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Design and Development of Automated Guided Vehicle for Collection, Sorting and Disposal of Metal Chips in Mechanical Workshop

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Abstract-- Machining operation involves the integration of assorted processes for material removal of any work piece. Machining allows variety of material to be processed and multiple part shapes with high dimensional accuracy and surface finish could be created. One of the major shortfalls of machining is that the metal chip waste generated is noteworthy. Reusing these metal chips can enhance the economic profit and reduce the environmental impact of the manufacturing organization. Current manufacturing companies either put these wastes in landfills or pay a third party to haul them away. This calls for incorporation of automation in chip collection, sorting and disposal operations in lesser possible time involving lesser human fatigue and high safety. The paper includes development of an Automated Guided Vehicle (AGV) structure comprising of storage section and various subsystems and selection of suitable controller and related electronics components like sensors, controller & drives for overall operation and control of AGV for a small scale mechanical workshop.

Keywords-- *Machining, Chip collection and Sorting, Industrial Automation, AGV, Sensors*

I. INTRODUCTION

Metals are widely used in the manufacturing industry for producing a wide variety of products with metal chip waste handling and disposal being one of the major problems. Generally, the first step for metal chip recycling is to separate different metals from each other, so as to improve the quality of recycled metals.

In manufacturing, iron is the most commonly used metal in the industry. Currently there is a lack of effective and economical techniques in separating these ferrous and non-ferrous metal chips to fulfil the needs of the manufacturing industry. The chips could be continuous or discontinuous or chips with built up edge. The chips formed depends, on type of material employed, rake angle, speed of cutting, depth of cut and friction between chip tool interface. The presence of metal chips or swarf hampers the surface finish of the components and tool life due to excessive wear and tear. The metal chips removal also results in soreness, skin abrasion, incision or septic etc. of the operator. The presence of chips on the work floor could be uncomfortable due to bad odour of coolant or oil on chips, resistance to free movement and related injuries These waste metal chips, if sorted, could be recycled through melting in foundry and further processed to form billet or bars of respective materials, so these unwanted chips are to be collected, sorted and disposed involving minimum human interference, time and cost. Industrial automation which is they application of control system and information technology for management of different processes and machineries in an industry could be one of best possible solution to fulfil above requirements. Automated guided vehicles (AGV) are flexible mobile devices which could be modified as per the user application and with advent of latest internet technologies they could be made flawless and autonomous. [1] The work involves design and development of working prototype of an AGV for collection of waste chips from various stations, sorting of the chips and subsequent disposal at the prescribed dumping area. AGV equipped with hopper will collect the chips from various machines which would be stored in separate compartments as per the material type. These chips would be sorted using appropriate mechanism and finally would be commuted to the dumping area. The storage compartments would be emptied using suitable design mechanism. It also includes design of AGV structure along with storage section, selection of various subsystem for AGV and selection of suitable controller and related electronics components for overall operation and control of AGV. The testing validation would be carried out through interfacing the hardware and software components and set of trials.

II. LITERATURE SURVEY

M. D. O'Toole Peyton, (2019) re-examined. Magnetic induction spectroscopy (MIS) using real scrap metal samples drawn from a commercial sorting line. It was found that moderate purity and recovery-rates of brass and copper were between around 70% and 90%. However, the classification of aluminum was poor with 55% and 80% purity and recovery rates respectively. Magnetic induction sensors satisfy the specifications of the industry. They are capable of high throughputs, are unaffected by dirt or contaminants and are mechanically and physically robust. Although their results were modest, they were not insignificant, given the simplicity of the algorithm and the relatively low-cost of instrumentation.[2]

Fang Liu, Xueqi Li, Yilin Wang, (2018) developed an AGV operated on magnetic guidance which runs on guide rail and was controlled by controller while the upper computer monitored AGV motion, and all these elements communicated through network communication elements. [3]

Fabio Oleari, Massimiliano Magnani and Davide

Ronzoni, (2015) considered technological issues related to AGV system employed for logistics of goods and materials inside the factories. They discussed integration of advanced sensing technologies like laser scanner, cameras etc. and the control technologies development for Plug-And-Navigate (PAN) robots and advantages and limitation of the same. [4]

Qiang Zhai, Chris Yuan, (2012) found that metals like Fe, Al etc. are widely used in manufacturing thus creating a huge amount of metal chips solid waste causing both environmental and economic issues they developed a combined hydrodynamic and electrodynamic approach to separate Fe and Al metals based on different moving behaviours resulting from their different size and density.[5]

