of material to the belt conveyor is established. This is due to the fact that during the forming of the pile empty space needs to be maintained between the pile with material and conveyor belt, so that the material doesn't overflow and block the conveyor belt. In order to start the flow of material to conveyor belt, a portal scraper first takes down the material from the pile to fill this empty space. When that is done, all the material scraped from the pile flows directly to the conveyor belt. Also the freshly formed pile has the shape that is not in line with the axis of the scraper chain. t Consequently, the scraping of material from the freshly formed pile is done only with the small part of the scraper chain at the top of the pile. It prolongs the time needed for establishing the flow of material to conveyor belt. When the flow of material to conveyor belt is established, the shape of the pile is actually formed in the way that the material is scraped with the whole scraper chain. Only when the pile is shaped, scraper enters normal operating mode where it can continuously provide the supply of material.

Normal operation

While in normal operation, a scraper needs to provide continuous flow of material on conveyor belt. This flow needs to satisfy demands of the process but it must not be so big that it can cause the conveyer belt system to malfunction. Material is transported from the store by conveyer belt usually in a silo or some similar storage unit from where it is forwarded into the production. This silo represents a buffer between a portal scraper and production, and it provides some time for situations when there is no flow of material from portal scraper because it changes position or shapes the pile. This silo is not big enough to provide sufficient time for a portal scraper to change position, shape freshly formed piles and go into normal operation at once. Because of that it is necessary to organize that shaping of the fresh pile is done while the other pile is in the normal operation. It is done by interrupting normal operation in the moments when there is enough material in the silo, shaping the fresh pile and returning on the pile in normal operation when the level of material in a silo is low. In this way the fresh pile is shaped after few interruptions of normal operation. The whole procedure of material scraping can be time critical so it must be organized in the way that in every situation minimizes the time requirements.

Automatization

The full automatic operation of a portal scraper implies that the control system needs to posses information about the level of material along the fresh pile so that it can perform appropriate algorithm that will minimize the time necessary for shaping the pile. The levels of material along the pile can create contour with significant variations in level for different points along the pile. For shaping the pile it is first needed to patch the differences in the contour along the pile bearing in mind the maximum depth that chain can go into the material is limited by chain's functional characteristics. Also the control system must provide that during the return from shaping the fresh pile to the pile in normal operation material flow to the conveyor belt is established as sooner as possible. In order to provide information about the level of material the appropriate level sensor, preferably ultrasonic level sensor, is mounted on the top of the portal. Before shaping the fresh pile, as the first step, the levels of material along the fresh pile are determined. Both chains are lifted to the final upper position and portal scraper is moved in maximal speed from one end of the pile to another in order to scan it. The pile is divided into number of zones and for every zone maximum level is determined by a level sensor.

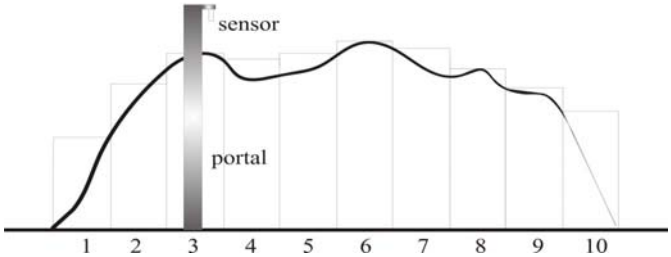

Fig. 2. Pile level measurement

After maximum level for every zone is defined, the zones to be treated during the next pass of the scraper chain are determined as shown in figure 3. The zones to be treated are all zones that have maximum level in the area defined by maximum level of the pile and depth at witch chain is to be plunged in material. In figure 3, those are the zones 3, 6 and 7 for the first pass. Before the first pass, the portal scraper is, because it just finished scanning the pile, in the final left or final right position. From that position it will move at maximum speed until it reaches the nearest selected zone where it will stop, lower the scraper chain at the appropriate level, power up the scraper chain and start to move in the current direction at working speed. It will go all the way to the last selected zone in its current direction. Every treated zone will have the current level of the scraper chain memorized as its new maximum level. When all the selected zones for the current pass are treated, the zones for the next pass are determined in the similar way. The difference from the first pass is that the first zone chosen to be treated in all other passes is the last zone in the current direction. If in the current direction there are no zones to be treated, the nearest zone in the reversed direction is chosen. Furthermore, since the chains are lowered and powered, the working speed is used for positioning the portal scraper.

