Honeywell

Magnetic Particle Process Improvement

Federal Manufacturing & Technologies

R. R. Hubert

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Final Report

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MAGNETIC PARTICLE PROCESS IMPROVEMENT

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R. R. Hubert, Project Leader

Contents

Abstract

The magnetic particle testing process is performed to find linear, surface, and near-surface

discontinuities in ferromagnetic test materials. A wet fluorescent method is used at Honeywell Federal Manufacturing & Technologies (FM&T). This method employs a liquid carrier mixed with iron oxide particles in suspension, and the particles used in the method are coated with a fluorescent dye to make them visible under a black light. The process in its current state employs the use of a tank of liquid solution of a mineral oil carrier with iron oxide particles in suspension. The change to the use of an aerosol delivery system with the same material reduces the amount of waste involved in the process while preserving the sensitivity of the testing, shortens the flowtime for the test, and saves labor and material costs.

Summary

Ferromagnetic test items such as fasteners, steel cases, and forgings are candidates for magnetic particle testing. The test method is used to detect cracks that can be caused by heat treat operations, material defects, cracks from cold working of the material, and cracks from welding processes. The magnetic particle method, as used at Honeywell Federal Manufacturing & Technologies (FM&T), consists of flowing the magnetic particle solution over a ferromagnetic part and then creating a magnetic field in the test item to capture magnetic particles at the discontinuities in the test item. The solution that is used must be replaced occasionally either to clean the tank when too much buildup occurs on the sides of the tank or due to contamination.

The use of a bath for this operation is not very efficient and to clean the tank requires disposal of 20 gallons of liquid waste. It has been determined that efficiency of the operation can be gained by the use of the same material with a different delivery system. Aerosol cans can be used to perform the same tests, and the amount of material entering the waste stream, when calculated on a yearly basis, would be greatly reduced.

Discussion

Scope and Purpose

The magnetic particle testing process involves the use of a suspension of iron particles in a mineral oil bath. Numbers of requests for this type of testing have declined over time, but the need to maintain the capability is still present. The overhead associated with beginning a test when the bath has been idle can be several hours in length. A change to the process was needed to decrease these times while maintaining the same test quality to meet product requirements.

The use of pre-mixed solutions, of the same material as in the bath but in aerosol cans, was studied for use as a substitute for the bath method of performing the test. The same magnetic particle solution is simply delivered to the product by spraying it on rather than soaking the part from material in the test bath. Test sensitivity was studied as well as particle concentration to determine that the two methods would deliver comparable quality of testing for the test item.

Prior Work

The use of water-based magnetic particle solutions had been investigated previously for use at Honeywell Federal Manufacturing & Technologies (FM&T). A comparable test quality can be achieved through the use of water-based solutions; however, the same preliminary operations must be performed before testing.

Activity

To perform a magnetic particle test, there are several system checks performed to determine that the testing machine and materials are within tolerance for the performance of the test. The steps involved in the process are included in the process maps in the Appendix.

The system employs a pump to circulate the magnetic particles for testing. This is run for 30 minutes to ensure uniform distribution of particles in the carrier. Normally a quantity of particles sticks to the sides of the holding tank since the agitation of the liquid cannot break them loose. The test operator can manually help loosen the particles on the tank by using a broom to brush the sides of the tank to free the particles.

After the circulating pump has been running for 30 minutes, a 100-ml sample is drawn and allowed to settle for one hour in a centrifuge tube. The magnetic particles and any contamination in the solution will settle to the bottom of the tube. The precipitate is examined by the operator to determine the volume of magnetic particles contained in the sample. This provides a method to judge the concentration of particles in the entire bath. Any contamination in the sample will

settle into a separate layer. This allows the operator to determine whether the bath has become contaminated. The fluorescence of the liquid is also checked to determine whether the fluorescent dye has separated from the particles themselves. When the concentration of particles is low, more particles are added to the carrier. When this happens, the mixture must again be circulated for 30 minutes, and a new sample must be drawn and allowed to settle for another hour. When the system is not used on a regular basis, particles must be added almost every time it is used due to the sticking of particles to the sides of the bath. If too many particles are added, part of the solution must be pumped out and more carrier added back. This is again followed by the 30-minute circulation time and one-hour settling time. Experience of operators combined with their training has prevented this from happening on a regular basis. If the mixture is contaminated, the tank must be pumped out, the tank cleaned, and new carrier and particles added. This is once again followed by the 30-minute circulation time and one-hour settling time. Contamination is a rare occurrence for this operation.

