

A Study to Optimize Chip Handling and Disposal Using Automated Guided Vehicle

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ABSTRACT: The basic function of any machine tool is to attain the desired shape of the component by removal of material from the blank in the form of chip or swarf. With the advent of carbide tip tools and CNC/NC machines higher removal rate has been achieved, apparently massive volume of chips are to be handled in judicious and safe manner to ensure comfort, safety of workers, and optimum utilization of floor space. There has been a dire need of systematic procedures for chip disposal. Recent innovations in the field of robotics and artificial intelligence have made it an indispensable aid in accomplishing hazardous and monotonous tasks. In view of the degree of complexity, danger, recurrence and precision involved, we arrive at a resolution of automating chip handling, by framing swift and organized methods to enhance productivity, safety with assistance of modern day robotic systems.

KEYWORDS: Chips/Swarf, CNC machines, safety, optimization, chip disposal, hazardous, monotonous, recurrence, automatic.

I. INTRODUCTION

The excess material removed from the metal as chips is disposed off and can be processed further to form billets. The chips have to be scavenged off the work floor periodically. Chips are of different forms such as straight, snarls, helical continuous, helical fragments, fragments, splinters and needle like spirals with rough surfaces, sharp edges and burred corners. There is a potential risk of scrapping off hands or get throbbled while retrieval, which leads to soreness, skin abrasion, incision, septic etc. Due to its high surface area, swarf of some reactive metals can be highly flammable. The volume of chips disposed at each machine or at different work stations depends on factors like cutting tool, material being machined, type of machining process, machining parameters etc., Thus the volume of chip being handled may be uneven across the work shop. The size of the plant and layout affects the ease and regularity of chip removal. Presence of chips in the vicinity of workspace is uncomfortable due to foul odor of coolant/machining oil on chips, occupancy of floor space, obstruction to free movement and menace of chip sting injuries. Unorganized disposal of chips results in pileup and encroachment. Tangled chips are problematic to handle.

Our objective is to provide a cost-consciousness method to process chips for size-reduction, centrifuging and transportation. The additional enhancements to the design allow processing and storage of chips in compact and efficient way rendering it more flexible to changes.

II. EXISTING SYSTEM

Machining is an essential step in manufacturing metal products, but it can also be performed on varied materials viz., wood, plastic, ceramic, and composites. Modern day machining is carried out by computer numerical control (CNC), which employs a detailed computer program to operate mills, lathes, and other cutting machines, producing massive volume of chips. The workers heap the chips generated beside machinery in a tray or drum, which are eventually emptied into trucks and ultimately sent for further processing. Till date only traditional method such as manual chip disposal is in place in small scale industries and sophistication is limited to large scale industries incurring huge expenses for equipment and skillful maintenance. Conventional rakes, spading forks are used in manual handling.

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Bulky vacuum pumping stations, above-floor conveyors, over flow pipe systems and a central processing station form a typical large scale chip disposal system offering minimal flexibility of plant layout variation or upgradation.

- There are no systematic and organized methods to safely dispose the metal chips and swarfs that are generated on a daily basis in the machine-shop floor.
- The lack of such system apparently causes wastage of massive amount of time in cleaning up and processing.
- Due to the inconsistency in processing, there is a decrease in the average geographic area of shop-floor available for commuting and for other equipments inside the plant.
- The overall efficiency of the plant is considerably altered when all the above factors are considered

III. VEHICLE ANATOMY AND FUNCTION

The chip disposal AGV (Automated Guided Vehicle) consists of various components to ensure functional propriety and to fulfill the objective of operation. The mechanical structure includes Reeler, Conveyor, Chip breakers, Cabin, Vacuum extraction of chips and a battery to supply power to various elements. The design is task-oriented with provision for optional aesthetic features. Various standard parts are used to the extent possible to fabricate the peculiar anatomy of the AGV.

