RFID based system for prevention of material mix-up at various stages in Metal-Injection-Molding process

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Abstract - Feedstock preparation for Metal Injection Molding (MIM) is a very crucial step since deficiencies in quality of the feedstock cannot be corrected by subsequent processing adjustments. Hence, it is important that the quality of feedstock is homogeneous.

At present, the complete identification process of raw material at various stages is manual which leads to the creeping in of errors in the form of wrong identification of powders. There is no fool proof method to check these errors. These errors are of very high magnitude and cause huge financial loss. Hence, an attempt is made to prevent mix-up and provide fool proof tracking and tagging using RFID at various stages of compounding and molding.

Keywords: identification, tags, RFID, tracking, material mix up, MIM.

I. INTRODUCTION TO METAL INJECTION MOLDING PROCESS

Metal Injection Molding or MIM (also referred to as Powder Injection Molding or PIM) is a net-shape process for producing solid metal parts.

The main production steps of the metal injection molding process are:

1.1 Feedstock Preparation:

Feedstock Preparation is also called as compounding. The feedstock is mixed from fine metal powder and a binder. The mixing of powders and binders is done in a Turbula mixer and then through a Planetary mixer.

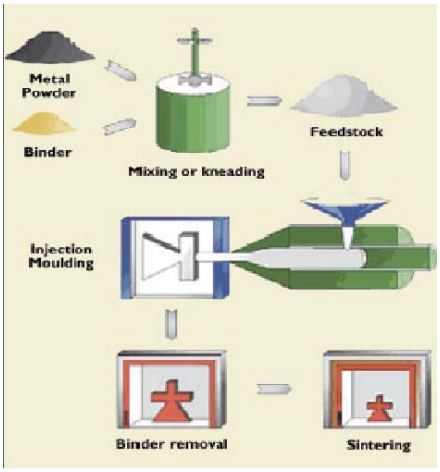

Fig 1.1: Flow process in MIM

1.2 Injection of feedstock in mold machine:

Molding is done in a conventional injection molding machine. The mold is designed similar to that for plastic but with allowances made.

1.3 Debind the part to remove major portion of binder.

The parts are removed from the mold. Before the part can be sintered, the bulk of the binder has to be removed. The debinded part is called "brown".

1.4 Sinter in vacuum or controlled atmosphere furnace:

The brown part is placed on a ceramic tray and processed in a high temperature furnace. Sintering temperatures go up to 2500^{o} F.

1.5 Finishing operations as needed.

Machining, grinding or lapping may be desirable to produce tighter dimensional tolerances or to add certain features which are not economical or feasible in the tooling.

II. BACKGROUND

Different uses of RFID were reported in recent years in the manufacturing industry. Ford Motor has successfully implemented a just-in-time (JIT) manufacturing model at its facility in Cuautitlan, Mexico. Updates are automatically written on the tag as the vehicle advances on the production line without the risk of operator error [1].

The work of Gavin Chappell, David Durdan et all [2] titled "The Value of Auto-ID Technology in Retail Stores", highlighted the benefits of using Auto-ID technology in retailing - to streamline operations, resulting in reduced labor requirements and consumer wait times at checkouts.

For pharmaceutical manufacturers and distributors, RFID will also be helpful to more easily and rapidly conduct drug recalls, manage inventory, and identify theft and/or diverted shipments [3].

A solution of material tracking information system was proposed, that integrates RFID readers, database and application [4].

Ken Congdon, in his work titled "Enhance Inventory Management with RFID" [5] focused on enhancing inventory visibility and cutting costs by using a closed-loop RFID solution to track parts in its manufacturing plant.

The present work aims at developing RFID systems architect to prevent the material mix-up and provide fool-proof tracking and tagging system. An attempt is made to prevent the material mix up at the feedstock preparation, mix preparation and also at the time of delivery of material to the correct molding machine.

III. RFID TECHNOLOGY

Radio frequency identification technology, known as RFID, has been described as "tech's official Next Big Thing". RFID is not actually a new technology, but it is being applied in new ways, spurred by technological advances and decreased costs.

RFID proponents believe that the ability of these systems to deliver precise and accurate data about tagged items will improve efficiency and bring other benefits to businesses and consumers alike.

3.1 How RFID Works

RFID wirelessly exchanges information between a tagged object and a reader/writer. An RFID system is comprised of the following components (Fig 1.2)

1. One or more tags (also called transponders), which consist of a semiconductor chip and antenna.
2. One or more read/write devices (also called interrogators or simply, readers).
3. Two or more antennas, one or two on the tag and at least one on each read/write device
4. Application software and a host computer system.

Tags are usually applied to items, often as part of an adhesive bar-code label.

Readers can be unattended standalone units (such as for monitoring a dock door or conveyor line), integrated with a mobile computer for handheld or forklift use or incorporated into bar-code printers. The reader sends a radio signal that is received by all tags present in the RF field tuned to that frequency.

Tags receive the signal via their antennas and respond by transmitting their stored data. The tag can hold many types of data, including a serial number, configuration instructions, activity history (e.g., date of last maintenance, when the tag passed a specific location, etc.), or even temperature and other data provided by sensors.

