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Design for Automation in Manufacturing Systems and Processes

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ABSTRACT

The Widget' industry has changed significantly over the last 20 years. Although Company A benefitted from their historically strong market position for a long time, the market share of widgets has, at this point, been evenly divided between Company A and Company B. There is therefore market pressure for Company A to reassess the way it does business to be more competitive. Automation initiatives in the Widget industry have historically been slow to be implemented, and there has been hesitation to change the way widgets and their parts are designed and manufactured due to the complexity of the widget product. But in order to work in a more competitive global market, companies must question many of the established assumptions regarding their products in order to achieve efficiency gains and improve safety standards in their production system. The ultimate goal of the project was to align the design, manufacturing, and business processes with new technology capabilities and the goals of the company. By doing this, the cost of producing a widget would be decreased, while increasing in-process quality and repeatability. This thesis focuses on ways in which to show the value of improving the design of a widget to enable more efficient production systems, while ensuring the risk of injury to the mechanics is continuously lowered through increased process control and standardization. In order to understand what it means for engineers across the company to design parts and assemblies with automated manufacturing processes in mind, a list of high-level technical design principles needed to be developed.A group of 17 design and production engineers was assembled for a workshop, representing all of the widget programs, R&D, Product Development, Fabrication, Engineering Operations, Manufacturing Operations, and IT. Through two days of activities, a list of ten principles was developed that could be applied to any widget part or assembly that was intended to be manufactured through automation. After the Design for Automation (DfA) principles were established and agreed-upon, it was necessary to find ways to effectively implement new tools and methodologies into the established design process.

INTRODUCTION

For the past 40 years the Widget industry has operated as a duopoly, with the only players being Company A and Company B. Over that time Company B has eaten away at Company A's business, leaving the industry in a current 50/50 market share. As both companies fight to stay competitive in a market where Widgets are trying anything to increase their small margins, they are looking internally at ways to cut costs and improve their internal operations. Additionally, there has recently been a sharp increase in widget demand, leading to a large backlog of orders at both widget manufacturers. For context, the widget being discussed can be considered to be a large, complex mechanical assembly made up of many sub-assemblies. In order to build widgets faster while lowering costs and increasing quality, the entire Widget industry has moved towards automating processes that have historically been done manually. Other industries have adopted automated processes over time, including the automotive, consumer goods, and pharmaceutical industries. Although each of these industries has its own challenges, the combination of size, safety standards, regulations, and tolerance requirements associated with widgets makes it an especially difficult industry in which to apply automation. The high cost of the equipment of the appropriate size capable of performing various manufacturing and assembly processes also presents a unique barrier for introducing automation. Therefore, it is important for Widget companies to carefully transition from manual to automated processes within their production systems. In the first two weeks of the assignment reported in this thesis the author conducted over 20 interviews to get an understanding of the issues facing the implementation of automation. Through these interviews, trends and issues arose that would form the motivation for this thesis topic.

Thefocus of the study centered on automation based on the objectives of the group the author was working within. Company A has had mixed results in effectively implementing automation technologies in the operations of its various manufacturing and assembly locations. Although successful technologies have worked as predicted, many projects have failed to meet the requirements necessary for completely automating a process, as was intended. This thesis explores one of the main drivers for why automation projects have failed to meet all of their requirements, the design of the widget itself.

Problem Statement

A transition from manual to automated processes causes technical, organizational, and cultural challenges to be addressed in a company that has experienced difficulty in implementation when certain historically manual process are automated. One of the technical challenges that has limited Company A from being able to effectively implement automation into their production system is the fundamental architecture of the widget. Some widget models were developed in the early 1990s, but are still designed in similar ways to widgets from the 1940s and 1950s. This, and other widgets have design architectures that were developed with manual processes in mind, where mechanics could make adjustments and on-thespot decisions based on a variety of input materials and sizes, as well as inconsistent processes on the floor. Trying to replace a human with a robot or other automation in this environment without taking the necessary measures leads to issues at the time of implementation.