Once it has been established that the mixture is properly circulated and not contaminated, the background white light is checked. Too much background white light interferes with the testing since the fluorescent property of the particles is apparent only under black light. The white light makes it much more difficult for the operator to see the fluorescence. A light curtain surrounds the magnetic particle machine to block out the white light as much as possible. The intensity of the black light is also checked to make sure that there is a bright enough exposure to the part for proper inspection. If there is not, it is normally due to a weak bulb and it is replaced.

The sensitivity of the solution is then checked. This is done with a special test piece called a ketos ring. The ketos ring has cross-drilled holes that simulate discontinuities at various material thicknesses. A test is performed at three different current levels, and the number of holes that must be detected on the outer surface of the ring is specified. This ensures that through a range of current settings on the machine, the magnetic particle fluid is sensitive enough to properly detect discontinuities. This check will also provide some indication if the machine is working properly as far as delivering the proper current when set to a given level.

After these checks, the actual part can be tested. A test technique specifies the parameters for the test part and how to perform the test. The test part is magnetized and then evaluated. Training and experience are relied upon to evaluate the parts. Operators are initially certified through general and specific written tests and a practical test on the machine to demonstrate their ability to detect discontinuities and evaluate them. This is only done after a mandatory training period with an experienced operator and a certified test engineer. To become certified, a test operator must have a minimum of 12 hours of training with a certified operator and 4 months of experience in the test method.

This project was initiated to look at the feasibility of replacing the bath of fluid with aerosol spray cans of the same material. The failure modes effects analysis (FMEA) in the Appendix indicates that the use of spray cans is an improvement in the process by the reduction in RPN numbers across the board when spray cans are used. Due to the infrequent use of the system, a timesavings in the processing of a test and the reduction in the amount of waste that would enter the waste stream can be realized. To maintain the best test conditions, the magnetic particle bath should be changed once per year when used moderately. It would make sense to stay with the current process if the usage frequency was high and multiple bath changes were needed per year. This is because the amount of materials when analyzed on a per gallon basis results in a lower cost with the bath. Since the current frequency of usage is low, the timesavings overshadow the material costs and make economic sense. The system is used on average only 20 times per year. It is this average that is used to calculate the time and cost savings from this change to aerosol cans.

Analysis of Results

The current process requires 3.8 hours of operator time to test a part. This labor applies each time that the machine is used throughout a year. The new process requires only 2 hours per test. This results in a savings of $828 in labor ($23*1.8 hrs*20 uses) per year on average with the new process in place. The material costs in a given year will also be less. The cost of the materials to fill the bath with a new batch of fluid is $316. The cost of a year's supply of aerosol cans is $80. This is a savings of $236. This is a direct cost savings of $1,064. There is a cost avoidance in labor and materials of an additional $97.45 ($23*3.5 hrs. + $16.95 in materials) associated with changing the bath once per year and maintaining the proper mixture levels in the bath. The ABM analysis in the Appendix contains the information that forms the basis of the savings.

There is a reduction in flowtime of 1.5 hours if there is not a need to replenish the particle concentration. Experience indicates that the particle concentration must be replenished every time the machine is used due to its infrequent usage. This means that realistically there is a reduction in flowtime of approximately 3 hours per usage or a 60 hour per year reduction in flowtime, allowing higher productivity through performance of other functions with the same resources in the area.

The waste stream is affected by this process change. The machine holds 20 gallons of mixture. The changing of the fluid introduces this 20 gallons into the mixed oils waste stream. When using spray cans at the rate of one case (144 oz.) per year projected usage, it would take
17.8 years to produce 20 gallons of the same material in waste rather than one year for the current process. This is a substantial reduction on a yearly basis. Even if the rate of usage were doubled, it would take nearly 9 years to produce 20 gallons of waste. There are no changes needed to dispose of the waste, since it is the same material only with a different delivery system. There would be an increase of 12 aerosol cans per year (or 24 depending upon actual usage) introduced into the waste stream.

Accomplishments

The move from a liquid bath to aerosol cans for the delivery of magnetic particle mixture to a test item reduces flowtime by 60 hours per year.

The change results in a cost savings of $1,064 per year and an additional cost avoidance of $97.45 per year.

