COMPUTER INTEGRATED MANUFACTURING FOR THE SHOT PEENING INDUSTRY IMPLEMENTED IN AN EMPOWERED ENVIRONMENT

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Abstract

The purpose of this paper is to analyze the human and technical constraints on improving the shot peen process where it limits acceptable product fatigue strength variability, and propose a systems approach to dealing with these problems. This paper analyzes non-traditional methods of production process control and process management.

The first area addressed in the paper is the concept of Computer Integrated Manufacturing (CIM) utilized for shot peening. The paper conceptually relates statistical reliability of processing to acceptable product variability. The second area is the need for implementing CIM in an empowered workforce environment.

Introduction

Using industry accepted methods of process control for shot peening has not provided a statistically reliable tool for insuring that the benefit for which the process was used is in fact resident in all parts processed. Some strategies have been introduced to try to quantify the process, but typically fall far short of the goal of optimized process benefit reliability. Statistical tracking of Almen Intensity measurements per existing specifications cannot provide sufficient process control. (Ref: Simpson and Barnesky, ICSP-5, Wieland ICSP-5, WIIB, EMAS, Fuchs Strengths and Weaknesses of Almen System). Absolute process control, accomplished through continuous monitoring and control of process variables, within cumulative variable tolerances known to deliver acceptable product characteristics can. This system of continuous statistical process monitor and control is the core of the CIM system.

Employee Empowerment is the management structure needed to provide timely responses to information provided by the CIM system. Data analysis in the quality office is, in most cases, too late to prevent improperly shot peened parts. A properly trained workforce, with the authority and responsibility to make decisions about the process, is essential to the success of the whole system. CIM is incomplete if the
information stays in the office.

Part one of this paper examines the inability of present control strategies and systems to provide a reliable process.

Part two examines how CIM and Employee empowerment can be utilized together to make shot peening a reliable and reproducible tool for fatigue strength benefit.

**Part one: Why CIM?**

1) **Fatigue strength benefit: It's relationship to changes in process variables.**

   The process variables that enhance or diminish fatigue life benefit can be summarized by the diagram in figure 1. A conceptual relationship first identified in the literature in 1985 by Simpson.[1][3][5][6] "The 'sweet zone' of optimum process benefit for a given set of workpiece and workload variables is defined by a distinct set of

   ![Figure 1 Process Variable Groups](image)

   process variables which yield optimum results. . . . Once acceptable tolerances for these optimums [Energy transfer variables and Saturation & Process procedural variables] and their sub-variables have been chosen through fatigue testing, the consistent reproduction of specific quantitative amounts of each variable and its sub-variables is paramount."[1]
1.1. Process variables vs. Intensity:

Currently the accepted measure of the shot peening process is Intensity. The tool for this measurement is the Almen strip. It measures the combined effects of 'energy transfer variables', 'saturation & process procedural variables'. Changes in either velocity or saturation can result in changes in intensity. (2)(3)

The example in Figure 3 shows a strong correlation between one process variable (Boostline Air Pressure) and Almen Arc Height. The test battery used statistical Design of Experiments included running 4 strips at each of 8 different trials of various boostline and pressure pot pressures (see table 1 for actual test data). The graph in figure 3 only includes the 16 almen strips that had a thickness of between .0500 and .0501.

Table 1 Design of Experiments on AP-14 Machine on 4-29-93

<table>
<thead>
<tr>
<th>Trial</th>
<th>Pot Pressure</th>
<th>Boostline Pressure</th>
<th>Strip thickness before peening of .0500 - .0501</th>
<th>Strip thickness before peening of .0506 - .0510</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>71</td>
<td>72</td>
<td>.0223</td>
<td>.0226</td>
</tr>
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<td>2</td>
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<td>78</td>
<td>.0231</td>
<td>.0223</td>
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<td>8</td>
<td>77</td>
<td>76</td>
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<td>.0214</td>
</tr>
</tbody>
</table>
TYPICAL ARC HEIGHT VS. BOOSTLINE PRESSURE PLOT
Advanced Material Process Corporation: AP-14 Machine
Correlation: .9012151    N = 16
Design of Experiments Test Matrix run on 4-29-93

Figure 3 Correlation between Almen Arc Height and Air Pressure
1.2. Intensity vs. Fatigue life benefit:
Many studies have been conducted to relate the 'sweet zone' of fatigue life enhancement to the Almen strip measuring system. The industry has accepted this as its standard for specification of shot peening. The listed references go into detail on this subject so it will not be covered here. [4][5][6][7][8][10]

2. Almen strips: An unreliable system for measuring the effect of shot peening.

The weakness of the Almen Strip system are well documented in the literature and will not be detailed here. Suffice to say that its internal variability and lack of correlation with work piece fatigue strength makes it a highly unreliable process measurement system. [1][3][5][6]

3. A high degree of process variable reliability results in a high degree of fatigue strength benefit reliability.

The obvious conclusion is to not rely on the Almen system as confirmation of the process, but instead continuously monitor, control and statistically track the process variables on a real time basis. The key is in the control. To insure a reliable fatigue strength benefit requires a system that will keep quantitative process variables levels consistently with those needed. [1][2][3][5][6][9][10]

4. Requirements for insuring reliability of process variables.

Systems must be designed and demonstrated to be statistically capable. This means all the process variables that contribute to fatigue life benefit must be capable. Knowledge of potential process variable system failure must be available before the failure occurs. This requires a statistical approach to data collection and identification of trends. This also requires that the factory floor be able to respond immediately to the information provided by the system.