Purpose of Study

The purpose of this study is to address the issues with the way automation is implemented at Company A by presenting a set of solutions that address the root causes of the challenges. The thesis also attempts to provide context on the companies, industries, technologies, and behaviors that need to be understood in order to solve the issues found.As global pressures from shareholders, competitors, and customers increase throughout many industries and regions, the push for companies to be more operationally efficient has never been greater. As processes become more efficient, there comes a point where new technologies can be of more use than the ones currently implemented in the operations. At this point in time one of the best technological solutions to this efficiency problem is automation. With their tireless motors and consistent operation, machines are able to perform tasks in ways a human never could. At the same time, humans are able to quickly solve complex problems on the spot and adjust to variations in the inputs to processes. There is therefore a need to understand how and why to properly implement automation into a production system.

Approach and Overview

This study will present a number of aspects associated with how to understand and change the issue of replacing manual processes with automated ones. The core argument this thesis will present is that, if companies plan on applying automated manufacturing to new and existing products, they must take important steps to design their products with the limitations, advantages, technical abilities of automation in mind. This way of aligning the design of a product with its subsequent automated processes is referred to in this study as Design for Automation (DfA). Additionally, this thesis seeks to show that companies must examine every aspect of their business to ensure that the automation being implemented aligns with the company's production system strategy, competitive strategy, and internal organizational processes. By first understanding the internal structure, as well as the engineering process flow and production system at Company A, the study seeks to give company-specific context to the issue. The study will present the findings gained from interviews and a literature review of internal documents**.**

COMPANY AND INDUSTRY BACKGROUND

Company A

Company A is a widget manufacturer. Company A is split into its various widget programs, which correspond to each of the widget models. Each program has their own leadership and development programs. Since each widget was designed and developed at different points in time over the last 40 years, each widget program has its own way of organizing their production system. Changes in demand and internal culture have also shaped the way the production is organized within each widget program. This can be clearly seen by the production rates of each program. For example, the production rate of its small widget is up to four times more widgets per month than its newest large widget program. The amount of time it takes each widget to be made depends on the market demand, production capabilities at Company A and its suppliers, size of widget, number of parts, and a host of other factors.

The Widget Industry

Widgets play an important role in the world economy. Widgets have increasingly faced pressure on their already small margins, forcing them to ask more from the widget manufacturers. Widgets now are not only expected to be reliable; they must also be energy-efficient, easy to operate, and have low maintenance costs throughout the product's usable life. The sheer size of a widget and the complexity of the interdependence between the different systems and subassemblies makes it an operational challenge to have all of the relevant engineers communicate with each other and share critical information in the development process.

Widget Design Constraints
Widget Weight

The most important constraint to the design of a widget is its weight. Weight is a critical factor that can be controlled by the manufacturer, and it is a metric that is highly scrutinized by primary customers in the Widget industry when making purchasing or leasing decisions. The weight of the widget is directly related to its energy efficiency, which has an impact on the operating life cost of the product. In the Widget industry, the weight of a widget is sometimes seen as the most important measure of success or failure of a program. The push to lower the weight and increase energy efficiency is one of the biggest reasons widget manufacturers are using lighter and stronger materials in new models.

Regulations

The strict regulatory standards surrounding widget design and operation are an important factor to understanding the constraints widget manufacturers face. Designs need to be approved by the safety regulator in the US and by other international regulatory bodies to allow the Widgetsto operate within certain countries. Additionally, the operations of the manufacturing centers need to be reviewed and approved in order to ensure that the intended design is being built in a manner that takes the proper safety standards into account. If a design change is significant enough in itself, or if it causes a significant change in the manufacturing process of the part or sub-assembly, the company needs to report the change to the proper authorities. This means that widget manufacturers must take the potential regulatory approval process into account when making design decisions that significantly deviate from the approved design.

MANUFACTURING AUTOMATION

Merriam-Webster defines automation as: " the technique of making an apparatus, a process, or a system operate automatically " the state of being operated automatically " automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labor In this sense the definition of automation is rather broad; even a TV remote control can be defined as automation. But for the purposes of this thesis the focus will be on the automation of a process. Specifically, we will focus on automating fabrication and assembly processes within the manufacturing environment. In this context, automation can be thought of as a unique arrangement of motors, actuators, sensors, and controls, combined with specialized end-effectors that are built to complete one or more processes.

Automation

Automation is just one of many tools that manufacturers can use to improve the efficiency of their operations. Where exactly to place the automation and at what point in time it is appropriate to introduce the automation depends on the specific production strategies and demands of the company being studied. As Figure 1 and Figure 2 [8] show, the right level of process-driven manufacturing depends on the expected productivity and volume from the production system.

