Improving Information Flow for Molding Maintenance Operations in a Medical Device Manufacturing Facility

by

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ABSTRACT

Manufacturing companies seek ways to eliminate waste from their operations to stay competitive. In this project, the waste is in the mold repair process which involves two main groups, Molding and Tooling. By using process flow mapping and analysis, the waste was identified in the information management aspects of the repair operations. The repair process was re-designed to incorporate existing but unused information systems, eliminating outdated methods that were inefficient. The process re-designs also incorporate several changes to have better accountability at various decision making stages in the mold repair work. Some of the changes have been implemented in a pilot project and have proven to be capable of improving the current methods. Other recommendations require a longer term approach to the problem through training and development of personnel.

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1 Introduction

CB is a medical technology company engaged principally in the development, manufacture and sale of a broad range of medical supplies, devices, laboratory equipment and diagnostic products. CB serves healthcare institutions, life science researchers, clinical laboratories, industry and the general public. CB has three worldwide business segments – CB Medical, CB Diagnostics and CB Biosciences. CB products are marketed in the United States and internationally through independent distribution channels and directly to end-users by CB and independent sales representatives. CB employs approximately 28,000 people in approximately 50 countries throughout the world with worldwide revenues, based on fiscal year 2008, of $7.2 billion which is a marked increase of approximately 13% from the previous year.

CB Tuas plant manufactures cannula, Product N, and Product S products. These products are first shipped to the various CB's distribution centers (DC), which then supply the products to their respective clients. The plant is organized into value streams (VS). There are currently 7 VS, each producing a different product family. The 7 VS are Product S, Product N, Insyte, Product F, Product U, Cannula and Tubing. Each VS is managed by a Value Stream Leader (VSL) and operates independently with its own equipment and workforce.

The core manufacturing process in CB Tuas is plastic injection molding. Out of the 7 VS mentioned, 5 are involved in manufacturing through injection molding which are Product S, Product N, Product E, Product F and Product U value streams. The CB Tool Room supports the operations by providing periodic maintenance and repair to the molds. The tasks undertaken by the Tool Room help to ensure the molds are in good operational condition for good production runs within the plant. Hence, Tool Room plays a critical service for CB Tuas. The Tool Room supports the repair and maintenance of a wide range of molds. Figure 1.1 shows the proportion of molds under the care of the Tool Room that are dedicated to each of the VSs.

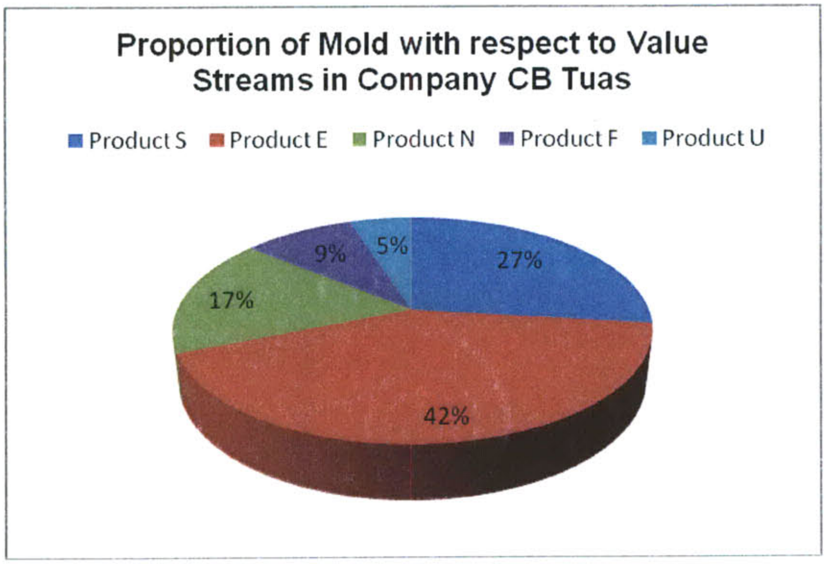


Figure 1.1: Overview of mold proportion by VS

The molds in each VS vary in size and shape since the products they produce come in various geometries and they serve different functional purposes. However, these products are still made from the same manufacturing process of injection molding. The following section provides an overview of the components and of the processes that constitute injection molding.

1.1 Injection Molding Production Process

The medical devices made by CB are comprised of plastic components that are injection molded. The injection-molding process involves plasticizing or melting plastic pellets and injecting them into a metal mold via small openings called gates. The melted plastic is then formed into a specific geometry in the cavity of the mold. Upon cooling and solidification, the final part is formed.

Each mold consists of the male and female mold halves and is an assembly of over 100 parts. These parts may or may not directly contribute to the geometrical formation of the final parts. Personnel in CB refer to the components of the mold that require more frequent replacement as a result of wear-and-tear due to their contact with hot or moving parts in the mold as "spares". For example, an insert in the cavity would be considered as a spare but a screw on the mold block exterior would not be considered as one even though they are all components of the mold. Figure 1.2 shows the cross-section of a mold.

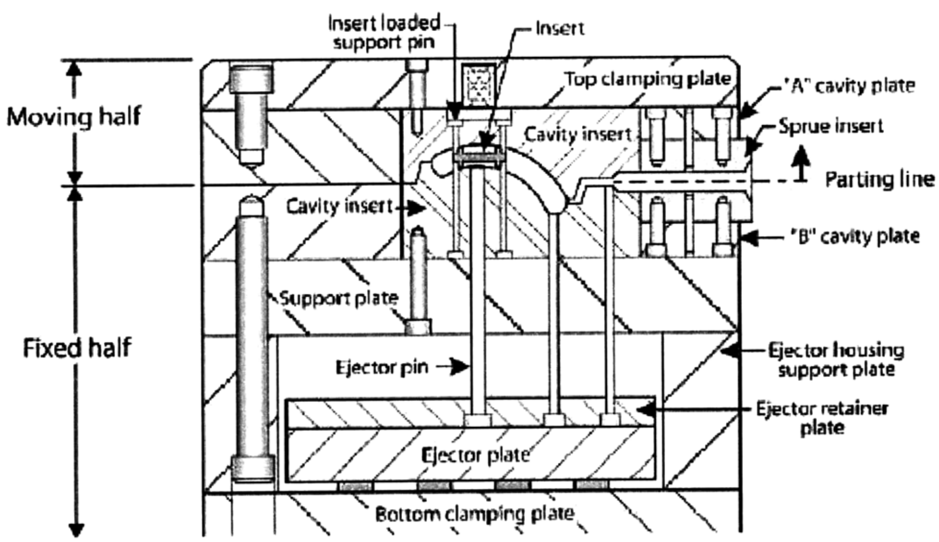


Figure 1.2: A schematic of a mold cross-section [1].

The male portion is referred to as the core whereas the female portion is called the cavity. The mold may consist of a single cavity connected to flow channels or runners which direct the flow of the melted plastic to the respective cavity. The fixed (stationary) half would consist of the ejector system. This enables the parts to be separated from the mold at the end of the solidification process. The moving half of the mold is connected to a hydraulic toggle of the injection machine which will retract to accommodate for part ejection. To support high production outputs, it is typical for injection molds to have multiple cavities. In CB, the injection molds can have as few as 4 cavities or as many as 96 cavities per mold. The complex geometry of CB products places stringent requirements on the mold and its cavities with some part dimensions in the mold controlled to five-thousandths of an inch. The molds are mounted on an injection molding machine.

Figure 1.3 below shows a schematic of an injection molding machine and Figure 1.4 depicts the injection molding process.

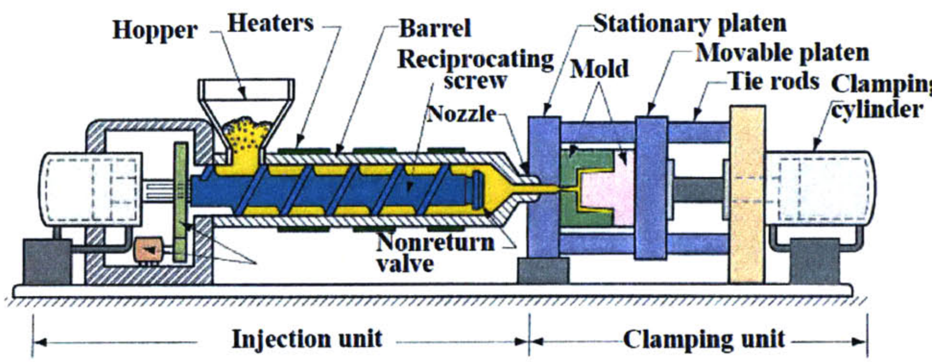


Figure 1.3: An injection molding machine [2].

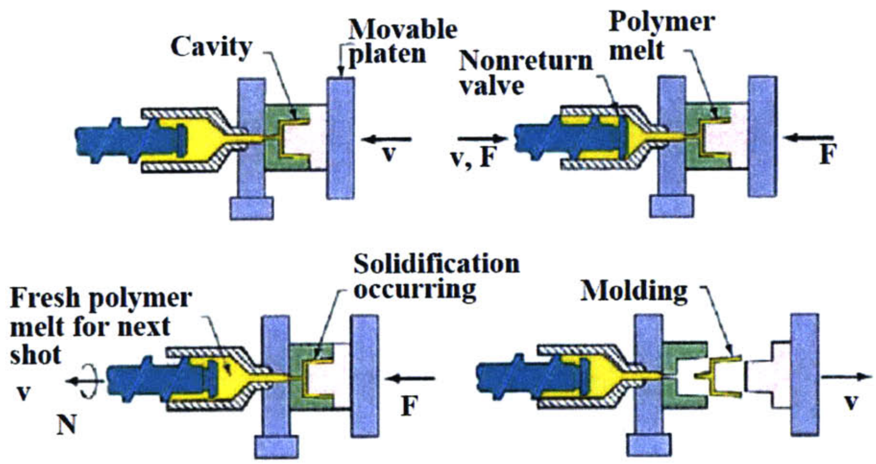


Figure 1.4: An injection molding cycle [2].

From the machines, operators can input the necessary parameters that govern the molding process. There are three basic operations to consider:

1. Raising and holding the melt temperature to a pre-determined level to necessitate flow

The raw plastic usually comes in pellet form. The pellets are heated in the injection heating chamber until the pellets reach a state of suitable viscosity. Heater bands and a reciprocating screw help to push the melt through to the gates ensuring the melt is flowing at a required pressure and viscosity.

2. Solidifying the melt in the mold

The molten plastic from the injection cylinder of the injection molding machine is transferred to the various cavities of the mold where it finally conforms to the contour of the desired shape (core). The male and female parts of the mold are kept in intimate contact for a determined period of cooling time during this process of shape-forming. Just like many other parameters in injection molding, cooling time is experimentally determined depending on the complexity and geometry of the part and the type of plastic used. The venting system within the mold is crucial to obtain good quality plastic products.

3. Plastic part ejection

The part is then ejected after being confined under pressure. At this point, the part would have frozen completely into the desired shape.

The above operations determine the process productivity since the speed of manufacturing the plastic products hinges on the speed at which the plastic can be heated to the molding temperature, how fast the molten plastic can be injected and the length of time for cooling to take place. Not all parts that make up the products are injection molded. Only the plastic parts are injection molded and then assembled with other non-plastic component to form the final product. The following section highlights the portions of the Product S, Product N, Product E, Product F and Product U which are injection molded and how defects in the plastic parts can affect the downstream production.

1.2 CB Product Types

A Product S is a medical device used to inject fluid into or withdraw fluid from the body. Figure 1.5 shows an example of a Product S manufactured at CB. A Product S typically consists of the barrel, plunger and stopper.

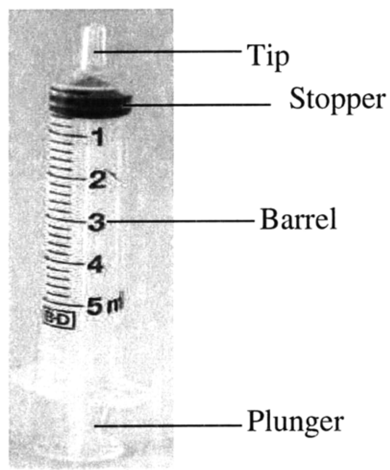


Figure 1.5: Parts of a Product S

The barrel comes with different types of tips, namely LL, LS, and Ec tip. Figure 1.6 shows the assortments of Product S tips.

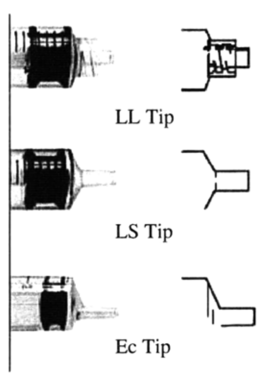


Figure 1.6: The various types of CB hypodermic Product S tip

All parts of the Product S except the stopper are injection molded. The Tool Room supports the manufacturing operation of these parts by doing repair and maintenance on 22 different types of molds with 7 molds responsible for plungers and the remaining tasked to produce the barrels. Of the 15 barrel molds, 3 are dedicated for 1cc LL production and 1 mold is reserved for 1cc LS production.

A CB Product N, as shown by Figure 1.7, consists of a polystyrene Product N hub and a stainless steel cannula. Both the hub and the shield are injection molded.

Figure 1.7: CB Product N configuration

The Tool Room supports Product N manufacturing operations by doing repair and maintenance on 6 hub molds and 6 shield molds.