Reeler-It is a commercial IS:3038 steel which is casted using investment, die or sand casting. It grasps the tangled chips and drops it on conveyor. The ground clearance of reeler is upto 5mm. Tiny bits which cannot be carried by reeler are collected by vacuum cleaner.

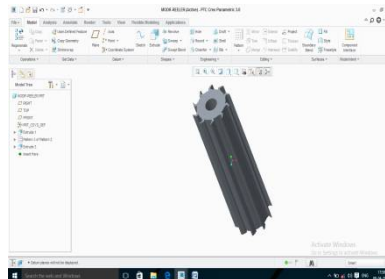


Figure 1. Reeler

Conveyor-It is a thin flexible material with protrusions to carry over collected chips. It is a flat sheet looped by joining two ends by stitching or latches. It is coated with wear resistant liquid to protect the conveyor from abrasion.

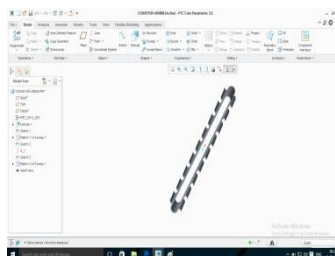


Figure 2. Conveyor

Cabin-Cabin is a sheet metal compartment used to store collected chips. It is fabricated by welding gauge-10 steel sheets. It has flap door hinged at the bottom. There is a rectangular opening at the top to provide an entry for processed chips.

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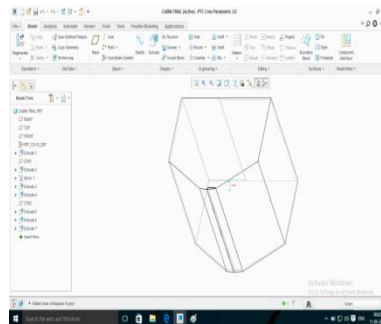


Figure 3. Cabin

Chip breaker- Chip breaker is of Herringbone profile made of IS:2708 steel. It is tempered at 600-650 degrees centigrade to obtain Brinell hardness of 230-260 HB. It is further subjected to surface hardening treatment by cyaniding to a depth of 2-3 mm. Its function is to break larger chips into tiny bits.

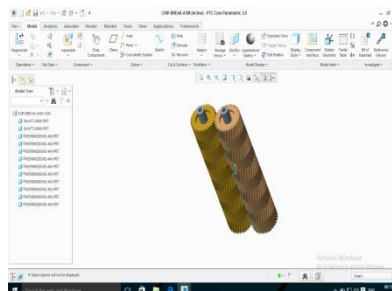


Figure 4. Chip-breaker sub assembly

Power house-It is a steel rack made of guage-10 steel welded rectangular with T-joints. It has provisions to house battery, C.P.U and Vacuum pump and container.

Brushes-They direct the chip-bits and swarfs into the path of the vacuum cleaners' hose ensuring nothing is left back on the floor thus perfectly cleaning the surroundings. Brushes are made of tough polyurethane bristles stitched deep into the brush. There is a hollow rod on top surface of brush.

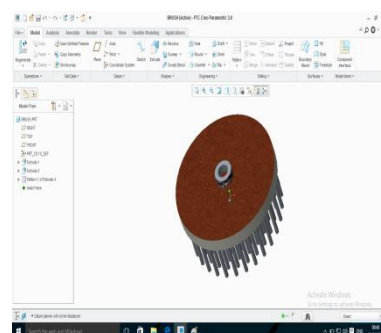


Figure 5. Brush

Vacuum pump- It is an integrated part which is custom made to suit the requisites of the AGV. The highly efficient vacuum pump collects the swarfs and simultaneously stores them in a separate container.

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Wheels-Wheels bestow agile maneuverability to the AGV and the ability to direct it in the right path by taking cues from the sensors. They are individually motorized and are controlled by the computer onboard. Wheels are standard polyurethane made selected as per load and agility requirements.

Shafts-The shafts host the various rotating components and simultaneously hold them in place without sliding away from perfect alignment. The shafts are hollow and made of austenitic manganese steel.