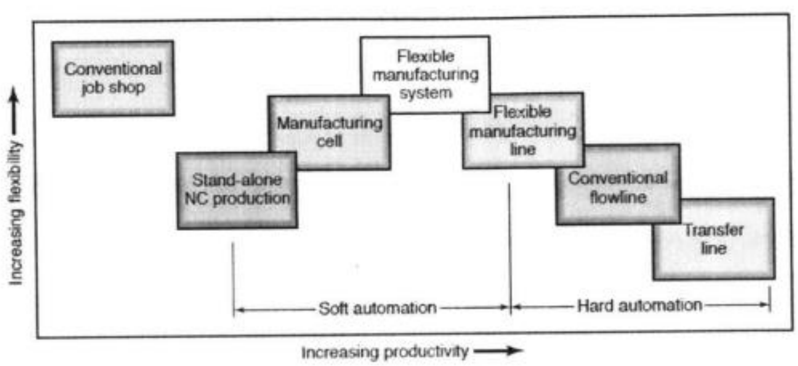


Figure 1 Recommended Flexibility in Production Based on Productivity and Volume Output

Type of production	Number produced	Typical products
Experimental or prototype	1-10	All types
Piece or small batch	< 5000	Aircraft, machine tools, dies
Batch or high quantity	5000-100,000	Trucks, agricultural machinery, jet engines, diesel engines, orthopedic devices
Mass production	100,000+	Automobiles, appliances, fasteners, bottles, food and beverage containers

Hard Automation

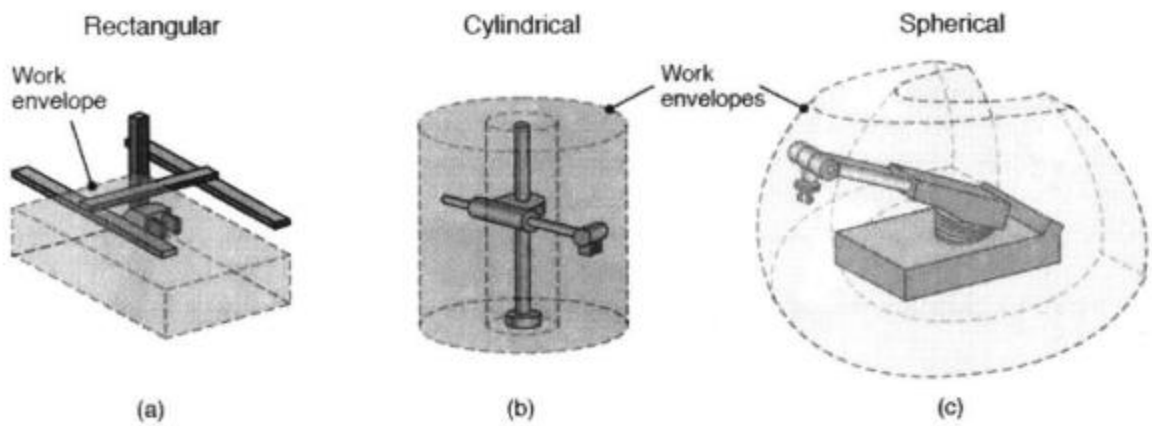
Hard automation machines are designed for very specific tasks with high volumes with low variability of the input material or the process. Hard automation can be seen in places where one operation will produce thousands or tens of thousands of units in a relatively short amount of time. By having one dedicated machine to do one specific process, manufacturers can instantly increase the throughput in that specific area of the production. This automation is also relatively cheaper compared to the other types of automation. An example of this type of automation is a metal stamping press in a high-volume production line. This single-purpose machine uses one die at a time, and has the ability to form the metal sheets into the desired shape very quickly.

Soft Automation

Soft automation is a more flexible form of hard automation. This type of automation allows for different interfaces to be switched on and off, allowing for multiple processes to be done on a single machine. This kind of automation can do multiple jobs on a single product before it moves to another process, or it can allow for different product configurations to allow customer customization. An example of soft automation is a computer numerical controlled (CNC) machine. This machine can perform many subtractive manufacturing operations within one system, giving it the flexibility to create different parts with the same machine.

Flexible Automation

Flexible automation is the ultimate type of programmable automation. An example of this type of automation is the six-axis robot seen in a variety of manufacturing environment - from automobiles to toys. The multiple degrees of freedom of this automation allows it to be completely programmable in its function and motion. The way the software is written to create the paths for these robots is more important here than with hard or soft automation, where the mechanical architecture defines the abilities of the automation much more.