A CB Product E, as shown by Figure 1.8, is comprised of the Product N with a safety shield that serves to cover the sharp Cannula after use.

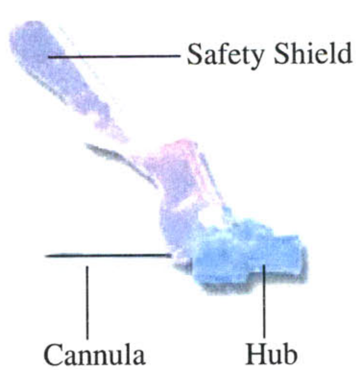


Figure 1.8: CB Product E configuration

The safety shield and hub are injection molded. Tool Room supports Product E manufacturing operations by performing repairs and maintenance on 1 Product N shield molds, 2 safety shield molds, 22 hub molds and 10 LS hub molds.

A CB Product U, as shown in Figure 1.9, is a pre-filled injection device targeted to provide a cost-effective way to deliver vaccines and other drugs safely to people in pre-specified dosage.

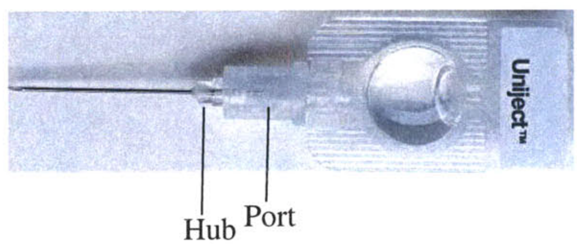


Figure 1.9: CB Product U configuration

The CB Product U is consists of the shield, port, hub and seat. These are injection molded plastic parts. The Tool Room supports the manufacturing operation of these parts by doing repair and maintenance on the 4 distinct molds.

Figure 1.10 shows a CB Product F product. It entails a luer and a shield which is injection molded.

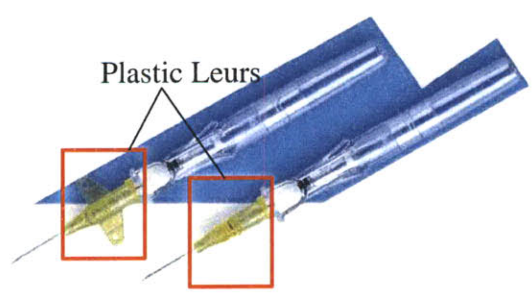


Figure 1.10: CB Product F products used in CB Catheters

The Tool Room supports the manufacturing operation of these parts by doing repair and maintenance on 3 male luer and 2 shield molds.. Table 1.1 summarizes the molds available in CB Tuas and the type of products that they are responsible for.

Table 1.1: Summary of the molds and the related products they produce.

Product S

S/N	Product Volume	Product Part	Mold
1	1 cc	Barrel	L6 (LS-Tip)
2			L23 (LL-Tip)
3			L75 (LL-Tip)
4			L78 (LL-Tip)
5		Plunger	L81
6			L13
7	3 cc	Barrel	L40
8			L7
9			L81
10		Plunger	L41
11			L21
12	5 cc	Barrel	L9
13			L10
14		Plunger	L15
15	10 cc	Barrel	L11
16			L12
17			L42
18		Plunger	L16
19	20 cc	Barrel	L27
20		Plunger	L26
21	50 cc	Barrel	L29
22		Plunger	L28

Product E

S/N	Product	Mold
23	Needle Shield	L43
24	Safety Shield	L44
25	Safety Shield	L45
26	Hub	L50
27		L51
28		L52
29		L53
30		L54
31		L55
32		L56
33		L57
34		L58
35		L59
36		L60
37		L61
38		L62
39		L63
40		L64
41		L65
42		L66
43		L67
44		L68
45		L69

Product E

S/N	Product	Mold
46	Hub	L70
47		L71
48	LS Hub	LS1
49		LS2
50		LS3
51		LS4
52		LS5
53		LS6
54		LS7
55		LS8
56		LS9
57		LS10

Product F

S/N	Product	Mold
58	Male Luer	F1
59		F2
60		F3
61	IV Shield	F6
62	NP Shield	F7

Product N

S/N	Product	Mold
63	Short Shield	L1
64		L19
65		L77
66		L79
67	Regular Shield	L2
68		L20
69	Hub	L3
70		L4
71		L5
72		L73
73		L82
74		L34
75	HP	L24
76		L25

Product U

S/N	Product	Mold
77	Shield	L30
78	Port	L31
79	Hub	L32
80	Seat	L33

1.3 The Role of Injection Molding on Production Flow

In a company that manufactures medical equipment, quality is paramount in ensuring that each of these products is able to deliver its respective function. These injection molded parts are put through stringent quality controls. Part feature tolerances can be as low as in microns. As shown by Figure 1.11, the production flow overview, molding operations form the top of the flow followed by printing, assembly and packaging.

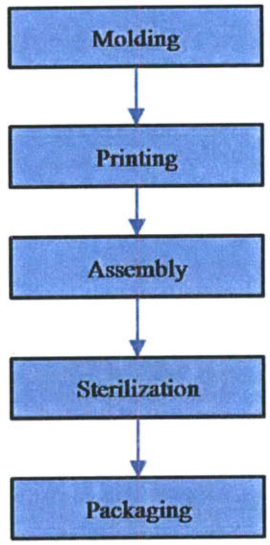


Figure 1.11: Overview of production flow in CB Tuas

Printing is responsible for the measuring labels and lines on the device components. Assembly is tasked to put together the components, plastic and non-plastic, that make up a device to form a functional product. Packaging refers to packing the products into individual blister packs and/or cartons to prepare for shipment out of CB Tuas. The sterilization process would take place before the product is packaged.

Inspection occurs during molding and after printing. Inspections done during the molding process ensure that product parts are not defective. Quality checks at the molding operations are performed bi-hourly on the current batch run of parts. Inspections performed after printing ensures that measuring labels are consistent and visible. Flaws that occur in the molded parts during molding operation will mean that the downstream operations cannot proceed until the proper troubleshooting on the molds and/or molding process is carried out. Consequently, the shipment of products to customers might be delayed. Since molding operations sits at the start of the production flow, it becomes a critical factor in ensuring if CB meets the targeted customer service level or not. Hence, the support that Tool Room provides to the molding operation becomes equally as important too.

1.4 CB Tool Room Department

The Tool Room department is responsible for ensuring that the molds used in the injection molding machines are capable of supporting production demand. Operations carried out by the Tool Room include:

- Repair molds and mold cavities to ensure good quality parts are produced
- Conduct periodic maintenance on molds
- Setup changeover in molds for different product production
- Investigate defects in molds and conduct Root Cause Analysis
- Purchase spares and other mold-related parts
- Control the quality of incoming parts
- Manage the inventory of spares and mold-related parts
- Keep records of the above activities

The primary task of the Tool Room is to repair molds and mold cavities, the overall process flow can be seen in Figure 1.12 below:

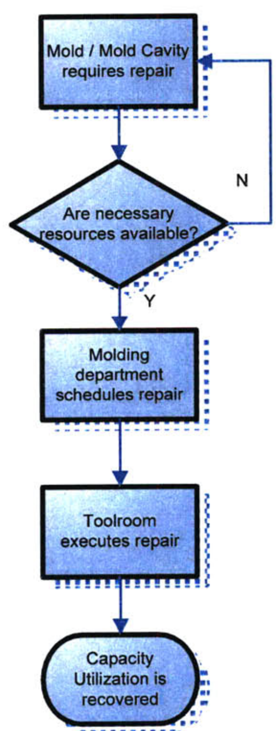


Figure 1.12: Simplified repair process flow

The necessary resources in this case are the spares availability, labor, and time. This is why the inventory of spares is being managed by the Tool Room as well, as they are expected to ensure that the necessary spares are kept for any repair operation to be carried out.

1.4.1 Tool Room organization and CB value streams

As described in the previous sections, CB organizes the product families into value streams which are managed separately from each other; each value stream will have it's own set of molding machines which are dedicated for that VS. Thus there is not a functional department for molding; rather each value stream independently manages their respective molding processes.

Thus, the Tool Room organizes itself to support the value streams in a similar manner. For larger value streams such as the Product N and Product S department, there are two Technical Specialists (TS) assigned to each VS to execute any required repair operations. Product E is a smaller value stream with lower production volumes, so there is one TS assigned to support it. Product U and Product F are the smallest value streams of all, so there is a single TS who is responsible for overseeing both value stream repair operations.

To perform the other functions of Tool Room, there is one TS with responsibility for the scheduled preventive maintenance programs for the molds. These programs are organized by time, so molds are maintained every quarterly, six-monthly, or annually. There is one more TS who is in-charge of purchasing spares at the request of the other TSs in the Tool Room, and for checking the quality of incoming spares. The TS working in the Tool Room is commonly referred to the Tool Room TS (TTS) whereas the TS working in the production area is called the Molding TS (MTS).

1.4.2 Tool Room Vision and Our Project

The Tool Room vision states "*To work as a team and provide better mold turnover time while meeting targeted Capacity Utilization with CB's quality requirements to satisfy our customers.*"

Capacity Utilization (CU) refers to the percentage of the cavities per mold that are able to produce good parts. This is also a key performance indicator of Tool Room operations. Our project is thus to focus on helping the Tool Room improve its operations so as to achieve this vision. The ultimate goal is to maintain and repair the molds so that each mold achieves close to 100% CU at all times. This is the service level that the senior management hopes to achieve in the long run.

1.5 Mold Repair Work Function

The primary function of CB Tool Room is to carry out mold repair work to support the molding production operations. In order to carry out the work, the Tool Room has to work closely together with the molding function in order to understand the problems they encounter. The Tool Room also carries out analysis of the defective parts that do not meet the quality requirements. and the Tool Room diagnoses the problems and then carries out the necessary work on the molds to correct them. This requires a significant level of technical skill and experience.

1.6 Purchasing and Inventory Management Function

Another key function of the Tool Room is to manage spare component inventory. Inventory levels need to be managed such that a high service level is achieved in providing spare components for maintenance activities. This complements the goal of the Tool Room to meet its proposed service level of close to 100% in terms of CU recovery.

Traditionally, spare components that are used for the repair, maintenance and setup changeover activities are managed by the individual TS for each VS. Each TTS has the responsibility to carry out all these activities on the molds from their value stream. This includes ensuring that they keep enough quantities of the spare components on-hand for their needs and purchasing these parts whenever they need to replenish the inventory. They have to ensure that the cost of the purchases each month does not exceed the given budget for such spare components.

1.6.1 Purchasing Process

The task of purchasing spare components is assigned to one TTS in the Tool Room, who oversees other non-technical tasks within the department. Each TTS who needs to purchase spare components would submit an order verbally to the purchaser. The purchaser would then communicate directly with the vendor to inform them of the item to be purchased, the order quantity, the requested delivery lead time and other custom requirements for that particular spare component. Following this, the purchaser will raise a Purchase Requisition (PR) through the SAP system that would be sent to the Purchasing department. Once this is vetted by Purchasing, the PR would be converted to a Purchase Order (PO) that is sent to the appointed vendor. The vendor will deliver the spare component to the warehouse when it is manufactured. Once the part is received by the warehouse, they will inform the Tool Room of the availability of the spare component. The warehouse is located on the same premises but at a different location, and is considered a department by itself, responsible for storing inventory. The purchasing process is completed when the order is delivered to the warehouse. The purchaser will draw out the spare component from the warehouse when it is required by the TTS for either the repair, maintenance or setup changeover activities. Once the component is drawn from the warehouse, it is considered as used in the system and the quantity is deducted from the on-hand inventory level. The system is setup in this manner so as to provide traceability of inventory levels and also the usage of spare components. The TTSs are not allowed to keep any inventory of spare components within the Tool Room but only to draw out the spare components when they need it. The TTS are responsible for monitoring the inventory levels of each spare component and ensuring that they have enough on-hand to meet requirements.

Variations to the whole procurement process flow occur on certain occasions. Firstly, if the vendor faces unexpected delays in fabricating the spare component on time, he would either apply for an extension to the lead time required for delivery or deliver it late. Secondly, whenever a new spare component is bought, it needs to undergo a quality control inspection to ensure that the dimensions of the spare component conform to requirements. The component might be rejected because it did not meet the specifications and the total lead time to deliver a finished part would be extended.

The SAP software is utilized as an inventory management program by CB. During purchasing activities, the program is used to create a PR form. Each individual spare component is assigned an SAP number which acts as an identifier of that component from the particular mold that it is used in. This identifier, together with the unique PR and PO numbers for a particular order, are used by the system to track the purchasing history of the spare component in SAP.

The tracking of the spare component would allow the user to generate reports regarding order patterns of the spare component inventory. They would be able to monitor via the reports when the particular component was purchased by month, the quantity that was purchased and the total cost of the spare component purchased.

The SAP software also contains values for the safety stock and reorder quantity. Based on past purchasing and usage history, the system utilizes this information to recommend safety stock levels, reorder quantities as well as other metrics that are related to inventory. These recommendations are provided to the user and the decision lies with the user whether to use the recommended metrics. In addition, the SAP system is able to send an alert to the purchaser to recommend making an order when the inventory level of any spare component drops to the safety stock level or below.