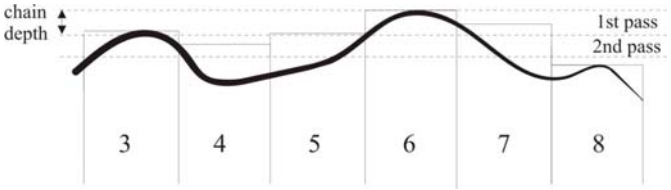

Fig. 3. Determining the treated zones for the current pass

Every time the portal scraper goes from the pile in the normal operation to shape the fresh pile it is needed to determine the treated zones in the same way as for the first pass, but the scan-

ning of the pile is done only when the portal scraper goes to the fresh pile for the first time. Also every time the portal scraper returns from shaping the fresh pile back to the pile in normal operation, the zone to be treated in normal operation is determined in the same way as the first treated zone in the first pass. This is done in order to position the scraper to the nearest position where it can start to scrape the material and establish material flow as soon as possible.

Since the portal scraper needs to provide the flow rate of material big enough to satisfy demands of the process but not so big that it can cause the conveyer belt system to malfunction, the flow of material from the pile to the conveyer belt needs to be controlled. The flow of material is controlled by changing the speed of the portal scraper since motors that drive the portal scraper are powered through inverters. The precise control of the material flow would include the measuring of the flow on the conveyor belt and maintaining the defined flow setpoint with the regulator that determines the appropriate portal scraper speed. Since it is not necessary to maintain the exact setpoint, it is possible to use the scraper chain drive current as the measure of the material scraped by the chain from the pile to conveyer belt. In this way the setpoint is the drive current that is controlled by PID whose output determines the speed of the portal scraper. When the chain is in the upper position, the material is scraped with the smaller amount of energy from situations when the chain is in the lower position since in the upper position the slope of the pile is steeper. Because of that, the current setpoint needs to be increased as the pile becomes smaller and chain is lowering its position. This change of current setpoint can be done linearly from the highest up position to the final down position.

RESULTS AND DISCUSSION

The proposed solutions are implemented for full automatic operation of a portal scraper in industrial facility. During the operation, the main observations of system performance were focused on ability to maintain the stability of material flow to production process during shaping the pile. The Fig. 4 shows one typical situation where shaping of a pile was active from around 7:30 to around 15:00. On portal positions from 3m to 50m the fresh pile is formed and it needed to be shaped while the other pile, on positions from 53m to 100m, was reclaimed in normal operation. It shows that on starting the procedure for shaping the pile, portal moves fast from current position to the beginning of the new pile in order to determine the contour of a pile. After determining the contour, a portal scraper starts to take down the material and shape the pile when there is enough material in the silo. When the level of material in a silo is low, a portal scraper returns to the pile in normal operation to establish material flow and, in order to do it as soon as possible, it chooses the nearest one of the zones that is supposed to be treated.

As it is shown in the Fig. 4 the procedure of shaping the fresh pile takes significant amount of time. The number of trips a portal scraper makes from a pile in normal operation to a fresh pile depends obviously on the contour of the fresh pile but even more on the production rate since the higher production rate means shorter time intervals for shaping the pile. During the 5 months of observing, the system performance portal scraper was able to cope with all variations in production rate and always provided stable material flow for production process.

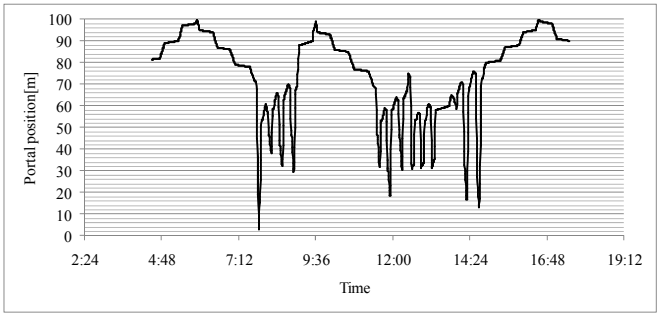

Fig. 4. Portal position while shaping the pile

CONCLUSION

In this paper the solution for a fully automated portal scraper is proposed. First, the brief analysis of portal scraper's functionality is presented where the main points of concern for proper operation of the system are highlighted. Main points of concern recognized in the analysis are time critical operations, especially in the situations when the procedure for shaping the fresh pile is active, and maintaining the appropriate flow of material from the pile to conveyor belt and further to the production. The algorithm for determining the path that a portal scraper needs to pass during operation is developed to minimize the time spent in unproductive motion of the portal during shaping of the fresh pile and returning from shaping to the pile in normal operation. Also the way to maintain the appropriate flow of material from the pile to conveyor belt is proposed by controlling the scraper chain drive current. The proposed solutions are implemented for the full automatic operation of a portal scraper in an industrial facility, and during operation it showed high performance in coping with high production rate and maintaining the stability of material flow to production process.

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