Governing Equations of Flexible

Automation Motion Since flexible automation has many degrees of freedom, even simple translation can be a challenge to program. Luckily, there has been significant advancement in the mathematics of robotic motion that allow the motor control commands to be made more simply. To show the basic concept of the mathematics, a simple example will be shown [9]. In a two-degree-of-freedom system, there are two links and two joints, with a point at the end that will be used as the reference for what we want the robotic arm to do. Figure 4 shows a visual representation of this sample system.

ENABLERS OF AUTOMATION

The successful implementation of automation in the manufacturing environment requires much more than just understanding and choosing the right type of automation for the task. In order to ensure that an automated system will live up to its requirements and expectations, companies need to ensure that other aspects of its business are coordinated with the effort to automate processes within the production system.

Automation Planning

Before a company decides to incorporate automation in their manufacturing environment, they first need to understand the need that is being addressed. Replacing manual processes with automation should not just be about updating existing processes. Rather, automation should be one of many ways in which a company can go about reaching its production goals. In some instances, improving existing manual processes may be better than bringing automation in. That is why a careful analysis of a company's needs, from the highest strategic positioning to the smallest timescale of a process, is necessary. To do this, companies need to understand themselves and their production needs through a series of analyses and strategic decisions.

Production System Strategy

Having a production system strategy is key to a company's competitive advantage over others in the market. This production system strategy synthesizes requirements from many parts of the company. First, it is mostly influenced by the company's high level strategy. In order to compete with others on the market, gain the largest market share, or provide more dividends to shareholders, the production system is a key driver to the success of the company's overall goals.

Production System Modeling

As a first step to creating the production system strategy, and how automation fits within it, a baseline understanding of the current process is necessary in order to have a reference point to compare to when changes are made. This entails understanding all of the processes and subprocesses associated with the manufacturing and assembly of a product in order to get a holistic view of the operations. Time studies and process flow diagrams are essential in getting a highresolution understanding of the inputs, outputs, and process times for each step in the manufacturing operation.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions for Implementing Design for Automation at Company A

Company A has been a successful company for a long time through its ability to be innovative with its products and tenacious in the marketplace. Company A hires some of the most talented people in the world, and its ability to adapt to changing market trends, financial crises, and even world wars proves that it is truly a company built to last. In a modem society that has seen unprecedented disruption and change through innovative technologies, Company A must look within itself to understand how to avoid losing in the market. In doing so, it must reassess many of its fundamental principles and cultural behaviors. The goal of Design for Automation is to bring to light the importance of creating robust and reliable automated technologies within the production systems that will allow the company to be competitive in the future. Collaboration between engineering groups will be key to going from an inefficient "throwit-over-the-wall" culture to one of collaboration and cohesion between all engineering disciplines. This change requires the efforts of all Company A employees, from executives to mechanics. Allowing middle management to be flexible enough to change its ways will be important to avoid the "frozen middle", where middle managers are unable to enact change because of the risk they must take in order to positively affect the system. Creating the right incentive systems and performance management metrics that align with the high level production goals of the company will allow middle managers to feel comfortable taking risks and trying new things (within the safe regulatory bounds). With this collaboration, a proper way to trade-off between design decisions is necessary. Specifically, it is important for the company to understand the quantitative value of improving its production system in the short and long-term.

Recommendations for Future Automation Projects

" Co-locate engineering teams to improve collaboration between engineering disciplines. This will allow the different engineering groups to develop and incorporate as many requirements as possible early in the development of a new widget or widget upgrade. " Create indexing schemes for all assemblies in order to effectively communicate key assembly characteristics throughout the supply chain. " Provide design engineers with tools and information that will allow them to better incorporate automation-specific requirements into the widget design. This can be done through further developing the principles and flowing them down to specific design guidelines for each part of the widget within each widget program. " Change the engineering process to involve production engineers knowledgeable in automation early in the widget development process. The allocation of resources should also be changed throughout the widget development process. Create transition periods between the different development process steps instead of "handing-off' work from one engineering discipline to another. " Emphasize the use of modeling and simulation in order to make better production system decisions. Better analytical tools in the production environment will also help in understanding the true value of flow time improvements.

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