2 Problem Statement

The aim of the tool room is to restore any defective mold to 100% capacity utilization (CU). This would ensure that each mold can produce the maximum yield when it is run on the production press. The problem that the tool room faces is that many of the molds do not run on 100% CU. Defects which occur due to mechanical wear occur very frequently, lowering the CU of the mold. Due to the inability to restore molds to 100% CU, each mold is set a respective targeted capacity utilization. The targeted CU currently serves as a benchmark for all production for that mold. Molds running below 100% CU are more likely to require longer production runs to meet the desired work-in-process (WIP) level or demand. Inevitably, such molds wear out more quickly. Since there are no replicates of molds for each part or component, a quicker wear rate means more disruptions to production.

Molds running below their targeted CU will be removed from production for inspection and repairs. During this process, spare components that make up the mold might be replaced with new ones if they are found to be unrepairable. Ideally, the Tool Room TS should be able to return the molds back to production in an as-good-as-new condition with all cavities running flawlessly. However, they are often not able to return the molds to 100% CU even after performing their repair work. The inability to return a mold for production with full CU has implications downstream of the production line. It takes longer to produce a certain volume of the end product to fulfill a customer order, thus increasing the lead time taken for CB to fulfill customer demand for that particular product. Lengthier production runs will lower CB's service level which could lower customer satisfaction. Therefore, the implications of not meeting 100% CU are potentially felt all the way downstream to the customer.

Three key areas have been determined to contribute to the overall problem of the tool room's inability to meet the 100% CU aim for its molds. These have been identified as (1) inefficiencies inherent in the current CU recovery process, (2) the lack of on-hand spare components to carry out repairs and (3) the lack of data on defect characteristics in the molds which could be used to identify underlying trends.

2.1 Inefficiencies in CU Recovery Process

The effects of inefficiencies inherent in the CU recovery process can be easily seen. They cause the inability of the current system to meet the target of 100% CU recovery. Finger pointing and fire-fighting are the norm between the Molding and Tool Room departments. However, the constraints faced by the current process are not as easily identifiable. The TTS have been involved in tackling problems which are symptoms of the inefficiencies. As yet, no one has attempted to take a more in-depth look at the underlying causes which are the source of those symptoms. To some extent, the CU recovery process needs to be re-engineered to eliminate or reduce those inefficiencies, or "waste". The whole process can be broken down into separate parts that could be looked into in more detail.

2.1.1 Mold Recovery Preparation

Every morning, the TSs spend more than an hour in a meeting discussing the molds which need to be taken offline from their presses in order to be repaired to full CU. In this meeting, the issues that are discussed include:

- Determining what the exact problem is with the mold and how best to fix the problem
- The amount of lead time needed to carry out the CU recovery process
- The schedule of repairs to be undertaken for the various defective molds

This discussion is excessive and unnecessary, consuming a lot of time which could be spent on the CU recovery process itself. Waste is present as there are currently no specific standard procedures that are utilized in preparation of the CU recovery activities. The various stakeholders arbitrarily try to determine the best way to solve the problems encountered based on past experience and their subjective opinions. These stakeholders include the Tooling TS, the Molding TS and the Molding engineer who are in charge of the production line.

This problem can be attributed to the lack of a system of accountability and transparency in this preparation process. There is no way to identify repetitive problems and to make a quick decision based on past data. Despite the existence of software, such as Apriso and SAP that is meant to aid the stakeholders in the decision process of commencing mold recovery activities, these aids are not sufficiently utilized. Therefore, there is much scope for improvement in terms of decreasing the time taken to complete these preparations for repair activities. This would help to decrease the turnaround time for a mold that is not online. The lack of accountability is evident as the molds are used in the Molding department, which is where the defects and issues occur, yet the current system allocates the responsibility of ensuring the molds are at high CU levels to the Tool Room. This creates friction between the departments when problems occur.

2.1.2 Mold Recovery

While the CU recovery process is underway in the Tool Room, the TS also have to be continuously involved in expediting activities to ensure that the molds are repaired within the required lead time. There are two reasons why this occurs. Firstly, the schedule of repairs is often interrupted by more critical molds that have a higher priority. These molds are considered more essential for production activities by the molding engineer or production engineer, who overrides the decisions made between the Molding and Tooling technical specialists during daily meetings in the morning before the start of the morning shift, called Shift Start Ups (SSU). Often at times, this causes the Tooling TS to be overwhelmed with too many molds to recover at the same time. This creates a log jam of jobs that the TTS would struggle to repair in the expected amount of time due to the sudden increase in workload. Expediting the repair of more critical molds thus causes a disruption in the repair schedule of the defective molds that are in process with the TS. This eventually leads to more delays in the overall CU recovery process for each product value stream.

This situation is compounded by the practice of blocking cavities within the molds when a problem occurs during production and not carrying out the recovery process for the problematic cavities sooner, thereby allowing the mold with blocked cavities to continue operating on the production press. As a result, when these molds have reached the point when their recovery must occur, this time coincides with the breakdown of other molds.

The common responses to these situations are to increase overtime hours in the Tool Room, which increases the Tool Room's operating costs. Such situations increase the resentment among Tool Room members who feel that the Molding department is simply pushing all the work and blame to them.

Secondly, expediting occurs because on many occasions, the TTS do not have the necessary spare components that are needed to carry out the CU recovery work. They either discover that they do not have enough of that particular component in the inventory or that the part is out of specification when it is needed.

2.1.3 Post Mold Recovery activities

Until today, the Tool Room uses paper-based forms to record information. These handwritten forms are poorly maintained, are not standardized across value streams, and are filed away into cabinets and kept for storage. The open ended nature of handwritten forms results in naming conventions left to the whim of the person making the entry, barely legible handwriting which further aggravates the poor quality of the information. Initiatives by various individuals in both the Molding and Tool Room have been made, such as creating their own spreadsheets to record the information they feel is important to them. While they should be applauded for their proactive efforts, this is inefficient as there is no sharing of such information among the individuals.

2.1.4 Current Solutions

An attempt has been made to improve the process of CU recovery. The Tool Room manager has incorporated a system that rewards the TTSs who are able to maintain the molds, for which they are responsible above a certain capacity level. This encourages them to actively seek solutions to maximize the percentage of working cavities after each CU recovery process. They have an incentive to take more responsibility for the repair activities carried out and to manage the process better. The Tool Room engineer has also started keeping records of the defects which occur in the molds. This is an attempt to determine the root cause of the defects to the mold which could allow the TTS to carry out repairs more effectively and reduce the mean time to failure of the molds. This paper recommends a re-designed workflow that will incorporate existing software in CB Tuas to improve on this CU recovery process.

2.2 Inventory oversight for Spare Components

The lack of spare components to carry out necessary repairs is a significant problem for the Tool Room. The lack of on-hand spare inventory prevents the TTS from carrying out a 100% recovery for any defective mold. This results in the mold having to be used in production at less than 100% CU. A corresponding concern for the Tool Room is also the failure to meet the cost constraints imposed on it. With regards to spare component inventory, the Tool Room is provided with a monthly budget to purchase spare components. However, the purchases by each value stream on the spare component inventory frequently exceed the allocated funds deemed sufficient to meet the demands of the Tool Room.

Both of the above-mentioned problems occur primarily due to the lack of proper management practices for the spare component inventory of the Tool Room. This is characterized by two main issues.

2.2.1 Inadequate Safety Stock Levels

Lack of sufficient spare inventory on hand occurs because safety stock levels of the spare components used by the Tool Room have not been adequately set or are non-existent. As a result, the TTS, who manage the inventory of spare components, bases the amount that they should have on-hand on an arbitrary figure. This could create bias in stock keeping where the TTS underestimates the optimal level of inventory of the spare components to keep. Due to a lack of proper records of previous usage of the spare components, there is no basis to determine the proper level of safety stock.

2.2.2 Inconsistent Reorder Quantities

Excessive ordering of certain spare components also takes place. This is due to the lack of proper evaluation of past usage data. Ordering of spare components is largely dependent on the opinion of the respective TTS of the perceived future demand for the spare component in repairs. Thus, there is human error involved in the estimates of reorder quantities, resulting in inconsistent replenishment of spare components. As each value stream has a limited budget for the purchase of spare components, using this budget for rarely used components might prevent the purchase of other components which are as critical and which are ordered on a more consistent basis. This also creates a lack of spare components on hand when emergency repairs need to be carried out.

Having insufficient inventory of spare components results in partial CU recovery of defective molds. This hinders the service level of the Tool Room. Not having enough inventory is also a serious problem due to the fact that certain components have known lead times which can last up to several weeks. If the TTS requires a large number of the spare components within this period, he could run out of critical spare components. Furthermore, there could be unforeseen delays such as supplier production delays or the Tool Room having to reject the spare components because they are out of specification. Long lead times are due to some of the suppliers being located overseas and having to ship components to the Tuas manufacturing plant in Singapore.

Although metrics such as safety stock and reorder quantities can be determined by SAP, this was not done even with the SAP system in place. The cause of this lies with the improper use of the system by the Tool Room personnel. Historical data was not readily available for determining those inventory metrics due to the lack of proper records of previous spare component usage. The TTS resorted to recording the repair records manually using hardcopies. Such records were usually poorly filled with non-standard terms used by each individual TTS. Frequently, there would also be missing records of spare component usage due to time constraints on the TTS and human apathy.

Even when the usage of spare components was recorded on hardcopies, the transfer of this information to the SAP system was not meticulously done. Therefore, this led to the further loss of such information, not to mention the additional workload created by recording information both on hardcopies and in the SAP software.

In addition, the system is not adequately configured. Currently, only a low percentage of the spare components have been assigned an SAP number. This translates to approximately 15% of all spare components. This means that 85% of the other entire spare component inventory is not tracked properly by the system as they have not been assigned an SAP number. Historical records of usage and purchases of such parts are inconsistent due to the lack of standardization of names used. Furthermore, for the spare components which have been assigned SAP numbers, information about the vendors and the pricing are currently inaccurate due to recent changes made as a result of ongoing vendor evaluations.

The personnel also do not adhere strictly to the recommended practice of drawing spare components from the warehouse only when they require it for repairs or maintenance activities. Due to the added inconvenience of having to physically walk to the warehouse whenever a spare component is needed, each TTS also holds on to a quantity of each spare component to provide easy access to it. The actions of the TTS in doing so also hinders the traceability of spare component inventory levels as the spare components drawn from the warehouse are considered expended within the SAP system.

As a result, much of the information on inventory levels displayed in SAP can be considered unreliable. Historical data on mold repairs can also be considered inaccurate and does not give a true picture of actual spare component usage.

2.2.3 Current Solutions

The Tool Room has recently tried to improve the tracking of spare component inventory and tackling the problems causing stock outs to occur. The TTSs have recently been trained in the use of the SAP software to track the actions taken during the CU recovery process and the spare components that have been used for the repairs. They are being monitored in their use of the relevant forms that have to be filled whenever a repair activity is carried out. By closely monitoring the usage of spare components in SAP, the system can provide the necessary data needed to evaluate the appropriate inventory metrics such as safety stock and reorder quantities in future.

CB has also created a department named the Tool Crib to be wholly responsible for managing the spare component inventory. This is meant to provide more accountability regarding the usage of the inventory and more visibility regarding inventory levels of various components.

The creation of the Tool Crib is an important step as the TTS will no longer have to dedicate time to managing inventory of spare components. They will be able to focus on carrying out the CU recovery process. This will allow for increased traceability of the spare components due to the implementation of a uniform system to procure and withdraw spare components from the on-hand inventory.

The Tool Room has commenced the handing over of its inventory to the Tool Crib and it will take a period of time for the system to be used for handling the spare component inventory. Lim's [3] project aims to provide a framework to help the Tool Crib in managing this spare component inventory.

2.2 Lack of Analysis of Defects

Lastly, there was no proper process for defect tracking within the molds. The current practice is that the TTS records the repair activities into a form provided for them. Although the defects were recorded, these were usually disparate records done by various parties which created redundant work. Furthermore, these records were done for the sake of having them without being properly compiled and evaluated. Even if these records were used to obtain a defect trend across the various molds and within specific molds, analysis was usually rudimentary. These results could potentially be utilized to come up with a root cause analysis to reduce the frequency of breakdowns. In addition, the frequency of defects occurrences can be utilized to identify the appropriate time for conducting regular maintenance.

2.2.1 Overview into Defect Investigations

The morning SSU provides the information to the TTS and the engineer for the problem(s) sustained by the molds. Samples of the defective products are consolidated by the production technician (PT) and MTS and these will be handed over to the engineers for a close-up observation. Through the defects detected from the molded products, engineers and TTS might be able to identify the root cause to these defects. In analysing these defects, the experience of the engineer and TTS will prove to be crucial since the defects can be caused by the machine, mold components, operator-handling and molding process. There are instances when the engineer has to look into all four defect-causing agents before proposing a feasible root cause. Investigations into the defects that occur can range from a day to a week, or in some cases, it might even be longer.

Defect-types that have been identified are entered into the Monthly Mold Report form by the TTS who perform the mold repair. A particular defect-type can be called differently by different TTS. This lack-of-standardization issue seems to appear in the naming of mold components as well as defect-types. TTS performing the repairs tend to omit key information such as the length of repair time done for the respective defect-types. Even if repair times are entered into the form, they may appear to be ambiguous, for example, seemingly trivial repairs take longer than expected.

