DRM TECHNOLOGIES, INC.

5 Points to Failure-Free Equipment Design

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In September of 2002, a stamping plant located in the Chicago area was having press availability problems caused by an electronic transfer feed (ETF) system. The ETF is used to transfer parts between the various dies in the press. The plant stated that the ETF was in a "death spiral" and they could not meet the current production schedules. Overtime and maintenance dedicated to keeping the ETF running was consuming the budget, and the engineering group was being held accountable for all of the overtime associated with the ETF failures. The press was a definite constraint in the plant's lean manufacturing initiatives.

The central engineering group received funding for a redesign of the ETF to try to remove the various failure modes and rescue the ETF from certain death. An ETF design team was formed consisting of plant engineering, plant maintenance, central engineering, the ETF build house and reliability and maintainability (R&M) engineering personnel. The objective of the team was simply to improve the overall availability of the ETF system for a reasonable price and within an unreasonable amount of time - the same as any other project.

The team implemented the "5 Points to Failure-Free Equipment Design" process developed by DRM Technologies to expedite the design, build and installation process. This comprehensive R&M process includes 1) Data Collection and Analysis 2) Design for R&M 3) Life Cycle Cost Analysis 4) PM and Spare Parts Analysis 5) Reliability Growth Analysis.

Meetings were conducted with the plant, builder, central engineering and the R&M support group to lay out the plan of attack and to determine what key information points were needed to implement this project. Initial meetings with plant production indicated that a 95% uptime factor was required in order to meet the production schedules. An uptime of 95% on the ETF would need a mean time between failure (MTBF) of 500 hours and a mean time to repair (MTTR) of less than 1 hour. These goals were steep, but the team thought the ETF carriage could meet these requirements.

The team started with the data collection and analysis (Point 1). Information was collected from the plant's data collection system and interviews with various skilled trades, supervision and management personnel were conducted. These individuals provided solid information relating to failures, as well as design solutions for fixing the failures. Also of importance to the design team was a review of data collected from the computerized maintenance management system (CMMS) to see if various downtime incidents had been recorded. The CMMS data collection method being used was where failure codes were entered into the system by supervision. These codes were developed from maintenance tags filled out by the various maintenance teams. This method of data collection presented a cloudy picture of the downtime due to lack of detail and misrepresentation of the various failure patterns. With data being recorded in this way it caused the R&M engineering personnel to create various failure models that would filter out non failure events and capture actual failure events.

The initial data collected was analyzed and confirmed the reports from the various interviews. The press was in a "death spiral" and within a short period of time the press would make a better paper weight than a piece of automation. Initial data showed that the original design specifications called for the press to operate at 451 cycles per hour; but due to the failure pattern of the press, it was only able to reach 179.6 cycles per hour. This excessive amount of downtime was causing production to off-load jobs to other presses, increasing the risk of potential failure in those presses.

Armed with the analytical and interview data, the R&M engineers prepared a Point 1 report and presented the information to plant management and central engineering. The results indicated that further funding for the redesign should be pursued. The funding was approved and the project moved forward.

The results of Point 1 are illustrated in figure 1 below. Notice the major contributor to failures was the bearings (cam followers) followed by carriage and rail failures. It should be noted that the data collected on carriage and rail failure could be related to cam follower failures. The information was miscoded when recorded in CMMS. It is not illustrated that the rails and carriage were also major root causes of the failure of the bearings.