Chassis-The chassis is the main base structure of the AGV. It provides a steady support to all the other components that are attached to it. Two I-beams made of IS:4896 steel tempered for enhanced strength connected by horizontal ribs constitute the chassis.

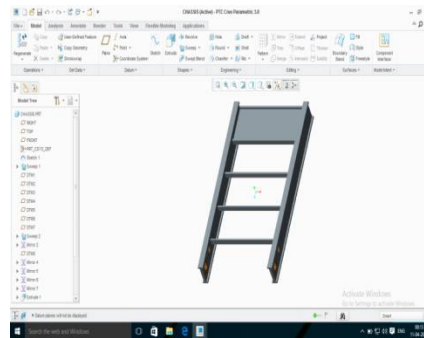


Figure 6. Chassis

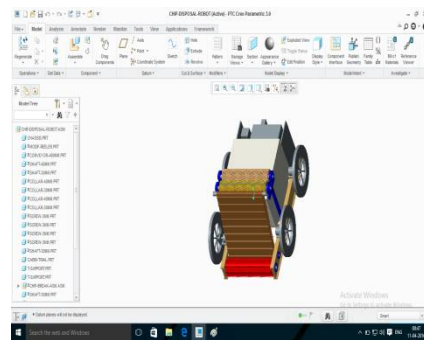


Figure 7. Final assembly

IV. WORKING PROCEDURE

The Chip Processing AGV is an independently operated, self-propelled vehicle guided along defined pathways. The vehicle is powered by on-board batteries that allow substantial hours of operation (8-16 hrs). The workstations are arranged parallel. At the workstation the AGV can detect the disposed chips automatically, process them and head towards the dumping station.

Vehicle guidance technology- Movement of the AGV can be controlled in the following three ways

- **Imbedded guide wires**- Electrical wires are placed in a small channel cut into the floor. The guide wire is coupled to a frequency generator, which emits a signal with a frequency in the range 1-15 kHz. This signal can be followed by sensors mounted on the vehicle on the either side of the guide wires. If the vehicle strays off from path, or if the guide wire path changes direction, the signal intensity at two sensors will become unequal. This difference is used to control the steering motor, to equalize the sensor signals. When the vehicle approaches a branching point , the guide path forks into two pathways, the vehicle selects a path using following ways
 - Frequency select method-the branching guide ways have different frequencies.

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- Path switch select method-it operates on a single frequency.
- **Paint strips-** When paint strips are used to define pathway, the vehicle uses an optical sensor system capable of tracking the paint. The strips can be taped, sprayed or painted. An on-board sensor detects the reflected light in the strip and controls the steering mechanism to follow it. It is used when surrounding electrical noise renders the wire guided method unreliable. Over long distances the propriety of the path followed by the AGV is ensured by beacons installed at strategic locations throughout the plant.

Vehicle management- For the autonomous system to operate efficiently, the AGVs must be well managed. Various tasks must be allocated to them to minimize waiting and congestion.

Traffic control- Two methods to control traffic congestion

- On-board sensing uses one or more sensors on each AGV to detect the presence of other AGVs and obstacles ahead. Sensors include optical or ultrasonic devices. When the obstacle is removed the AGV proceeds.
- In Zone controlling, the layout is divided into separate zones, and no AGV is allowed to enter a zone occupied by another. The spatial parameters of the zone are defined by considering the AGV's dimensions, allowances, safety and other factors (no. of AGVs, complexity of layout etc).

Vehicle dispatching-

- **On-board control panel-** AGVs can be dispatched, by using an on-board control panel, to a given station. It represents the lowest level of sophistication.
- **Remote calling stations-** The simplest calling station is a push button at the workstation. This transmits a hailing signal to any available AGV in the vicinity to dock at the station. The remote calling stations permit the AGV's destination to be programmed at the time of calling.
- **Central computer-** It is used to accomplish automatic dispatching according to pre-planned schedule or in response to calls from various workstations. The central computer possesses information on current location of the AGVs, storage capacity, and amount of chip to be disposed and takes an optimal decision. The AGVs communicate with the central computer.