Matti Kutila, Jouko Viitanen, Antero Vattulainen, (2005) presented a combined machine vision and inductive sensing system intended for scrap metal sorting. The computer vision setup was based on the color difference using the red channel as the common component to which amount of green and blue was compared. Brass and copper produced signals stronger red component while blue component was more significant for stainless steel and aluminum. [6]

III. INDUSTRIAL SURVEY ON CHIP HANDLING, SORTING AND DISPOSAL SYSTEM

An industrial survey was carried out in manufacturing industries primarily involved in machining process in and around Ichalkaranji and Kolhapur region in Kolhapur district in Maharashtra. The survey was carried through questionnaire based on chip handling systems available in these industries and around 10 industries were surveyed and questionnaires were filled through succeeding interactions with the personnel. The X-axis represents the parameters for comparison while Y-axis represents the percentage of these parameters. Fig. 1 to Fig.4 illustrate results in the form of graphs, obtained from responses for various criteria

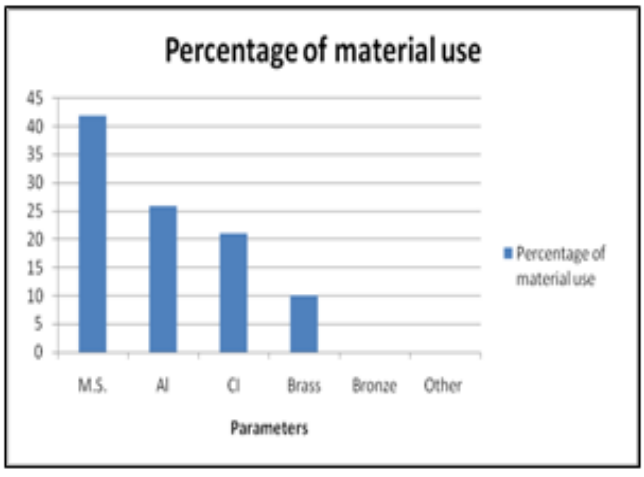

Figure 1: Result of materials used in industries

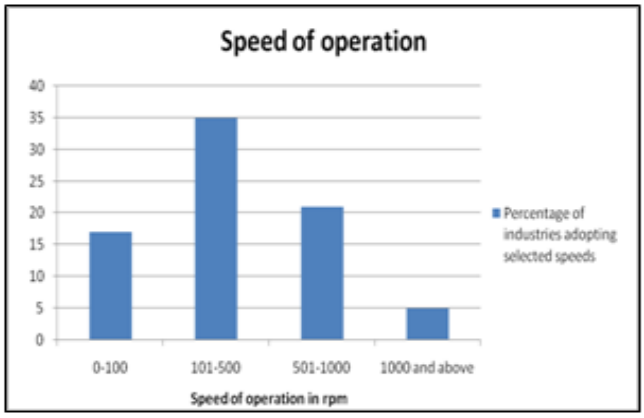

Figure 2: Result of speed of operation used in rpm

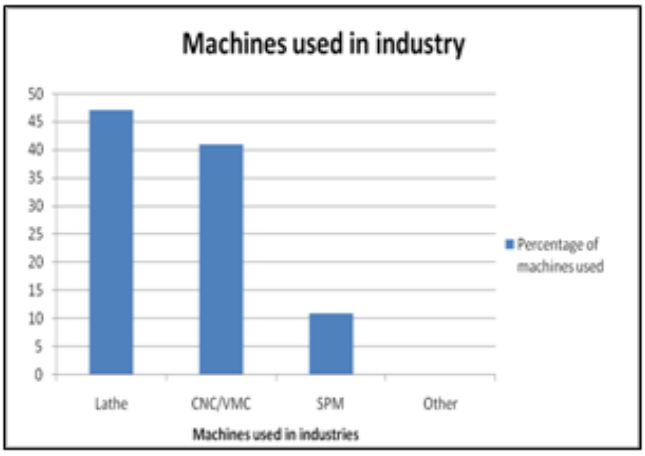

Figure 3: Results of machines used in industries

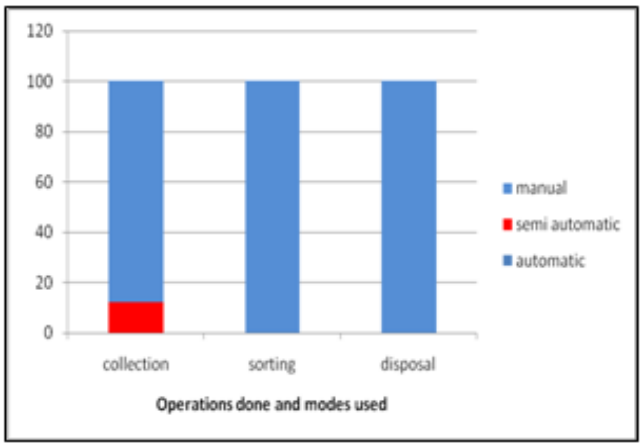

Figure 4: Result of operations done and modes used

Following results were obtained from the survey –

a) About 42 % of the total material machined is M.S. while Al is 26% and CI is 21%.

b) About 47 % lathes are used for machining operation while CNC/VMC comprises of 41% of the total machines used and the use of SPM is just 11%.

c) The maximum problems faced with existing conventional chip handling method were operator fatigue, operator injuries and more time consumption for manual handling.

d) Only 12 % of industries use semi-automatic means for chip collection and 88% of chip collection while entire chip sorting and disposal processes are done manually in

the industries surveyed.

The survey thus illustrates that majority of the industries practiced manual methods for chip collection, sorting and disposal. Due to manual systems currently used, there were many problems like high operator fatigue, more time consumption and operator injuries. So it was planned to develop an automation solution in the form of AGV to handle as well as sort and dispose the metal chips which would also save the now unnecessarily wasted floor space.[7]

IV. METHDOLOGY ADOPTED