2.2.2 Current Solution

The TTS make a conscientious effort to update the Mold Monthly Report form. Dates of the repairs done are entered accurately. At the present, Tool Room engineers will input the information from the Mold Monthly Report form into Microsoft® Excel spreadsheets. With the aid of a PivotTable function in the spreadsheets, engineers will be able to identify trends of defect occurrences. However, that is the only analysis that the engineers do with the data in the spreadsheets. In addition, there is no attempt as yet to standardize the names of defect-types and there is no enforcement on the TTS to provide accurate repair times.

Analysing the trend(s) in defect occurrences and reliability of the molds can be an area of study to better manage the repair activities in the Tool Room. Mohd Fauzi's [4] paper introduces a method by which such analysis can be carried out.

2.3 Project Objective and Scope

Our team aims to assist with the current efforts of the Tool Room in improving on their operations. The project will be split into 3 components targeting 3 different aspects of operations.

One component involves looking at using the SAP and Apriso information technology systems to implement a process to manage the information flow for mold repair operations. Improving the information management process will increase visibility to the states of the molds and their performances, enhance real time decision making, and reduce time wasted on unnecessary efforts in duplicated work to transfer data from hardcopy to softcopy.

Recommendations will be made to improve Tool Room work processes by utilizing this system to extract performance measures that will measure the productivity of the Tool Room. This part of the project will be further elaborated on in subsequent sections of this paper.

To assist with the setting up of the Tool Crib, another component will focus on improving the management of spare parts that are under the responsibility of the Tool Room. The task is two-fold. Firstly, the spare components will be categorized according to common characteristics such that the appropriate inventory management tools can be applied to each category of spare components. This is currently lacking in the planned system for the Tool Crib. Secondly, proper analysis will be carried out to define the optimal inventory level of these spare components by deriving initial safety stock levels and reorder quantities to be used by the Tool Crib. The aim is to reduce costs from stocking excessive inventory and improving the service level of meeting demand for spare components needed to carry out CU recovery. Indirectly, the service level in terms of percentage of CU recovery by the Tool Room will also be improved. This part of the project will be handled by Lim [3].

The last component will look at the top few occurring mold defects that are unique to a pilot of 1cc Product S molds, L23 and L78, and a 3cc Product S mold, L7. These top few occurring types of defects will be classified as priority defect-types. The damage to the associated mold components will be determined from the mold product defects. There are many factors causing defects to occur on the molded parts. These factors can be process, operator-handling skills, injection molding machine and environment and the parts condition of the mold. However, this part of the project will focus on the effect of defective mold components on product defects. Obtaining the trend(s) in top defect occurrences allows the prediction of the length of time a mold can run before the same defect occurs again. From this, the following will be derived:

- With the defects-to-components list mapped out, we can then proceed with designing and recommending tasks that handle replacement of necessary spare parts.
- Understand the reliability of the molds based on the past failure times data.
- Plan the preventive maintenance (PM) interval based on the available task list.

This part of the project will be handled by Mohd Fauzi [4].

3 Literature Review

To ensure competitiveness, many large manufacturing companies have taken some approaches of lean concepts in order to reduce costs and increase productivity. In order to fully realize the potential of lean manufacturing, the maintenance function of these companies must utilize lean principles too. Good management of the maintenance organization is therefore vital for the progress of a manufacturing firm, and there are many books currently available on such topics, such as the one by Smith and Hawkins [5].

Pintelon and Gelders [6] identified and discussed elements in the decision making environment. There are many levels of decision levels for maintenance management of equipment, such as operational planning. The availability of good data and having a good maintenance work order information flow are vital ingredients for approaching such levels of planning. For smooth management, well structured and efficient procedures should be in place. Managing resources such as personnel, documentation and MRO (maintenance, repair and operating supply) are also indispensable for effective maintenance management.

In maintenance management, human behavior and information flow are key factors in all strategic dimensions. Tsang [7] introduced one of these dimensions as the use of support systems such as management information systems to collect, retrieve and analyze data for strategy formulation, decision making and progress monitoring. For change programs such as lean transformations, the effective deployment of support systems is a critical issue that if poorly managed, can result in failure of these initiatives.

One example of such support systems is Computer Managed Maintenance Systems (CMMS) which are designed to manage accurately and timely the large amount of data which are useful tools for maintenance managers to efficiently allocate resources. Strong management and leadership are needed to successfully implement CMMS. The failure rate for CMMS installations is extremely high according to a book by Cato and Keith [8]. Common dominant factors include partial implementation, resource constraints, effort fragmentation, staff overload or a lack of staff, inappropriate expectations, lack of behavioral expectations, treating computers as deliverables, internal politics, poor communication, lack of expertise, and work culture restrictions.

Cato and Keith [8] also suggested some fundamental requirements for successful CMMS implementation. The work environment is key, where each department such as production, procurement, maintenance, and information systems has their roles to play. Discipline, standard procedures and practices are essential for success.

The way assets are used to deliver products or services is known as a process. When companies implement new computer systems such as CMMS, they often have to make changes to their processes for greater cost-effectiveness. Campbell [9] suggested that changes can be made either through continuous incremental improvements, or through process reengineering for dramatic performance advances. Reengineering the process involves process mapping and analysis, visioning and reengineering. In order to support the reengineering process, senior executive leadership and management commitment to change is required.

Madison [10] introduced a list of symptoms of a broken process, among them are finger pointing between departments, data redundancy, firefighting and no management of the total process. All these symptoms apply to the problem of the CU recovery in the Tool Room. He also described thirty-eight principles for process redesign, of which some were directly applicable to information flow.

A similar study at a consumer electronics manufacturing company has been carried out before by Chase [11] during an internship undertaken as part of the Leaders for Manufacturing program at the Massachusetts Institute of Technology. Work flow processes in the maintenance organization were investigated and suggestions to improve the processes and the CMMS infrastructures to support those processes were made.

CB does not have a CMMS. They do use other IT software such as SAP and Apriso. SAP is Enterprise Resource Planning software, and Apriso is a Manufacturing Execution System. They are not designed specifically for maintenance management, but have many possible avenues of data and communication flow and storage such that there is potential for them to be used as tools to enhance management of the Tool Room operations.

De Groote [12] introduced a series of performance indicators for maintenance performance strategies. These performance measures are defined in relative values as ratios to depict efficiency and are classified under two broad categories, economic and technical. Some of these ratios can be readily applied in this project's context whereas some are more applicable throughout an entire manufacturing plant.

Sawhney et al. [13] also introduced the concept of Mean Maintenance Lead Time and its breakdown into other time components to measure maintenance activities themselves and not the maintenance strategy. The ability to measure this performance would be useful for CB to monitor the Tool Room's performance.

4 Methodology

4.1 Overview

The primary tool used to formulate a solution to the Tool Room's maintenance information management problem is process flow mapping and analysis as recommended by Campbell [9] and Madison [10].

The steps taken were to first have a preliminary analysis of the problem by drawing an "as-is" state process flow map of the workflow for the mold repair process. Subsequently, an understanding of current practices with regard to information management and flow were established. Gaps in the process and areas for improvement were then identified for the project's focus. Following which, a review was carried out to determine the viability of utilizing other resources available within CB's existing infrastructure to improve this process. Finally, an improved process was designed and the future state process flow map was created.

4.2 Preliminary analysis by drawing an "as-is" process flow map

In order to identify the areas for improvement in the CB Tool Room operations, it was first necessary to understand how the CB Tool Room carried out its daily operational activities. The first level of understanding was based on a visual observation of the daily activities carried out by the Tooling Technical Specialists (TTSs) of the Tool Room. The TTSs were involved in not only the repair of the molds, but they also had to spend time doing other administrative tasks such as form filling and attending meetings everyday.

Questions regarding the TTS work practices were directed to them in an informal manner as the questions surfaced during the observation of their daily activities. This method was successful thanks to the TTSs being forthcoming and quite often they would provide even more information than asked.

In order to simplify the problem solving process, we developed a generalized workflow that ignored the variations in the process, presented in Figures 5.2 to 5.4 in Sections 5.1.4 to 5.1.6 from page 44 to 49 of this paper. This map was accepted by the various TTSs as a suitable, general reflection of their current situation, ignoring the other occasional variations due to different practices between the value streams.

Understanding the decision making process and information flow involving mold repair was the second level of understanding required for the preliminary analysis. Part of this was carried out by attending the daily morning meetings known as Shift Start Up (SSU) comprising of personnel from Molding and Tool Room department. The decision making process also varied between the value streams, which each conducted its own SSU. Information was also collected by going through several of the hardcopy archives of the paperwork that the TTS would file.

4.3 Identifying areas for improvement

Based on these preliminary investigations, the "as-is" process map was drawn, and from these investigations, inefficiencies in the work processes and information management were identified, documented and confirmed. These areas for improvement are presented in Section 5.2 of this paper.

4.4 Review of existing infrastructure to improve information flow in process

We observed that the information that was collected in the "as-is" process was via handwritten forms. This led to subsequent problems which we will elaborate on in the results section. After this matter was highlighted in one of the update meetings with CB management, we learned that CB had installed software that might be useful for this project; SAP and Apriso Flexnet.

SAP software is used for many other business functions in CB such as finance and logistics. It was understood then that there were modules available for use to support the maintenance function as well. However there is no one in CB who knows how to fully utilize the available modules in SAP for Tool Room's mold repair operations. Anyone who had known about these functions had already left the company and did not pass on the knowledge to others.

The Apriso system was installed in CB but it was not a properly implemented system in the Molding department. The Apriso implementation had died off a few years after its introduction in 2007 for the same reasons as mentioned above for the SAP modules. Apriso is actually a system that is designed primarily for managing the production output and performance of the machines that produce the products. Being a part of a molding machine's performance, some information pertinent to the performance of a mold is also required as inputs and is recorded in the Apriso system.

Thus a part of the project was spent to investigate how the modules in the software could be used in the information flow and management of mold repair operations carried out by the Tool Room. A discussion of this investigation is also presented in the results section.

4.5 Creation of future state process flow map

Finally, the future state process flow map was drawn up to incorporate the findings and improvements resulting from the internship at CB to facilitate better information flow. A discussion of the changes and their effects will be presented as in the following section as well.

5 Results and Discussion

5.1 Preliminary analysis of problem

5.1.1 Macro-view of mold repair process flow

As mentioned in Section 4.2, a preliminary analysis of the problem was done in order to specify areas for improvement in the information flow in the Tool Room mold repair work process. This preliminary analysis was conducted and the result of that analysis was a mold repair process flow map. Figure 5.1 below shows a macro view of the "as-is" mold repair process flow. The process can be broken down into five main stages, first with reporting the problem. Subsequently, there is a decision making process and then preparations are made. The repairs are then carried out and then some post-repair administrative tasks are completed to end the process.

At the beginning of the process in stage (1), information such as defect type, time of occurrence, affected mold and cavity position are recorded into hardcopy forms. These forms are used for discussion in stage (2) as the defects are analyzed and plans are made to repair the molds. At stage (3), the information is used to create the work order in the SAP system and to prepare for the repair work. After the repair work has been completed in (5), these forms are kept in files and work orders closed. Brief descriptions of the work that was carried out are recorded in a separate form with a list of spares that were used to replace defective mold components.

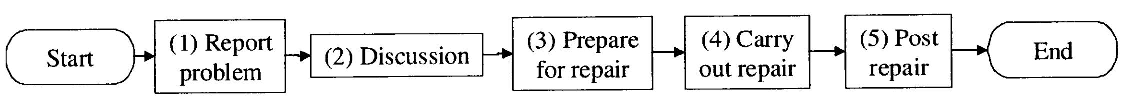


Figure 5.1: Macro-view of mold repair process flow

5.1.2 Key personnel involved in mold repair process information flow

5.1.2.1 Production Technician (PT)

The PT in the Molding department is the molding machine operators. The PT is the first to respond to any problems in the molding machine during production, and is also the first to discover defective molded parts as he or she carries out quality inspections on molded part samples collected bi-hourly. Information on the molded defects are entered by the PT in hardcopy forms known as Cavity Chart and Block Cavity Report Form in stage (1) shown in Figure 5.1 discussed earlier. Discussions on these forms are presented in Sections 5.3.1 and 5.3.2.

5.1.2.2 Molding Technical Specialist (MTS)

A MTS acts as the leader for a few PTs. The MTSs are responsible for determining if machine stoppages are tooling related and to call the TTS if so. They are also tasked by the Molding Engineers to schedule the mold for repair and to co-ordinate the repair work with the TTS. It is also the MTS who will discuss molding defect issues with the TTS based on the information given to them by the PTs.

5.1.2.3 Molding Engineer (ME)

In each value stream, there is one ME who oversees the molding operation for that VS. The ME is not directly involved in the information flow during the mold repair process. He is kept updated on issues during the Molding SSU or from the MTS and serves in an advisory role to the MTS and TTS if the problem that occurs is an uncommon occurrence.

5.1.2.4 Tooling Technical Specialist (TTS)

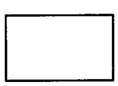
As mentioned in the introduction section, the person who carries out repairs on molds is the TTS. The TTS receives the information from MTS regarding the state of the molds and any issues that have occurred in the previous day during SSU which were recorded by the PTs. With the information given to them, the TTS exercises judgment on what needs to be done and the spares required in order to repair the mold. Before the repairs are carried out, the TTS will create a Work Order in SAP. When the repairs are completed, the TTS will update a new Cavity Chart and make a record in a Mold History Form. An introduction to the Work Order and Mold History Form will be presented in Section 5.3.4 and 5.3.5

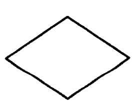
5.1.2.5 Tooling Engineer (TE)

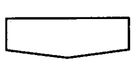
The TE is not directly involved in the information flow during the mold repair process. He is kept updated on issues during the Tool Room SSU or from the TTS and serves in an advisory role to the TTS if the problem that occurs is an uncommon occurrence. He also refers to the data collected to perform analysis of the mold's performance and to solve problems.