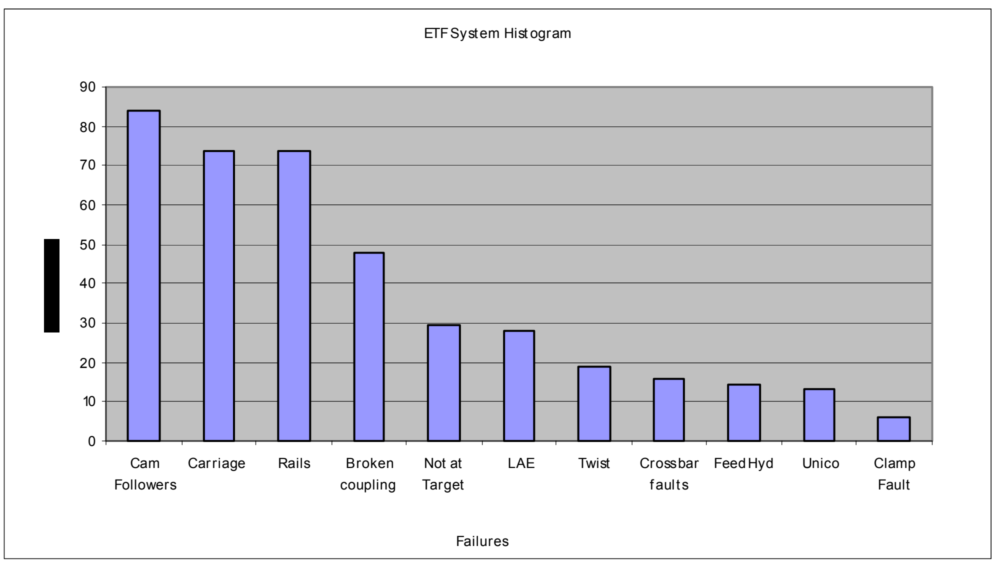

Figure 1 Failure Distribution

From the information collected during Point 1, Point 2, Design for R&M, was started. In order to meet the production requirements the new design would need an MTBF ≥ 500 hours, MTTR ≤ 1 hour, and operational availability to be >95%. The R&M engineers developed a hierarchical model for the equipment in order to develop failure cause relationships with the carriage. Figure 2 illustrates the hierarchical model.

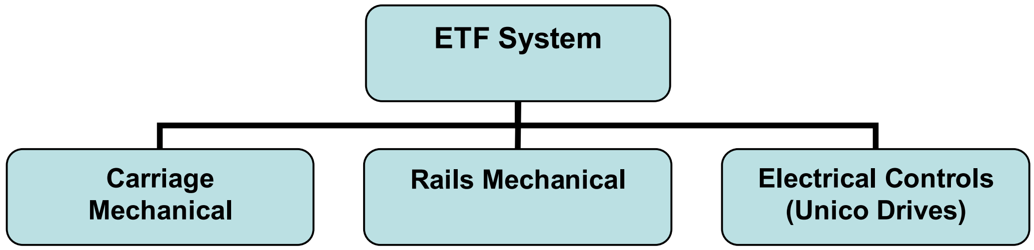

Figure 2 - ETF Hierarchical Model

Data from Point 1 indicated that the mechanical design of the carriage was providing the highest source of failure for the ETF system. The electrical controls were reviewed and, as listed in a “Top 10 Failure List”, the Unico drives systems provided little probability of failure. Therefore, the key design issues for the carriage were cam follower failures and weight and speed of the carriage.

The design team reviewed the programming for the acceleration and deceleration for the drive system. The results of this review pointed out that by increasing the ramp’s angle by one degree, it would result in a reduction of the load by 17%. Reprogramming this ramp would have reduced the probability of failure in the carriage and rails. However, this would cause the carriage to slow down which would impact cycle times. This reprogramming was a “last option” design solution.

The R&M design team applied various design tools to remove and analyze the different failures. These tools included:

- Environmental Analysis
- Weibul Analysis
- Hierarchical Modeling
- Mechanical Stress/Strength Analysis
- Machine Failure Mode Effects Analysis
- Fault Tree Analysis
- Design for Maintainability

- Finite Element Analysis

The hierarchical model developed for the system allowed the team to look at the system level operations down to the lowest replacable units (LRU). The R&M engineers applied various modeling methods to elaborate the various failure patterns for the ETF system. The model allowed the design team to focus on high probability of failures of the system.

The hierarchical models quickly identified that if the system's MTBF goal of 500 hours was to be reached, they needed bearings with a B_{10} life of 18,000 hours. This information was developed from a Wiebull analysis conducted by the R&M engineering team. It must be noted that B_{10} characteristic life represents where 10% of the bearing population would have failed by that point in time. However, 90% of the bearing would still be in service and would survive past that 18,000-hour value.

The new design called for a steel carriage which would provide the necessary strength for the new design. The major drawback was the steel carriage was going to add over 500 lbs. of load to the system. A finite element analysis was conducted on the carriage to review the impact of the added weight. The FEA results illustrated that the additional weight did not impact the cam follower operation and thus, nor its characteristic life. Additional analysis was also completed on the drive system's ability to handle the additional weight of the carriage. This also showed the drive had enough horsepower to keep the carriage within the proper operating range.

Better weight distribution on the carriage also reduced the load on the bearings. Using a statistical model for stress/strength interference the results indicated a safety margin would be <1 resulting in a low probability of failure.

Each of the various failure modes were addressed by implementing a machinery failure mode effects analysis (MFMEA). This tool was very valuable in determining the potential failure modes, effects and causes of failure. The MFMEA allowed the team to evaluate the different risk factors associated with each failure and develop cost-effective design solutions for the ETF carriage.