One of the major outcomes from survey was the selection of materials for obtaining chips for handling and disposing based on priority of materials used in the industries and M.S., Al and CI were selected accordingly. These chips produced would be collected through hopper at the top and would be sorted using suitable mechanisms. The sorted out chips would then be stored in separate compartments on lower side in AGV structure. The collection and sorting will continue till high level is reached. AGV, will then move to the next pre-defined dumping area and dispose the sorted waste.

If the battery level goes down at any intermediate point, AGV will be directed to the charging station. For the collection of chips at already defined location, AGV will move across these locations through suitable navigation system and certain delay will be provided for collection process. When overall load and thus, the chips to be disposed are less, the same AGV with minor modifications could be used for general material handling application. This AGV will currently be employed in the mechanical workshop. AGV will start from the base or charging station if the battery voltage is above 10.5 V and will travel across chip collection points 1, 2 and 3 where the machine operators would deposit the metal chips collected from various machines. The collected material will be sorted by the time AGV moves from one chip collection point to the other and the sorting will stop when the next chip collection point is arrived. Once the chips are collected at chip collection point 3, AGV will travel to various disposal points where small and large sized chips of M. S. and Al would be sorted in respective bins and then AGV will return to charging station.

If in case, the level of chips in the storage area in AGV exceeds high level, irrespective of location, AGV will travel to disposal area. Currently AGV is designed to handle maximum 6 kgs of chips. The Fig. 5 shows the proposed layout including all the stations, entry and exit.

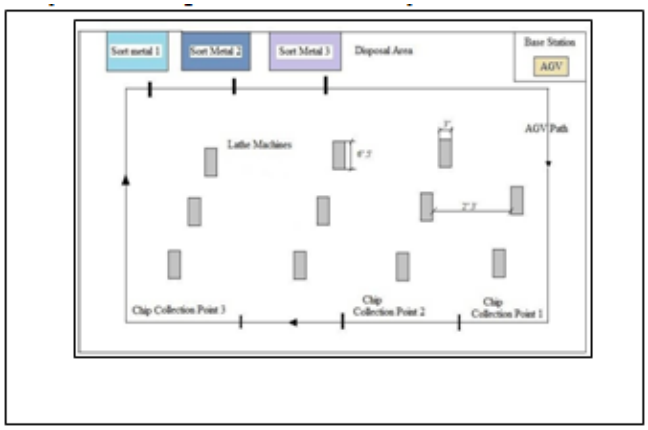

Figure 5: Proposed layout of workstation for AGV movements

V. AGV design

Fig.6 shows the proposed design of AGV for handling and disposal of metal chips in the workshop. The dimensions of AGV are decided considering the layout and the available space of the mechanical workshop shown in fig.5. The entire structure is made in sheet metal having internal compartments for collecting different metals chips separately. Detachable hopper is provided at the top which can be removed when AGV is to be used for material handling application. A metal sieve which is continuously vibrating is used for separating bigger sized chips. Electromagnetic door is used to separate the M.S. chips from other non magnetic material chips. Servo motors are provided for opening and closing of the disposal doors at the bottom once AGV reaches the disposal area.