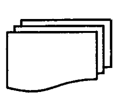
5.1.3 Flowchart Symbols Legend:

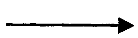
The flowchart of the "as-is" mold repair process and the suggested future mold repair process are presented from Figure 5.2 to Figure 5.6 in the following pages. The symbols used in the flowchart and their description are provided below.


: Flowchart Process Step / Activity


: Decision Diamond


: Off-page Connector


: Documents / Forms movement


: Main Activity flow


: Sub-Activity flow

5.1.4 "As-is" process flow (1): Problem discovery and reporting

Figure 5.2 on page 46 shows the activities carried out by the various personnel during the problem reporting process. Problems can be identified in two main ways: one way is during periodic checks on the molded parts by the PT, and the other is a complete stop of the machine. When defects are found on parts, the PT will locate the cavity number that produced the defective part, and refer to the Cavity Chart to identify the cavity's position so that the PT can block the cavity. An entry will be written in a log book and also in the cavity chart for that mold. This information will be handed over to the MTS who will share it with the TTS and ME during the SSU meeting. Depending on the outcome of the SSU, the TTS may or may not take any action. This will be elaborated on in "As-is" process flow (2).

The machines are run by Programmable Logic Controllers and are monitored by sensors that will stop the machine and trigger an alarm when the machine does not follow the specified parameters. An investigation will then be carried out to determine the cause of the stoppage and to take necessary action. This investigation will be led by the MTS, who will have to determine if the problem lies in the machine, or the mold. Only after the MTS has verified that the problem is related to the mold, will the MTS call TTS, who would have to be involved in subsequent steps of the repair process.

Some of the molding machines have robotic arms which pick out molded parts from the mold after it opens. Consider a situation when the sensor in the arm sends a signal that no part was picked up, thus the machine would stop and trigger the alarm. There are a few possibilities for this occurrence. For example, a component in the gripping mechanism of the robotic arm may have malfunctioned. In this case, this would be a machine related issue which the MTS will address. Another possibility for this alarm could be because of degradation of a mold component which increases the friction between the tool and the molded part; this would result in the gripper being unable to remove the part from the mold. A replacement of this mold component will have to be carried out by the TTS.

Thus problems can be classified in three broad categories for the TTS:

1. Machine / Injection molding process problems that do not warrant attention from TTS.

2. Cavity blockages by PT due to production of defective parts. These can be considered as partial malfunctions as the mold can still run, albeit with fewer functioning cavities.

3. Complete loss of production due to mold problems and the machine needs to stop running. These may be regarded as total malfunctions.

After the problem has been reported, the repair process will move into the next stage which is to decide whether or not the mold will be repaired.

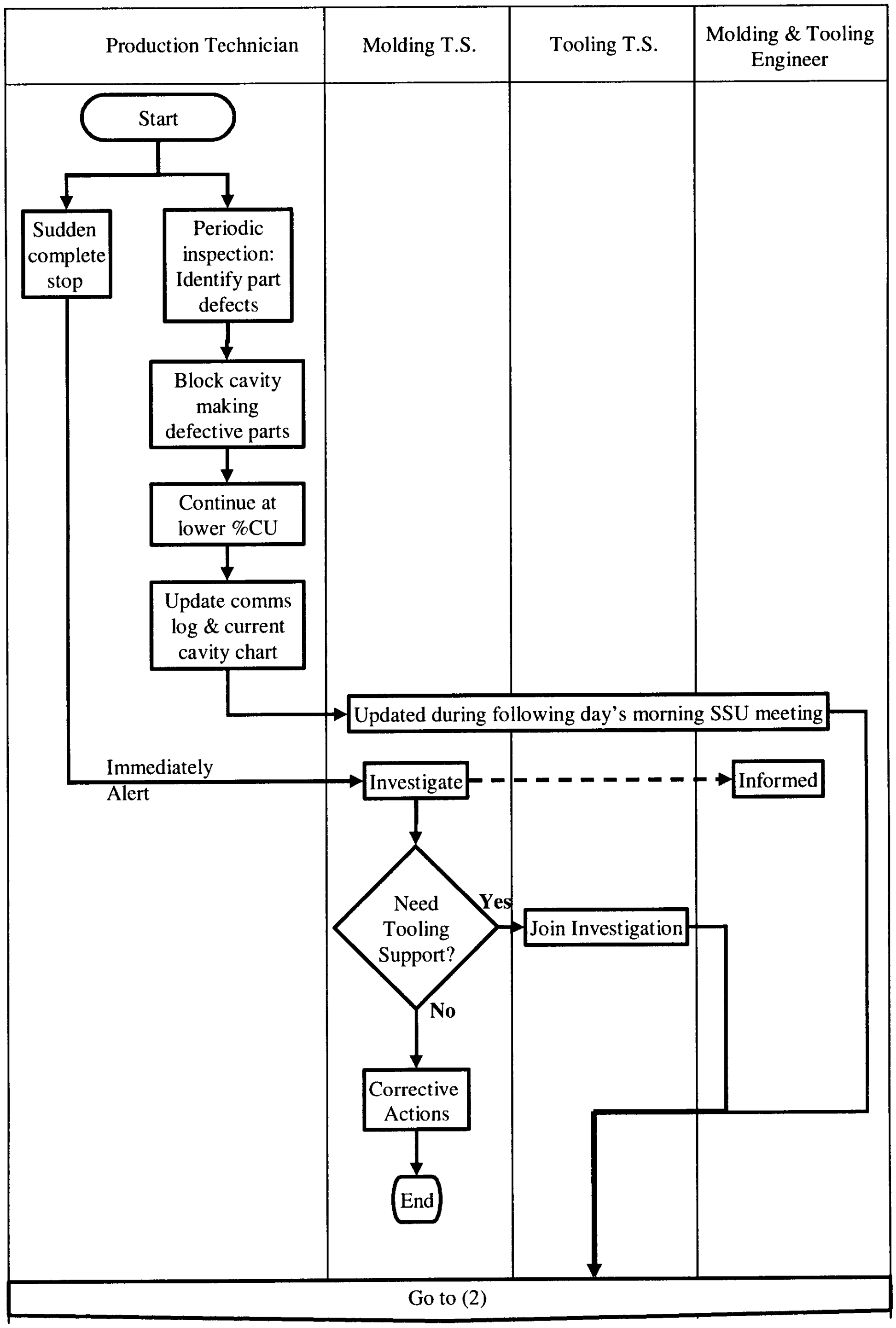


Figure 5.2: "As-is" process flow (1) Problem discovery and reporting

5.1.5 "As-is" process flow (2): Decision making

The decision making process is an undocumented process and is a result of discussions during the SSU conducted by the Molding section of each value stream. In most cases, there are considerations that each of the key players in this process makes, and there are often variations to the sequence and the factors considered during this process. Figure 5.3 below shows generally the hierarchy of the conditions that require consideration before repair work can commence on the mold.

Note that in this flow, the decision diamonds for identification of defect, availability of resources and running status of mold are between the lanes of the MTS and TTS. In the mold repair process, the PT may report a certain defect type to the MTS, but the onus is on the MTS to ensure that this report is accurate. For the TTS, they are responsible for understanding the part of the mold that requires repair or spare replacement due to that defect.

Resources in this context can refer to the mold spare parts, or the TTS having the time to take on this repair job. For the MTS, it may refer to the availability of labor to shut production down in the case of partial malfunctions, and the labor to bring the mold to the Tool Room.

WIP stands for Work-In-Progress; it refers to the molded parts that are being fed to the next set of operations in the manufacturing process. Sometimes, even when there is sufficient WIP available, the mold may not be immediately brought down for repair. One reason may be that the production lot is nearing the end and they have decided to let it complete before sending the mold for repairs. Another common reason is that the reduction in CU is still acceptable and Molding wants to produce a larger buffer inventory so that when the drop in CU is excessive, there will be sufficient WIP to keep the downstream operations running, and allow for the mold to be brought in for repairs.

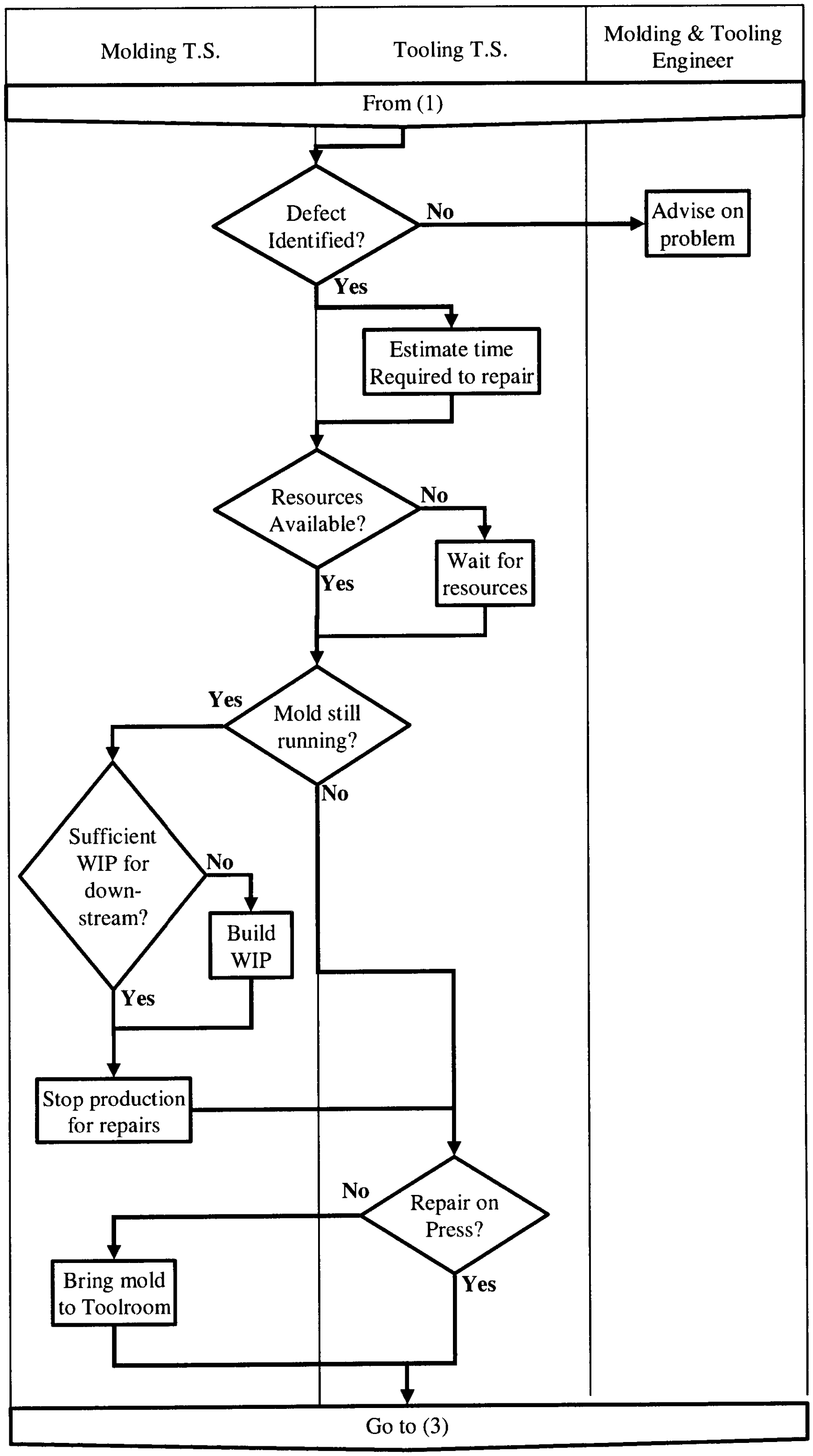


Figure 5.3: "As-is" process flow (2) Decision making

5.1.6 "As-Is" process flow (3) Repairing the mold

Figure 5.4 on the following page shows the final part of the mold repair process, namely the repair of the mold. The description of the process can be further broken down into three parts described below.

5.1.6.1 Prepare to repair

Once the decision has been made and the mold is scheduled to be repaired, some preparatory work is required to be carried out. The MTS will prepare three forms and hand them over to the TTS when the TTS is going to repair the mold. Then based on the information given to the TTS by the MTS, the TTS will go into SAP and create the work order for the job. In the current practice, the TTS will create the work order even before he gets the forms; he is able to do this because he already knows the necessary details from the SSU and decision making process.

5.1.6.2 Carry out repairs

It is only at this stage does the TTS have the opportunity to open up the mold to start the repair. In the previous stages, the TTS could only evaluate the problems based on the defect reported, and whatever observations that could be made from the inspection of the defective part. It is possible that only after opening up the mold for repair, that an actual diagnosis can be made.

5.1.6.3 Post repair

After all repair work has been completed, the TTS will close the mold and make arrangements with the MTS to take the mold back for production. He will have to update a new cavity chart and fill in a request form for inspection, and go into SAP to close the work order. There is a form for the TTS to fill in a mold history file, where all the incoming documents are also filed. This closes the loop of the entire process.