The reader receives the tag signal via its antenna, decodes it and transfers the data to the computer system through a cable or wireless connection.

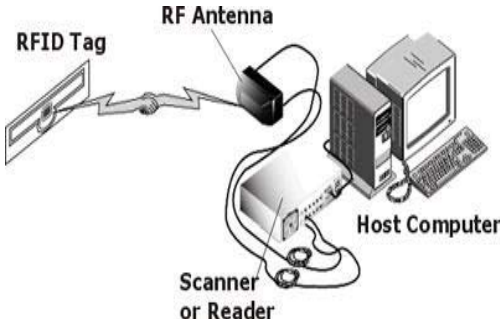

Fig 1.2: RFID System components

IV. DESIGN AND IMPLEMENTATION:

4.1 Objectives:

1. To prevent wrong material being taken for preparation of feedstock at compounding stage.
2. To prevent excess quantity addition and wrong powders/binders to be weighed without any sequence and prevent operator errors, thereby preventing the initial mix up and also control the excess addition of material for the given feedstock.
3. To help the operator track the material, at any point of time, through a series of process like mixing in dry mixer, planetary mixer and then through the cooling table and granulator.
4. Prevent the mix-up at mix preparation area, by identifying right virgin material and right regrind material to be used for mix preparation, and also control the excess addition of material for the given mix.
5. Provide wrong destination alert and delivering the material to the correct molding machine.

4.2 Assumptions made:

1. The raw material, i.e., the metal powders and binders are unloaded from the truck and tagged (RFID) before being stored in the storage area.
2. The crates which are used to move the metal powders from one workstation to another are permanently tagged using active tags. Initially the tags contain no information other than the tags unique id.
3. Color coded crates/bins are used for different elemental based compounds.

4.3 Problems Identified:

In the second step of material flow i.e., Compounding, following problems were identified:

1) In the process of weighing there are chances that the material which is to be taken for weighing may be different from the one that is to be taken for weighing. There is no conformation whether the material that is added to the container, is correct or not.
2) In planetary mixing stage, i.e., the third sub step of the compounding process, the problem lies in the tracking of the material. There is no way to check what type of material is being processed in the mixer. Only the operator has to remember and keep in his memory. As far as he remembers the details there will be no problem, but always there exists a chance of human error i.e. the loss of memory. It becomes difficult to track the material and process involved in tracking back the material is time consuming
3) In the sub step of cooling , granulation and extrusion, the problem is tracking of the material; there is no way to check what type of material is being cooled on cooling table, granulated in the granulator and processed in the twin screw extruder.

In the third step of material flow i.e., mix preparation, the following problem was identified:

1) There is no confirmation about whether the virgin material and regrind material taken for mix preparations are correct and are according to the check list. Also there is no confirmation about the weighing in a definite ratio. In some cases the tag (manual tagging) which is present on the bin goes missing and it becomes difficult to identify the material.

In the last step which is molding, the problem identified is explained below.

1) One of the major causes for material mix-up is in delivering of the material to wrong molding machine or a wrong material delivered to the molding machine. This is an operator error which cannot be prevented by manual method. The only way to know that the material delivered to the molding machine was incorrect is at the time of debinding or sintering stage. The part is finally scrapped making huge process loss and financial loss to the company

4.4 Proposed solution:

1) RF Solution to weighing:

The weighing machine is synchronized with the computer with the help of RS232 port along with a RFID reader and writer. In the process when the material is brought near the weighing area, the tag on it will be scanned for the correctness of the material with help of RFID reader, if the material brought is correct then the weighing machine will display the reading otherwise there will be no display on the weighing machine, and a display on the computer screen shows that this is not the material and prompts to get the right material to the weighing machine.

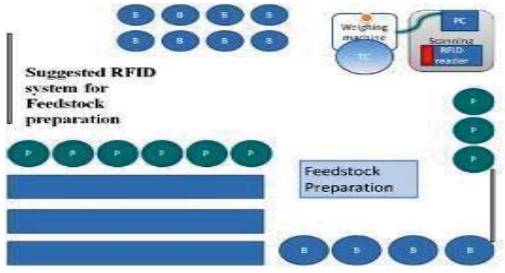

Fig 1.3: Feedstock preparation area with RF solution.

P – Powder B – Binder

TC – Turbula container

1.1) RF Solution to planetary mixer:

With the help of RFID tags the material can be tracked through individual machines by fixing a RF tag to the machine itself. When the material is fed into the mixer the tag information on the container is read first and the information is then transferred to the tag provided on the machine; hence at any point of time if the operator wants to know what material is being processed in a particular machine he can use the RF reader and get the information at ease.

1.2) RF Solution to cooling, granulation and twin screw extrusion:

With the help of RFID tags the material can be tracked through on cooling table and granulator machine by fixing a RF tag to the machine and cooling table and the extruder. So when the material is loaded onto the cooling table; tag information on the planetary mixer is read first and the information is then transferred to tag on cooling table and then when the material is cooled and transferred to the granulator, the information on the tag on cooling table is read first and then information is transferred to the tag on granulator and then transferred on to the tag fixed on the bin or crate were the granulated material is collected.
Tag information on the bin is read first and the information is then transferred to the tag on the twin screw extruder and then the material is palletized and collected into the same bin. Again the information from the twin screw extruder is transferred on to the tag on the bin.