Part two: Description and Application of CIM and Employee Empowerment.

A valid CIM system monitors everything that can effect quality or productivity conceptually. The definition of CIM is a system that is setup by a computer system that is linked to all machines on the floor and other auxiliary equipment that has an output for monitoring information from the machine to the computer system. The data that is collected from the machines is then put into software real time. CIM will record data and observations from everyone in the organization and pinpoint areas that need rapid improvement. [15][16] CIM is the core of an entire system of improvement for a organization at it applies to shot peening it provides better understanding of the process, allows the setting of quality goals and enables the measurement of the
performance against these goals in a real time quantitative manner. CIM provides commonality of data that leads to uniformity in understanding of the problems of the shot peening process. One of W. Edward Deming’s 14 prescriptions for effective management is to "Cease dependence on mass inspection". In the shot peening process mass inspection can be eliminated only if the stability of the peening process is good enough to eliminate the need for inspection.  

CIM provides strong tools aimed at developing the peening process so that quality becomes constant, lessening the need for inspection.

When data is generated from the CIM system from all areas of the manufacturing processes, the data is evaluated with a variety of expert systems. Expert systems are developed software systems that take the data and generate a variety of statistical, management, events, maintenance, MIS reports and graphs for the factory floor. These expert systems are then utilized for good decision making and to improve the quality of the peening process. When a parameter is out of control in the peening process the CIM system alarms the process of the parameter that is out of control. The alarm is displayed with the value of that alarm and corrective action can be made.

Historically, where fatigue is the limiting factor, it has been demonstrated that large fatigue strength increases due to shot peening are attainable. However, once applied in high production volumes much, if not all, of this gain is statistically eliminated due to large fatigue data scatter of production parts. The reasons for this is lack of adequate process control, statistical understanding, optimization and reproducibility. This type of shot peening process, which is often referred to as "controlled shot peening", in most cases, cannot consistently provide fatigue strength increase of the same magnitude in production as preproduction test parts.  

If conventional controlled shot peening could consistently and cost effectively provide large fatigue strength increases, industry’s utilization of the process would be much greater. The explanation lies in the false assumptions that fatigue strength improvement derived is relatively insensitive to process parameter values and variation; this is not supported by available data.  

Greater understanding of the effect of peening process parameters on the workpiece, as well as sensor development, have created a need for a computer integrated system for more significant and reliable fatigue strength increases in high volume applications, than indicated by historic lab and production data.

Absolute process control is necessary to be able to respond to continuous changes in the shot peening process on a real time basis. This continuous process monitoring and control is the core of the computer integrated manufacturing system. Absolute process control is looking at each individual data point of the process variables being electronically monitored and controlled both statistically and real time. This information will allow you to see variability of those variables being monitored that you would not see using traditional controlled shot peening practices. The benefits
of real time statistical process control in the shot peening process gives you an understanding of the way the individual components of the machine perform. These components may be mag valves, air pressure regulators or any other component of a machine that can output information to be evaluated and acted on.\textsuperscript{15,16,18,19}

The peening equipment stability improvement phase provides the method to identify the machine process variations and determine solutions which begin to place the peening processor into the proactive mode, resulting in long-term performance stability. Key ingredients is to understand the reasons for long-term variations, identify and eliminate the common causes for long-term drift, identify and fix environmental-related problems, Fix the equipment/personnel related problems and establish long-term machine performance stability. These and others are what make this tool the tool of choice to enhance fatigue strength.

With the push for increased control of the peening process the author realizes that time is a valuable commodity and he does not have enough time or enough manpower to handle the problems of the day. The capability of a CIM system and the gathering of real time data with the need to react real time is necessary. Data gathering and analysis needs to be removed from the quality office and onto the factory floor.\textsuperscript{15,16}

Employee Empowerment is the management structure needed to provide timely responses to greater enhancement in fatigue life. The most important part of empowerment is that it is a tool for making decisions on the factory floor. All employees are participating in problem solving using the data generated by the CIM system in all areas of the organization on a real time basis. The speed of the problem solving on the factory floor will be increased by a magnitude. This is due to the data being available real time from the CIM system and the response is also real time from the factory floor to solve the problems.\textsuperscript{16,17}

Understanding empowerment may be the first step to achieving it. The basic definition of empowerment is an environment that fosters open unrestricted exchange of information and open opportunities for innovation; employees trust each other and most of all are willing to take risks. In order for empowerment to take root and thrive, one must encourage these conditions: Participation, Innovation, and Access to information from the CIM system and accountability. These factors that the author has stated can produce an organizational feeling and tone that can have a dramatic, positive effect on employees. Participation: People must be actively and willingly engaged in their jobs. They must care about improving their daily work processes and work relationships. Innovation: It's almost impossible for empowerment to exist in environments in which innovation is ignored, stifled, or discouraged. In traditional organizations, the senior managers decide who receives what kind of information and how much. In organizations which employees are empowered, people at every level make decisions about what kind of information they need for performing their jobs and attaining goals. Accountability: It is important to ensure that employee accountability is egalitarian; in other words if employees are accountable to managers, then managers should be accountable to employees. The authority and responsibility must be visible and all of the above conditions must be
integrated in generating data that can be acted upon in a timely matter to achieve fatigue life enhancement.\cite{(16)(20)}

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