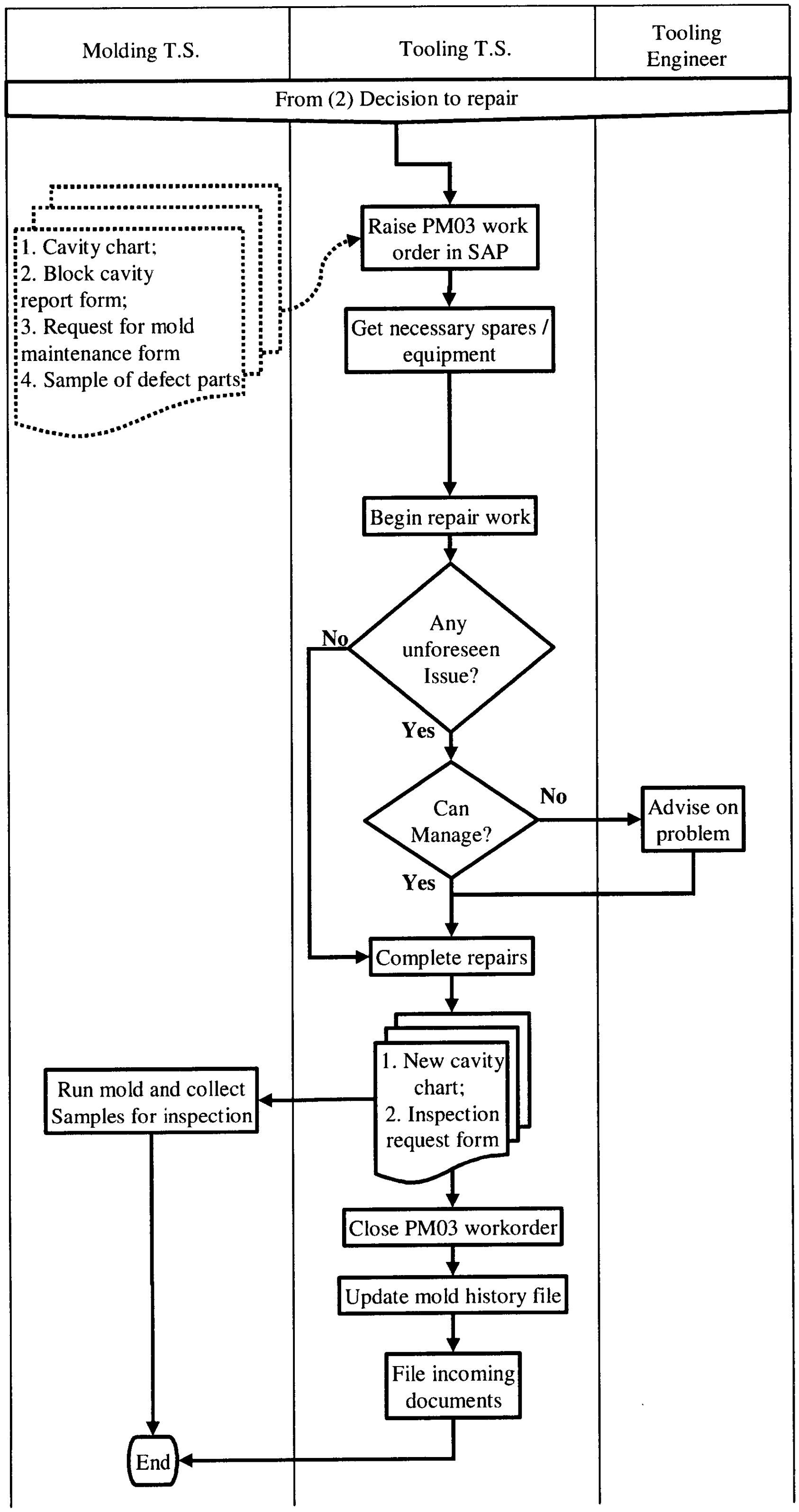


Figure 5.4: "As-is" process flow (3) Repairing the mold

5.2 Process flow analysis of current work practices

5.2.1 Delays in process flow

5.2.1.1 Practice of cavity blocking

In the current practice, only major problems that cause the injection molding machine to stop will receive immediate attention. Individual plastic defects that occur during production have their cavities promptly blocked by the PTs and are only made known to the TTSs the following day. Furthermore, blocking cavities of a mold may change the operating conditions of the mold in a way that leads to subsequent failures in other cavities due to the redistribution of pressure and melted plastic.

One reason for the prevalence of cavity blocking is due to the current allocation of responsibilities within CB's production floor. The Molding team is given the authority to block cavities to prevent wastage from raw materials being molded into defective parts; this creates an environment where blocking cavities is seen as the immediate (and correct) action to take. Furthermore, the Molding team is not held responsible for the CU level of the mold; rather this is the responsibility of the Tooling team, which further aggravates the situation.

5.2.1.2 Decisions being overridden

In the current processes, most of the decisions are made between the MTSs and TTSs. However, there are often times where arrangements are made between the MTS and TTS during the SSU in the morning, but by mid-day or afternoon, an overriding set of instructions from the ME or planner will be given. This can be disruptive as preparation for repairs are already underway. One reason for this override can be attributed to the changes in the downstream operations. There are times when the assembly machine downstream faces shortage of another component part, and is thus unable to utilize the WIP of molded parts that are available. The operations engineers may then decide to do a setup changeover of the entire line to produce a different item to avoid any idle line at the assembly machine; this impacts the repair operation since a mold will require a setup change to supply parts to the downstream. This setup change will thus take precedence over the previously arranged mold repair operation.

Sometimes the amount of time given to the TTS to complete a repair will be shortened as well. For example a TTS could have been given three days to repair a mold, but by the second day a change in instructions from the ME or planner from the downstream line would require the TTS to return the mold on that day itself. In a scenario similar to the above, the mold being repaired could become required for a setup change. Thus not only would the mold repair time be shortened, an additional setup change needs to be carried out as well.

5.2.1.3 Resources not available

One of the key delays in the current process is the shortage of resources, primarily the lack of spare parts to execute the repair. The key reason is due to the lack of a proper spares inventory management program. The work done by Lim [3] addresses this issue and is aimed at mitigating this spares stock-out situation. The other problem is due to the manpower shortage in the Tool Room itself. This issue has already been addressed with the hiring of new staff which has occurred during the course of the internship.

5.2.2 Information management

During the process of mapping the flow of the current work practice, it was evident that there was an area for waste elimination in the information management process. The primary cause of this was due to the practice of using hardcopy forms to enter information. Some effects of this practice are elaborated below.

5.2.2.1 Duplication of effort

One of the key elements of information carried by these hardcopy forms is the information about which cavity in which position of the mold was blocked, and the corresponding plastic part defect type associated with that blockage. Each time a mold is repaired, the incoming copy of this form is filed away and a new blank form is printed and attached to the mold when it is returned to Molding. To understand the historical performance of a mold, additional work needs to be carried out to go through the files to sift through the handwritten notes, and type them into a computer spreadsheet for further analysis. This results in duplicated efforts of re-entering the same data into the computer from the hardcopy forms.

5.2.2.2 Poor visibility of performance

Another consequence of this practice is the lack of visibility of the historical performance of the mold and its cavities. All the information is written on paper and filed away into filing cabinets. The information is as good as being non-existent and the past performance of the mold is not easily accessible, unless duplicate work is done as mentioned earlier by re-entering this data into computer spreadsheets so that trends can be observed.

5.2.2.3 Lack of standardization

The two problems mentioned above are further aggravated by the lack of standardization in the forms. For example, a certain spare component for the mold may be referred to in three different terms by three different TTS. This results in even further difficulty and a lack of integrity in the data when extracting information from these archives.

5.2.2.4 Slow response times

When the TTS needs to carry out the preparations to repair a mold, he needs to have several pieces of information with him. One is that he needs to understand what the defects are and where they are in the mold. Currently that information is recorded onto the forms, but they are not handed over to the TTS until the mold is sent to the Tool Room. Such a practice would result in preparations being made only after the mold arrives at the Tool Room. In order to make preparations as early as possible, the TTS has to attend the daily SSU meetings and take notes with regards to the defect, the mold, and the cavity. Sometimes, they also request samples of the defective product to verify that the reported defect in the forms was accurately stated. They will then return to the Tool Room and ensure that the parts are available and the repairs can be carried out.

5.2.2.5 Non-value added time in daily activities

The TTS have to attend two sets of SSUs every day. They first have to attend the SSU with the Molding department to be updated on any of the molds having any performance issues the night before, and the discussion process with Molding with regards to recovering any mold capacity on that day. They then have another SSU to attend within the Tool Room where they have to update the TE about what are the tasks they will be carrying out that day. It is not uncommon for the TTS to not be able to start on any repair work on the molds in the Tool Room until after 9.15 a.m. CB's working hours begin at 7.45a.m., Thus on average, there is an approximate loss of 1½ hour to such non-value activity.

5.3 Forms currently used to record information

As part of the information flow, several forms are currently being used by CB Tool Room and Molding to exchange and record information. Some of these forms and the information that they collect are introduced in the following paragraphs.

5.3.1 Cavity Charts

A cavity chart consists of simple tables where each cell in the table is used to represent a cavity in the mold. Cavity charts may look different between molds. Each cell in the chart is numbered and is regarded as the position number. There is a second number called an insert number. This number is molded onto the plastic part itself. By associating an insert number to cavity number, a molded part can be traced back to its originating cavity position.

The cavity chart also has some fields for entering information with regards to blockages of cavities. When a cavity is blocked, a big X is drawn in its cell in the chart. Depending on the value stream, the associated plastic defect may or may not be recorded in the cavity chart. The date of the cavity being blocked is also recorded. Some cavity charts also include the last temperature recording at certain positions in the mold. Most TTS do not hold this information in high regard as it only serves to inform them that the mold was running within the specified temperature range. The comments were that it is more useful for the MTS than the TTS.

5.3.2 Blocked cavity report form

A blocked cavity report form lists down the cavity position number and corresponding insert number of the cavities that were blocked, the date they were blocked, the PT or MTS who did it, and the associated plastic defect.

5.3.3 Request for Mold Maintenance

The request form varies between value streams. Common information in the forms includes the requested date and time, required date and time, and description of work required. Other information that may be recorded by some value streams is the date and time the mold was set down, completed repairs, and set up. Some even go to more detail to record the number of cavities that were expected to produce good parts after repair, and how many actual good parts were produced after the post-repair inspection.

5.3.4 Work order form in SAP

The work order forms in SAP have many data collection points, yet not all of them are used. Some of the information currently being recorded includes: Brief description of work, estimated work hours and spares part used.

5.3.5 Mold History Form

The mold history form is filled in by the TTS after every repair job for each mold in its mold history file. Information recorded are the date of entry, the defects and the actions taken to resolve them, number of manhours spent, and the parts used.

5.4 Review of existing infrastructure

5.4.1 Apriso - Mold Cavity History and Capacity Utilization

The Apriso system in CB allows for tracking of the mold cavity performance. There is an interface which can be accessed through the CB intranet network where the MTS or the PT working under them can update the performance of the mold by selecting a cavity of the mold and updating its status when it is blocked and providing the reason for the blockage. The log of this block-unblock history and the reason for the blockage with respect to the molded plastic part defect are stored in a server and can be retrieved for further analysis. The status of the mold and its cavities can also be updated via any computer in CB which is logged into the intranet network.

5.4.2 SAP - Notification and Work Order forms

There are forms setup inside SAP that allow for notifications and work orders to be created to keep track of the requests for mold repair and the work done for each mold repair event. Notifications for maintenance can be created whenever a request for mold repair is required. Requested start dates and end dates can also be entered to facilitate planning of maintenance work. Other details such as the descriptions of defective parts and the defect type can also be entered.

Work order forms in SAP can capture a lot of inputs regarding each repair event. Some of these inputs are time, by entering the number of working hours, parts used to complete repairs, description of work carried out, the nature of the work whether it is a preventive maintenance or a repair of a breakdown or a setup changeover. All of this information can be saved and extracted to provide a history of the mold repair. The data gathered can subsequently be used for some performance analysis, such as the frequency of repair work required, or the cost of repair work.

We see that there is significant opportunity to improve the work process by replacing the current practice of paper forms with the already existing software in CB. The next step would be to introduce work practices to utilize these technologies and to create the new work process flow.

5.5 Future process work flow

5.5.1 Basis of design

We applied the following principles introduced by Madison [10] in the design of the future process work flow:

1) Design the process around value-adding activities

The value-adding activities in the mold repair process are activities which focus on solving problems and recovering the CU lost.

2) Work is performed where it makes most sense

Since the mold is being used in the molding area and problems first appear there, the PT and MTS should attempt to eliminate the problems at the time of occurrence on the shop floor in order to keep CU high and downtimes low. Ideally, the first person to discover the defects would correct them without the need to block cavities and without having to pass them on to others. In this project, given the skill level of the PT, and the specialization of the MTS and TTS, we still need to permit problems being handed from the PT to the MTS and then to the TTS when necessary.

3) Bring downstream information needs upstream

In the previous process workflow, the TTS gets the information from the MTS during SSU discussions. By reducing the time at SSU and channeling it to spend more time solving the problem, the TTS can be on the scene as early as possible to resolve the issue

4) Capture information once at the source and share it widely

This information capture and sharing can be handled by Apriso and SAP.