Chip detection and calculation algorithm

- step-1 Start
- step-2 Chips are dumped on collection platform
- step-3 The location, orientation and occupancy of chips is detected by sensors
- step-4 Data is transferred to central computer
- step-5 The volume of chips and mass is calculated using sensor input values and available data
- step-6 Computer compares the quantity of chips to be collected with load capacities of each AGV
- step-7 Computer assigns a suitable AGV to the chip collection zone
- step-8 Stop

Chip collection algorithm

- step-1 Start
- step-2 The proximity sensor on the AGV searches for chips in collection zone
- step-3 If the sensor feed is positive, then initiate power supply to reeler, conveyor and chip breaker
- step-4 Check the space available in storage cabin
- step-5 If the cabin is full, then signal the AGV to empty the load into silo
- step-6 Else, go to step 2
- step-7 Check the space available in vacuum storage cabin
- step-8 If space is available and feed is positive, supply power to brushes and vacuum pump
- step-9 Else, terminate power supply
- step-10 If the sensor feed is negative, signal the AGV to wait for next assignment from computer
- step-11 Stop

Chip disposal algorithm

- step-1 Start
- step-2 Check the space available in silo
- step-3 If space is available, then computer commands the filled AGVs to dump chips into silo

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- step-4** Else, assign a waiting slot to the filled AGVs
step-5 Stop

V. DESIGN CALCULATIONS

Lewis equation transmitted force $F_t = \sigma_d C_v b Y / p_{dn} C_w$

$Y = \pi y$

Axial thrust $F_a = F_t \tan \beta$

Dynamic strength $F_s = \sigma_d b Y m_n$

Limiting load for wear $F_w = db Q K / \cos^2 \beta$

Where, pitch circle diameter of chip breaker $d = 100$ mm

Number of teeth on the chip breaker $z = 25$

Helix angle $\beta = 45^\circ$

Pressure angle $\alpha = 25^\circ$

Allowable static stress $\sigma_d = 105$ N/mm²

Wear and lubrication factor $C_w = 1.35$

Lewis form factor $y = 0.158$

Velocity factor $C_v = 5.55 / (5.55 + v^{1/2})$

Load stress factor $K = 2.189$; Ratio factor $Q = 2z_2 / (z_2 + z_1)$

Substituting the above parameters in respective equations we obtain following design constraints

Circular pitch $p_n = 8.885$; Normal circular pitch $p_d = 0.25$; Diametric pitch $p_{dn} = 0.353$

Module $m = 2.828$; Normal module $m_n = 1.994$; Formative number of teeth $z_e = 70.71$

Face width $b = 23m_n$; $y = 0.158$; $Y = 0.4963$

$F_t = 1293.848$ N; $F_s = 4821.43$ N; $F_w = 20.3$ kN; $N = 50$ rpm; $v = 261.79$ mm/sec

VI. CONCLUSION

The chip processing AGV handles chips of all shapes, sizes, thickness and materials. The entire processing system is independent and intelligent requiring almost no or least human interference. The AGVs interact with the host environment, thus ensures safety of workers. AGVs communicate individually with a central computer which monitors multiple operations simultaneously and transmits appropriate signals for hassle free function. The sturdy design calls for occasional inspections. The processed chips are stored in large silos. A sensor installed in the silos sends a signal to logistics center/central computer when the chambers are full. There is a provision for centrifuging the broken chips before transferring them to silos. Recovered coolants/lubricants can be returned to the production process. Chip processing AGV is a pioneering idea which paves a great scope for automating tedious, repetitive and dangerous tasks involving less or fair degree of complexity. It relieves human workers from monotony and also safeguards them from plausible hazards. The various sequences of operations can be tracked remotely from a computer or from a mobile application. It is cost effective, flexible, portable, intelligent and independent. It is a way of the future.

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