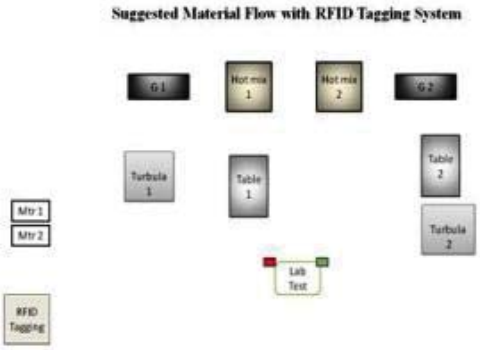

Fig 1.4: Turbula mixing, planetary

mixing, granulation and tagging.

TURBULA 1, 2 – DRY MIXER

HOT MIX 1, 2 – PLANETARY MIXER

G1, G2 – GRANULATOR;

TABLE1, 2 – COOLING TABLES

2) RF Solution to Mix preparation:

According to the requirement from the molding department the mixes are prepared and delivered to the molding machines. A mix sheet is generated in the mixing area through ERP and according to it the mixes are prepared.
A mix bin is kept on the weighing machine and then with the help of RF reader the information on the tag available on virgin material bin is read, if it matches with the mix sheet in the computer database then it allows for weighing and adding the material to the mix bin. And the same is practiced for the regrind bin.

After the confirmation is done then the information from the virgin material and the regrind material is transferred on to the tag on mix bin and then is sent for V-cone mixing.
When the mix material is sent for V-cone mixing, the tag information on the bin is read first and the information is then transferred to tag on V-cone mixer and then the material is mixed and collected into the same bin, again the information from the V-cone mixer is transferred on to the tag on the bin.

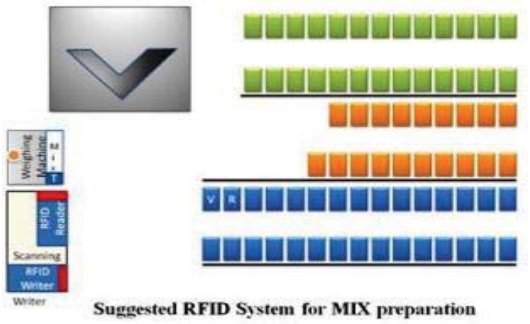

Fig 1.5: V-cone mixing, mix preparation, and storage

V – VIRGIN MATERIAL, R – REGRIND MATERIAL, MIX – VIRGIN+REGRIND

COLOUR CODE:

BLUE – IRON BASE COMPOUNDS

ORANGE – ELEMENTAL BASE COMPOUNDS

GREEN – STEEL BASE COMPOUNDS

3) RF Solution to Molding:

With the help of RFID system a material can be delivered to the correct destination. At the entrance of the molding department a computer and a RFID reader/writer is provided. The material running in each of the molding machines is fed into the ERP software. All the molding machines are provided with a flash light or a rotating light atop each and are connected to the output of the computer. When the material from the compounding is brought into the molding department the RF reader will scan the tag and through logic controllers compares with the molding machine running with the same material and gives an output signal to that machine. The operator visualizes the flash light and delivers the material to that molding machine thus preventing wrong delivering of the material to the machine.

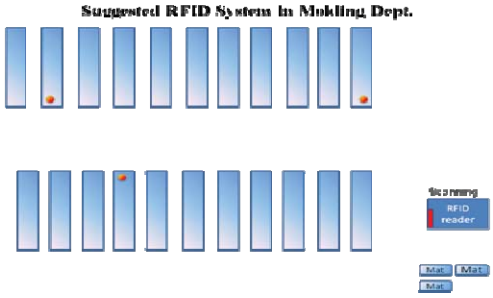

Fig1.6: Molding machines

MAT – MATERIAL FROM COMPOUNDING

VERTICAL BLUE BARS – MOLDING MACHINES

V. CONCLUSION

On the basis of experimental / trial run using RFID system in the present manufacturing process material mix can be prevented:

1. At the raw material storage area where the material can be tagged and kept. Whenever information is required it can be read through the RF reader at ease.

2. At the weighing area for the feedstock preparation. Right quantity and right powders and binders will be weighed in sequence without any operator errors, thereby preventing the initial mix up and also control the excess addition of material for the given feedstock preparation.

3. At the time of mixing in dry mixer, planetary mixer and then through the cooling table, the material can be tracked and can be checked by the management committee through the network connections.

4. At the time of mix preparation the right virgin material and right regrind material will be identified by the RF reader , thereby preventing the mix up at mixing stage, and also control the excess addition of material for the given mix

5. At the time of delivering the material to the correct molding machine, the RFID system ensures that the correct material is being delivered to the right molding machine

VI. SCOPE FOR FUTURE WORK

The scope for future work may include the use of RFID system integrated in the organization for:

1. Tracking the parts at different stages of manufacturing process
2. Logistics to sub contractors required for finishing operations
3. Packaging and shipments to various customers.

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