5) Share all relevant information

This can be achieved by ensuring that the information is properly entered into Apriso and SAP.

In addition to the design principles described above, there were a few requirements by the CB management that were included in the new process flow as well:

a) Blocking a mold cavity is not to be used as reactive measure but as a last resort.
b) The MTS is to be held accountable for any cavity blocking activities

Successful implementation of this future process work flow depends on the following conditions.

- The work done by Lim [3] on spares inventory management will ensure 97.5% service levels for mold repair, so there will be very infrequent stock out of spares
- The current increase in personnel in Tool Room will be sufficient to meet repair demands
- Personnel are proficient in the use of Apriso and SAP forms

5.5.2 Future process flow (1): Problem reporting in Apriso and SAP as they occur

In Figure 5.5 below, the future process flow is presented. During production, when any defects in the molded parts are discovered, the machine is to be stopped and the PT will be the first to address it. If they can't solve the problem, they will raise the issue to the MTS. Cavity related defects are to be reported into the Apriso system to capture the information and history.

Regardless of which level of solution, the MTS will create a breakdown work order (PM01) after the issue has been addressed. This work order will record essential information such as the date and time the event occurred, the duration time the machine was stopped, the problems, corrective actions, and any parts used. Corrected cavity related defects will have their status updated in the Apriso system as well.

If the problem cannot be solved after the MTS has carried out troubleshooting the processes, he has to make the decision as to whether the problem is a more complicated process-related issue or it is a Tooling issue. If it is a Tooling-related issue, the MTS will have to get the TTS on board to carry out the investigation. He will have to collect and handover to the TTS the output of the last production cycle (refer to Figure 1.4 for production cycle definition), which is referred to as the last shot of production. He will also handover the defect samples to the TTS. He will create a Notification in SAP to record the problem and the actions carried out earlier in the attempts to solve the problem. These can be handed over to the Tool Room at anytime of the day. This is to bring the TTS up to date as early as possible with all the necessary information in order to carry out the repairs.

The TTS will then evaluate the problem and decide if it can be resolved with the mold still in the machine or if he needs the mold to be brought to the Tool Room for further action. If so required, the ME is to schedule for the mold to be repaired. Based on the dedication of TTS to value streams, the ME is already aware of the amount of work the TTS has already and thus there is no need for a discussion between the MTS and TTS every morning with regard to the available workload. If the TTS cannot work on the mold because he is engaged in another repair job, the MTS will decide whether cavities are to be blocked for production to continue.

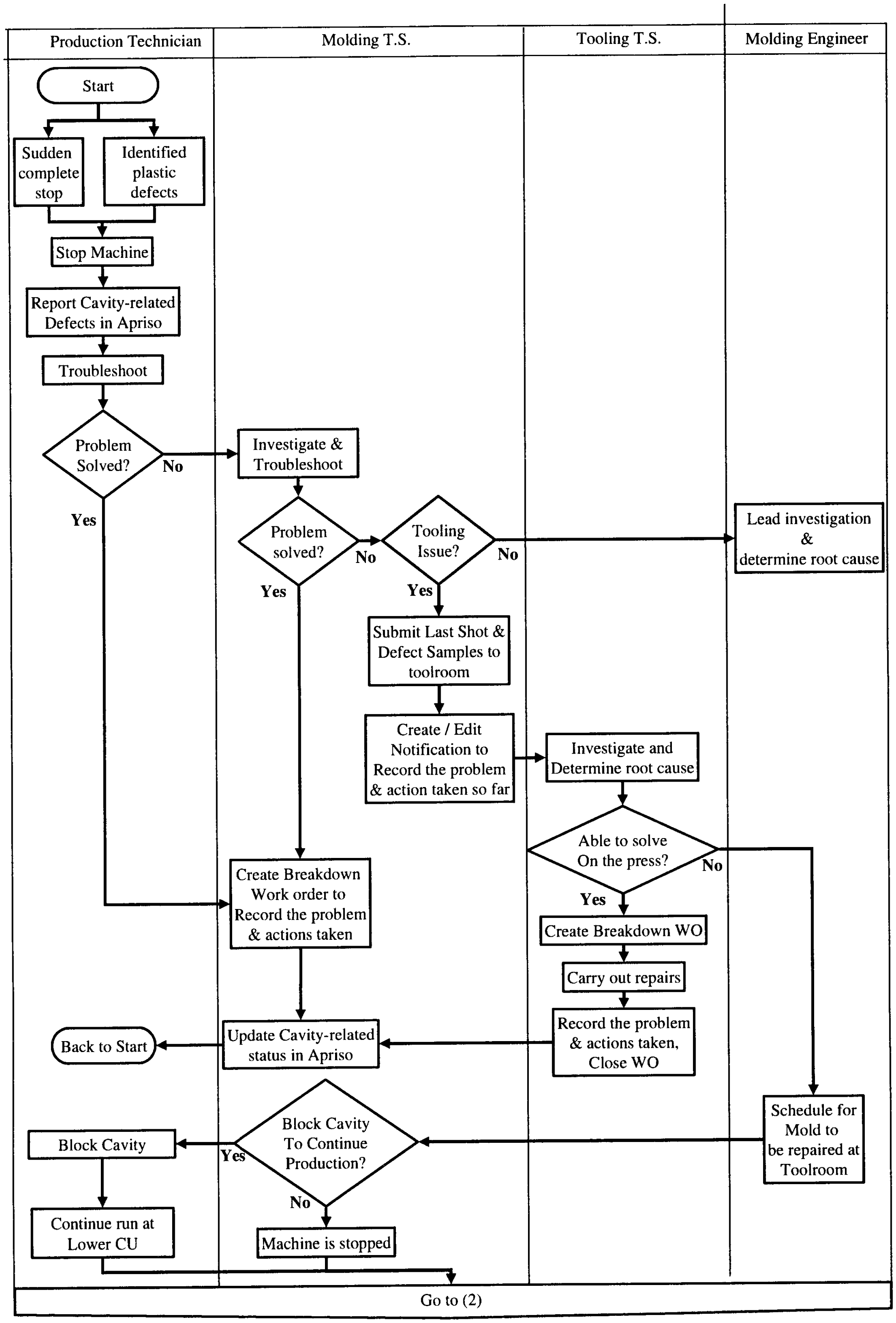


Figure 5.5: Future process flow (1): Problem reporting in SAP and Apriso as they occur

5.5.3 Future process flow (2): Tool Room repair process

Figure 5.6 below shows the second half of the future-state mold repair process. Instead of discussing the issues during SSU, the items and reports will be submitted from the MTS to the TTS for their review and investigation. The TTSs are technically competent enough to be able to handle these issues. For issues that are beyond the TTS capabilities, they will have to seek advice from the TE. If the TE is unable to solve the problem, such problems will most likely be atypical and the ME will have to notify the Value Stream Leader. The ensuing investigations into the problem should be led by the TE to determine the root cause and to solve the issue.

Under daily operations, the TTS will first review the problem and create the work order based on the notification in SAP. This will create a complete history of both the problem and the action taken. The main change in this process is that more details need to be entered into the work order compared to the current situation. Other than that, the repair work has no change.

When the repair work is complete, the TTS will have a reduction in post-repair administrative work as he only needs to enter all the technical findings into the work order and close it. When the MTS receives the repaired mold, he will update the cavity status in Apriso. Although it is more logical for the TTS to do that, the Apriso system only allows such changes in the mold to be done when it is linked to a machine in the system, and only the MTS will know which machine the mold will be mounted on after it is returned from the Tool Room. Hence, the system will have to be changed in order for a more logical process flow; this change is beyond the current scope of the project.

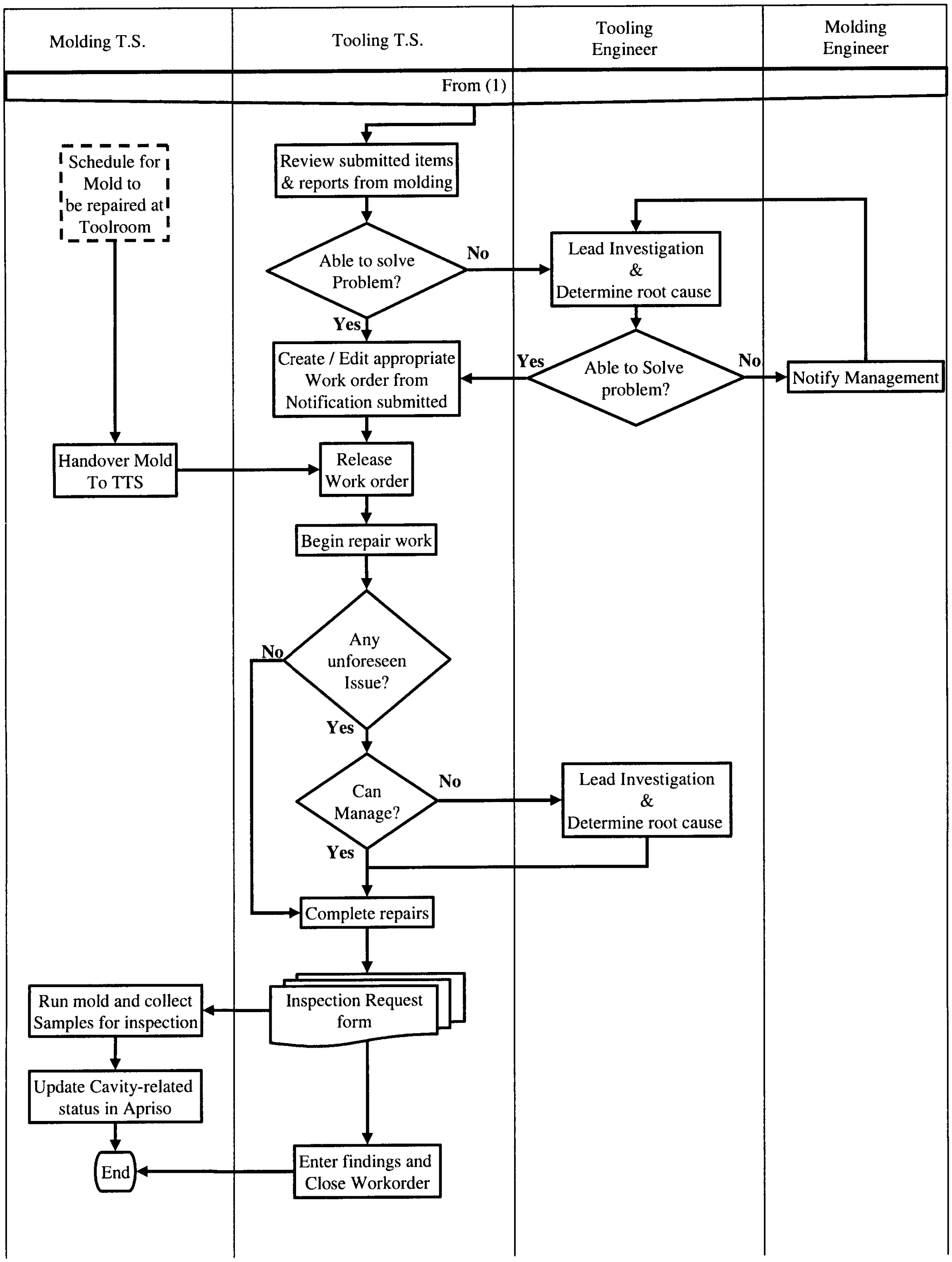


Figure 5.6: Future process flow (2): Tool Room repair process

5.6 Implementation of future work process flow

Implementing this future work process flow will eliminate the use of hardcopy forms to record information. Direct entry of mold cavity defects into Apriso by the PTs creates the mold defect history data in the database as it is entered. This also eliminates the problems of inconsistent entries, as the defect descriptions are based on a list of potential defects; this also reduces the amount of work the engineer needs to carry out when he does a technical analysis of the molds. Instead of re-entering the information from hardcopy forms into Excel spreadsheets as he is doing now, he can just export the cavity defects information from the database and carry out the analysis. One possible framework for making use of this information to carry out analysis is introduced by Mohd Fauzi [4].

Increasing the amount of information recorded in the SAP work order forms will significantly reduce the amount of work carried out by the engineer and provide greater visibility to different aspects of Tool Room operations, for example, the costs of maintenance. There are pre-set functions in SAP that can be used, so the engineers need not even export the data for analysis. A report showing the costs of breakdown repairs, preventive maintenance programs, and setup changeovers is provided in the SAP system. With the appropriate settings of labor costs and material costs in SAP, and the diligent entries by the TTSs, these cost analyses can be as focused as on a single mold. In the current situation where parts usage is noted down on the hardcopy forms, there is no way to track these costs easily. The only method the TEs currently employ to monitor costs is to monitor for each value stream the purchasing budget for mold spare parts, which is not as detailed as what the system can provide.

5.6.1 Using Apriso system to track mold performance

During the course of the internship, some areas of the new flow have been implemented in a pilot project in the Product S value stream. The first part that has been implemented is the practice of reporting cavity related defects by the PT and updating the cavity related status in Apriso by the MTS after repairs are completed,. Monitoring of this part was carried out by referring to the mold status in the system and ensuring that it matches the actual mold performance as reflected in the cavity charts and mold repair request forms. Some problems encountered during the implementation of this part are mainly due to the oversight of the PT, as they are not accustomed to the new system. The MTS overcame this by reinforcing the need for them to update the cavity status.