AGV is a self driven vehicle, which operates autonomously, guided along defined paths for chip handling and disposal activity. The AGV in consideration is a mechanical hardware light in construction with proper ergonomics, a two wheeled vehicle driven by high torque DC geared motors. The operator has to bend down for collecting the chips and move to the disposal area every time causing excess fatigue and subsequent muscular disorders. Hence, taking ergonomics into consideration, the height of AGV is maintained about 1 meter, so that chip handling will be less hectic.

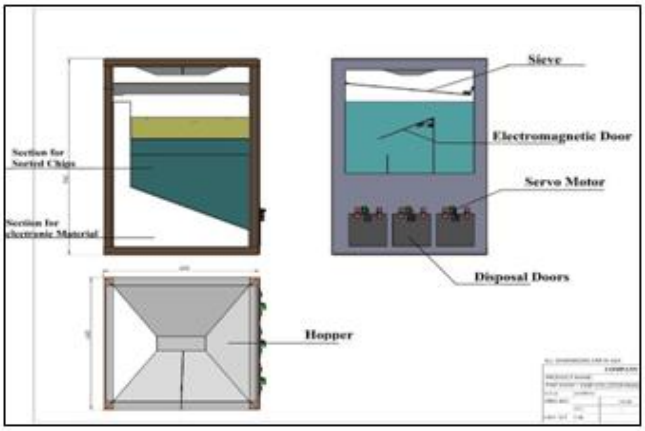

Figure 6: Proposed schematic layout of AGV

AGV is battery powered. Suitable sensors were selected and assembled on AGV for line detection as well as obstacle detection. An appropriate controller is selected and interfaced with various systems of AGV for precise operation and control. A provision for placing electronics circuits, power source, controller and related components is made on the lower side of structure. If any obstacle comes in front of AGV, it is sensed by suitable proximity sensor and subsequent action like alarm or stopping of AGV is taken for further accident avoidance. Wireless communication is preferred for its technological advancements and it offers advantages in terms of lesser cost of installation, reduced mechanical wear and ease of information retrieval. Wireless control can be a beneficial option for obstacle avoidance, distributed control and coordination of multiple AGVs for material handling in industries.[8]

VI. ELECTRONICS COMPONENTS

For better accuracy and speed, electronic control and drives were selected for the motion and control of AGV. Fig. 7 shows the basic components of electrical circuit and the flow for overall control of AGV.

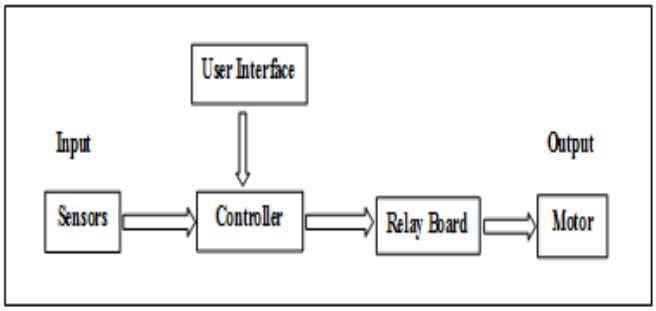

Figure 7: Components of electrical circuit

SmartElex RLS08, a line follower sensor module was used in AGV to detect the line. It consists of 8 array IR Transmitter and IR receiver pairs. A device can be a black line or white line follower. Line follower and works on the concept related to light. When light falls on white surface it is nearly reflected and in case of black surface light is totally absorbed.[9] Arduino MEGA 2560 was preferred more I/O lines were required with higher RAM. This controller has 54 digital I/O pins and 16 analog inputs.[10] Relay module is required for voltage protection while based on torque required, high torque DC geared motor 60 rpm was selected which offers a torque 38 kg-cm.[11]

CONCLUSION

An AGV has been developed which is implemented to handle and dispose the waste metal chips thus reducing the manual efforts and associated issues. The total manual handling time on above proposed layout with halts at three chip collection points for collecting chips was computed through time study and it was found out to be 85.13 sec. With introduction of automation this time is expected to be reduced by 30% in the initial phase which can be further reduced by advancements in the programming and electronics section. AGV with removal of hopper can also be utilized as normal material handling equipment so it can be effectively utilized during lesser load at the workshop too.

The system could be made capable of being flexible towards the change in path as per the layout changes, if any, and can be made smart by applying Artificial Intelligence approach to it.

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