Design for R&M (Point 2) used the various tools to provide confidence that selecting the proper cam follower would provide the necessary uptime for production requirements. This also resulted in a standardized design for the carriage that can be used in other facilities with similar failures. Also noted was that the quantifiable data led the team to have a high degree of confidence that the design would achieve its MTBF goal of 500 hours.

An R&M Trade-off analysis was completed on the various bearings comparing the cost, MTBF, PM schedules and other metrics associated with the bearings. The R&M engineers applied a statistical model to the R&M trade-off data. The trade-off analysis directed the design team to a 90mm cam follower. It was a common off-the-shelf (COTS) part which met the MTTR requirements, but it was more costly than the other bearings included in the trade-off analysis. The upside of this cam-follower was that it provided an 88.86% probability that the system MTBF of 500 hours could be reached, as well as provide the necessary carriage uptime to meet production schedules. The increase of $400.00 to the project provided only a 12% chance of failure during production hours. The design team was willing to take the risk.

The new design moved the bearings to outboard locations on the carriage allowing an efficient load distribution for each of the bearings. The new design was constructed from structural steel instead of the cast aluminum from the older design.

A life cycle cost (LCC) analysis (Point 3) provided the team with costs associated with the different design activities. The LCC tracked the acquisition, operation and scheduled and unscheduled maintenance costs associated with the design. The results of the LCC analysis illustrated an initial cost savings to the plant of $132,025.00. Table 1 illustrates the various costs associated with the carriage and the lost production comparison between the old and new design.

LCC Category	Old Design	New Design	Savings
PM Labor Costs	$7,680.00	$64.00	$7,616.00
Unscheduled Maintenance	$4,375.00	$2,100.00	$2,275.00
Spare Parts Costs	$9,700.00	$550.00	$9,150.00
Maintenance Total Costs	$21,755.00	$2,714.00	$19,041.00
Lost Production Units	27,429	13,306	14,123
Cost per Part	$8.00	$8.00	
Lost Revenue	$219,432.00	$106,448.00	$112,984.00
Total	$241,187.00	$109,162.00	$132,025.00

Table 1 Lost Production Projections

A reclaimed revenue projection analysis was completed for the new design and the results of that calculation is illustrated in table 2. The results clearly point out that a $500,000.00 return can be established when the carriage reaches an MTBF of 100 hours. These savings were developed from the reliability growth chart shown in Figure 4.

LCC Categories	Old Design	New Design	Future State
Hours of Operations	4032	4032	4032
MTBF (hours)	13.41	25.22	100
Events	307	160	40
MTTR (minutes)	32	37	37
Part Costs	$8.00	$8.00	$8.00
Job Loss	40,261	24,379	6,175
Potential Lost Revenue	$322,088.00	$127,056.00	$49,400.00
Net Revenue Gain		$127,056.80	$272,688.00
Reclaimed Revenue		$195,031.20	$467,719.20

Table 2 Reclaim Revenue

The reclaimed revenue analysis clearly demonstrates that with the ETF system achieving a 100-hour MTBF value, the reclaimed revenue would reach $467,719.20 per year. The R&M design activities proved clearly that the ETF system had a high probability of reaching its objectives.

A spare parts and PM analysis (Point 4) was also conducted as part of the overall R&M plan for the redesign of the ETF carriage. The team evaluated the MFMEA for high risk potentials and, using the software package called eRAM Notes®, developed by DRM Technologies, Inc., the spare parts analysis was completed. The spare parts analysis indicated that if a failure occurred, and since the spare parts were COTS parts, they could be available at the plant within an hour. This timeframe would meet the MTTR goal. The PM schedule was reduced significantly from the past design. The tools required to complete the PM actions were already being used by the trades personnel in the plant. In addition, the team recommended to place visual factory placards on the ETF system highlighting lubrication points, belt tension and spare part numbers. All of these elements assisted the trades personnel in implementing the PM schedule.

Reliability Growth (Point 5) was used to determine from the data collected on the floor if the design improvements were meeting the original objectives. The model that was developed provided interesting data related to the “old design” versus the “new design”. The RG model illustrated in Figure 3 shows that the original design was in a death spiral and heading for complete failure. The current state RG graph shown in Figure 4 shows the design improvements are impacting the ETF’s uptime characteristic and shows the upward trend providing management with the necessary confidence that the design is meeting design expectations.