One of the issues that needs to be resolved before full implementation is the comprehensiveness of the defect list in the Apriso system; the current list of defects is lengthy but cannot cater for all possible problems. A suggestion has been raised to consider giving the MTS access into Apriso to add these rare occurrences to the list when they happen, to ensure accuracy in the system.

Another Apriso related issue that is hindering full implementation is in the report generator in the system. One report known as the Mold History Report generates the collected information about a mold and the cavities that were blocked and subsequently repaired in a specified time interval. The problem faced is that the reports cannot be generated for any period of time; rather, it will only work as long as the specified time period includes events from two years ago.

These two issues require action by system/software engineer. However,a s of the date of the thesis, these issues have not been addressed due to time constraints and the fact that the system/software engineer was too busy with another project.

5.6.2 Improving information collected in SAP work order forms

In the previous process, a very simplistic use of the Work Order function was carried out. Only one category of work orders were created for both breakdown maintenance work as well as setup changeovers. Breakdown hours were not entered before closing the work orders thus losing valuable data. Many mold components did not have records in the SAP system; thus the use of these parts was not reflected in the reports. No information describing the cause of the problems were recorded, only description of activities carried out to repair the mold were entered.

In the implementation, a distinction was made in the specification of work orders to differentiate between breakdown work and setup changeovers. This would provide the level of detail required when evaluating the costs associated with the work done on the mold. The creation of records of the spare parts in SAP system is still ongoing. Entering breakdown hours has been implemented as well but needs reinforcement to the TTS.

5.6.3 Abolishing older practices

The suggestion to reduce non-value-added time by eliminating the need for the TTS to attend Molding SSU is still pending further review by the management. The main concern is a view that the SSU is a vital part of the plant culture where the team of Molding and Toolroom personnel can get together to discuss the mold issues face-to-face. SSU is also viewed as a platform for sharing among the personnel where they can describe some of the issues they had encountered in their work the previous day and enlighten the others about how they had overcome the issues.

The suggestion that Molding should make all efforts to repair a cavity immediately upon defect detection, rather than wait for an SSU or TTS support, is also still being considered. Currently, molding department personnel are not trained in the repair of a mold, which is viewed as the TTS job, and the MTS only needs to ensure the machine is running smoothly. An implementation of this suggestion would mean added responsibilities to the MTS and PT; furthermore, this suggestion requires an increase in technical competency in mold repair. This suggestion has implications on the current work structure of the individuals, which was not looked into as it was not in the scope.

The current partial implementation of the suggested future is being done together with the old practices. Thus both the hardcopy forms and the IT systems are both being used, which creates more work for the personnel who view the use of the system as an additional burden. But with the other issues presented earlier yet unresolved, the management is reluctant to abolish the previous work practice.

5.7 Potential analysis that can be carried out based on data collected

In order for the information that is collected to be useful for CB management, some analysis of the information can be made. Some measures that have been suggested by De Groote [12] and Sawhney et al. [13] have been adapted for CB Tool Room, as presented below.

5.7.1 Breakdown repair costs vs. Preventive Maintenance costs

Labor hours and spares part usage make up the costs of either breakdown repair or preventive maintenance activities. Expressing the breakdown repair cost as a percentage of the preventive maintenance cost serves as an indicator of the preventive maintenance program's effectiveness for that mold. For example, if the ratio (Breakdown repair cost / Preventive Maintenance cost) is 2 that mean for every dollar spent on preventive maintenance program twice that amount will be spent to repair breakdowns during the same period. A ratio that is low indicates an effective Preventive Maintenance program

5.7.2 Cumulative cost of maintenance over time

Tracking cumulative costs of maintenance and repair of the mold over its lifetime will assist CB management to make important decisions between continued usage of molds or the purchase of new ones.

5.7.3 Number of breakdowns occurred during gross operating time

The gross operating time is the planned production hours minus the unplanned downtime . The number of breakdowns per unit of gross operating time is a measure of the breakdown rate. Because of the time taken for a mold to be heated and the start-up wastes involved in plastic injection molding, it is desirable to have as low a rate of breakdowns as possible. This measure is useful when there are more than one mold exhibiting similar cost ratios or breakdown times, but the frequency of breakdown can determine which mold warrants more attention for improvement in the preventive maintenance activities

5.7.4 Mean Time To Repair (MTTR) and Mean Time Between Repairs (MTBR)

By entering the information of the start and end times of each repair work order, the MTTR and MTBR values can be derived. These are measures of equipment reliability and are parameters in production line analysis, providing future data for further analysis into the production systems.

5.7.5 Mean Maintenance Lead Time (MMLT) and Maintenance Efficiency

Maintenance Lead Time consists of three components: Time taken to organize, time to repair, and time to yield. The time taken to organize repair is the period from the mold breakdown and needs repair (or falls below the allowable CU level) until the TTS begins repair on the mold. The time taken to repair is the time spent by the TTS performing the repair operation. Finally, the time to yield is the interval from the completion of the repair until the mold is producing good parts again. Taking the average values of these three components for a mold will give the Mean Maintenance Lead Time. Out of the three components the only value-added time is when the actual repair is being performed, the time taken to repair. The maintenance efficiency can thus be calculated as *(MTTR/MMLT) * 100 %*

Some possible performance measures CB can adopt to monitor the Tool Room's performance using the information systems and the future process work flow have been suggested. As the information are collected primarily from the input by the PT, MTS and TTS, it is imperative that they are proficient in using the systems and understand the significance of their inputs. It is also important to note that information is only useful when extracted and analyzed.

6 Recommendations

CB Tool Room now has the opportunity to leverage existing infrastructure to achieve better information flow and management in mold repair operations. There is also an opportunity to implement a proper work flow process that ensures transparency and clear roles and responsibilities for all stakeholders in the mold repair process. To attain this objective, there are several steps that CB will need to take to have a proper system in place. In addition, the course of the author's thesis project had provided him with many opportunities to interact with CB associates from many levels and value streams. Some of these interactions have resulted in observations not directly related to the scope of the project but have sparked some possible recommendations as suggested below.

6.1 Improve technical competency of the PT

Being the people who first respond to any issues, the PT will need to have an increased set of technical skills to identify and troubleshoot defects, rather than thecurrent practice of blocking cavities and delaying any decision making to the next morning. The increase of technical competency cannot be achieved overnight but below are the recommended steps to take.

6.1.1 Proper identification of problems

The first priority in the training is to train PT to be able to correctly identify and report defects. Inaccurate reporting of defects will lead to incorrect analysis and response from the TS. The future process flow prevents that by requiring the Molding to submit the items and reports so that the TTS will have a better understanding of the situation instead of relying on a defect description. Currently the PT receives rudimentary training but there are occasions where reports are skewed due to incorrect reports of defects.

6.1.2 Competency in advanced troubleshooting of problems

The next step is to increase the skill level of the PT by making them responsible for solving certain type of defects on the spot. There are a variety of issues that may occur that can cause plastic defects; a review of these defects can allow a separation of defects that can be resolved at the machine, and those that cannot. In the current process, the majority of the PTs lack that competency, as it is currently at the MTS level. Thus training is required to impart these skills to the PTs. Once the PTs are competent to carry out these advanced tasks, then clear distinction can be made as to what types of defects are expected to be handled by the PT. By making them responsible for addressing such issues, the onus will then be on the PT to clear them instead of passing the problem along to the MTS.

6.2 Adopt existing Information Systems

CB has committed capital investment in the installation of systems such as SAP and Apriso. As mentioned in the previous chapters, these systems have not been fully integrated in all aspects of the facility, such as the Tool Room. It would be cost-ineffective if CB continued to use traditional paper-based methods for communication and information storage. The following points are recommendations on what CB needs to do in order to quickly implement these systems.

6.2.1 Management review of Apriso system

Part of the scope of this project was to investigate the use of the systems to improve the mold repair process. It has been described that Apriso is a system that is installed but not yet fully implemented in the molding operations. Although not part of the scope, the author has made several findings with regards to the system that warrant immediate attention by CB management.

It was established during the course of this project that the Apriso system had the capability to meet the mold repair process requirements of mold cavity history tracking as well as real-time updates via the intranet system. There are many more functions and capabilities that are not understood and therefore not being used by the engineers and management.

6.2.1.1 Creation of review team

A review team needs to be set up immediately to address this issue. It would be advisable that this team be headed by a suitable senior management level that can drive this review. The team should at least be comprised of the people who need to monitor and extract information from the system, team leaders from the production floor who use the system, and the system/software engineers who understand how the system works and are capable of making the changes in the system itself.

6.2.1.2 Establishing user needs

The next step is to establish the needs of the system users: those who monitor and extract information and those who are interacting with the system and making inputs.

6.2.1.3 Reconciling Apriso capabilities with user needs

Once all users needs have been identified, the next step would be to evaluate the current capabilities of Apriso and determine if these needs are being met. For example, the cavity related defects are entered into the system by a drop down menu. Feedback from the implementation team was that the list had certain defects that were irrelevant and was missing certain defects that were existing issue. An update of this list thus needs to be made.

6.2.1.4 Draw up plan of action

A subsequent plan of action can be drawn up to prioritize the work and to assign tasks to correct any issues that exist in the existing system. A strong drive by the review team leader is required to ensure that this occurs.

6.2.1.5 Follow through with plan

The reason that the Apriso system failed to be successfully implemented when it was first brought into CB was because there wasn't a proper continuation of the project. Members of the project team who had left the company were not replaced and the project was not handed over to any other people in CB, which resulted in the installation of the software but not the implementation of any work processes to make use of the software for the Molding and Tool Room departments. Thus re-occurrence of such situations must be avoided at all cost.

6.2.2 Configure SAP records for spare parts

Records can be created in SAP for the mold spare parts, primarily for inventory management purposes. One of the parameters of the part records is the cost of the spare part. This makes the records a useful tool for CB in both areas of spares inventory and maintenance costs management. Furthermore, Bill Of Material (BOM) structures can be created in SAP to assign individual spare parts to their parent mold. This will ensure both accurate and quicker entry of spare parts usage into individual work orders.

6.3 Facilitate Information Systems usage

6.3.1 Increase technical specialists' proficiency

Currently the MTS and TTS are the ones who use the systems in SAP, such as creating Notifications and Work orders. In order to maximize the advantage of the system, a program can be launched to enhance the MTS and TTS proficiency in using the systems. By understanding the purpose of the entries they make into the system and by being proficient in making those entries, then the data can be truly reliable and useful for future analysis and decision making.

6.3.2 Understand the report functions of the systems

SAP and Apriso have reporting functions; in just Apriso alone there are a total of 63 reports available. No study was made on the usefulness of all the reports available but through interactions with the engineers, it is certain that little is known about what the reports provide and how the data from the system is fed into the report produced by SAP and Apriso. Such knowledge will be useful to the engineers and even the managers in order to correctly interpret the output from these systems.

7 Conclusion

This investigation has shown that there is a lack of information management in the molding maintenance operations in CB, although there is existing infrastructure in CB that could be harnessed for this purpose. The current methods used to manage information are crude and are not easily accessible for analysis, using paper forms and keeping stacks of files in cabinets lining the corridors of the plant.

Using process flow mapping and analysis, the mold repair process has been refined to incorporate the use of these systems to improve information management. Also, the process was redefined in certain areas to ensure clearer accountability for events such as blocking mold cavities and scheduling repair.

Recommendations have also been made to address certain pressing needs in order to fully utilize these systems. The key to the success of these systems implementation is the continued drive from management and proper training for affected users.

The successful implementation of the use of this future process flow will also mean that spares inventory usage and the defect occurrences in mold cavities are recorded in SAP and Apriso respectively. This information can then be exported from these information systems and be applied into the framework developed by Lim [3] in the area of spares inventory management and Mohd Fauzi [4] in the area of preventive maintenance scheduling.

8 Future Work

8.1 Horizontal integration of Molding into a single department

In this work, the suggestions and recommendations were made on the premise that there were no major organizational changes within the CB structure. As introduced in the early part of the thesis, CB organizes itself by value stream, where each value stream is linked to a product family, and the molding operations are thus separated into these value streams. It would be an interesting study to investigate the effects of breaking down the boundaries and combine molding operation into one department.

8.2 Application of Toyota Production System concepts

Another topic that may be of interest to CB is how to apply the concept of Jidoka used in the Toyota Production System, the ability to stop production lines when quality issues or equipment malfunction arises. There have been attempts at introducing such concepts and articles have been written about why they had failed. It is in the author's consideration that Jidoka would only be possible if there is no separation between Molding and Tooling, since problems in the molding operations can be attributed to either, or both. An attempt to implement this concept is in the future-state process flow where the PT is encouraged to solve defect problems instead of blocking the cavity and passing the problem along. This leads to the third idea for a future topic.

8.3 Cost-Benefit-Analysis of having higher skilled PTs

The third topic that would be of interest is to study the cost and benefits of having higher skilled labor at the operator level. In order to minimize time wastage when defects or machine issues occur, a competent technician who is well versed in both molding processes and mold issues is more likely to be capable of solving problems than a PT who does not necessarily have specific skills in that area. However the cost of such a skilled technician will be much higher than a PT. The benefit however will be the reduction of down time which can lead to increased production hours and increased output.

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