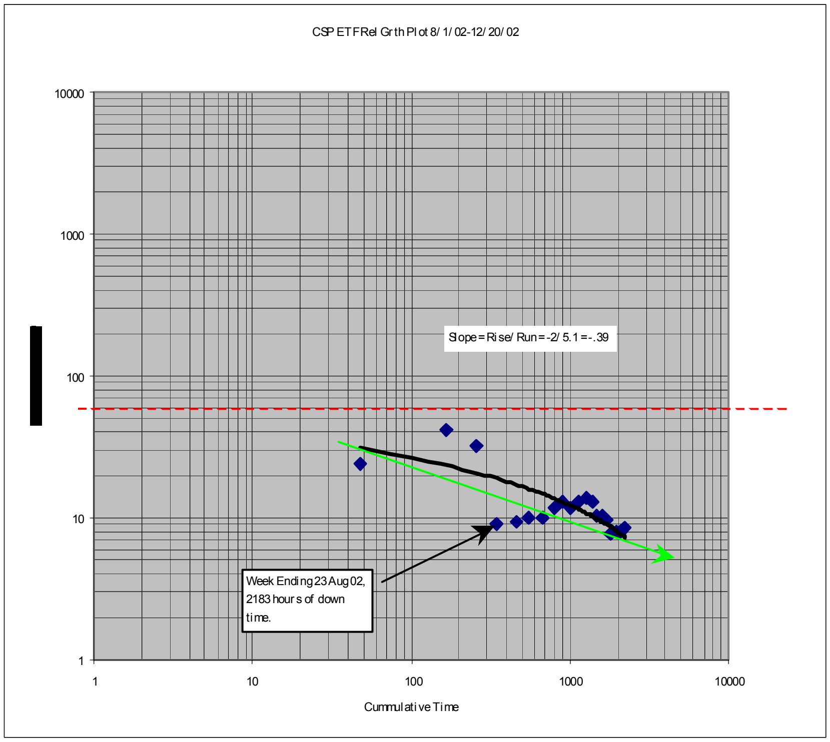

Figure 3 – Old Design's Death Spiral

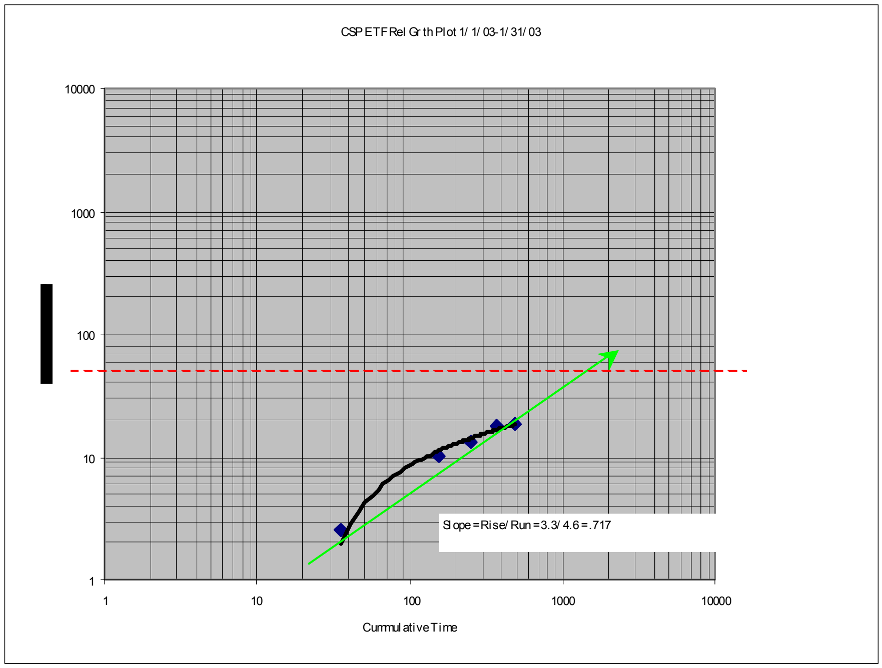

Figure 4 – New Design’s Reliability Growth

In conclusion, the “5 Points of Failure Free Equipment Design” process to this project supplied a fast-track from design to installation. The process has provided the plant with a quick return on investment, as well as a design standard that is being used in other stamping facilities. Each additional hour of MTBF achieved increased the reclaimed revenue due to reduced design times, spare parts, PM schedules and unscheduled downtime events. All of these elements translate into increased profits, reduced inventory costs, and moving the organization into a Lean Manufacturing environment.

For additional information relating to this project, a reprint of the full case study is available at www.drmtech.com.