The change also reduces the amount of mixed oil waste introduced into the waste stream by at least 89% per year, based upon a yearly usage of 24 cans per year compared to 20 gallons per year. There will also be 24 additional empty aerosol cans introduced into the waste stream.

The new process has been put in place and, following the first year, the savings are being realized and the new process is working well.

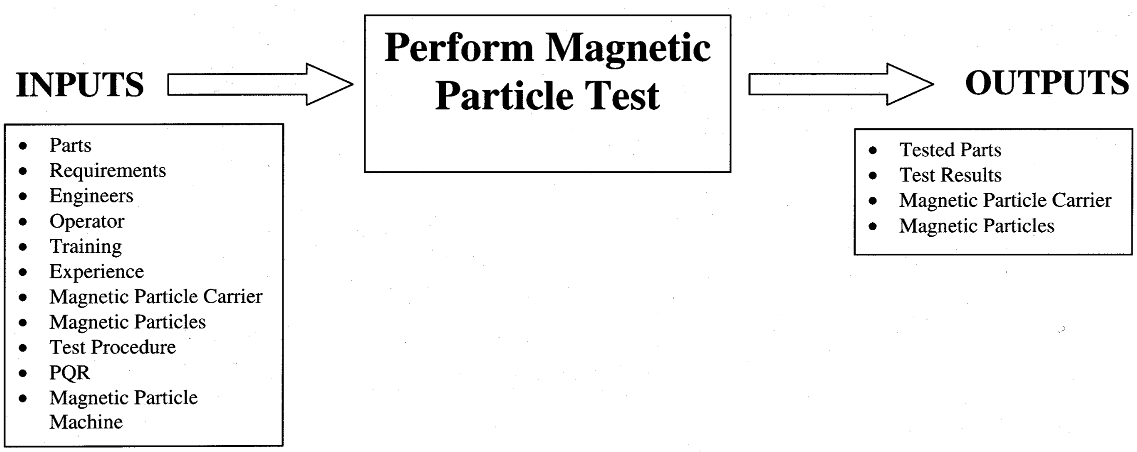
Appendix

Process Maps, Failure Mode Effects Analysis, ABM Analysis

Top Level Process Map

Perform Magnetic Particle Test

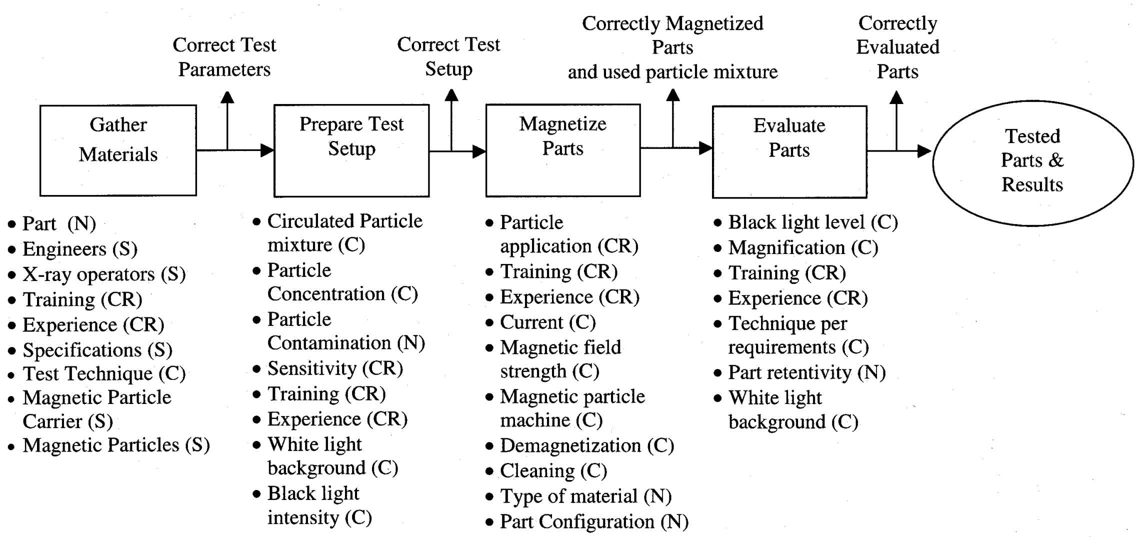
(As-is)



Level 2 Detailed Process Map

Perform Magnetic Particle Test

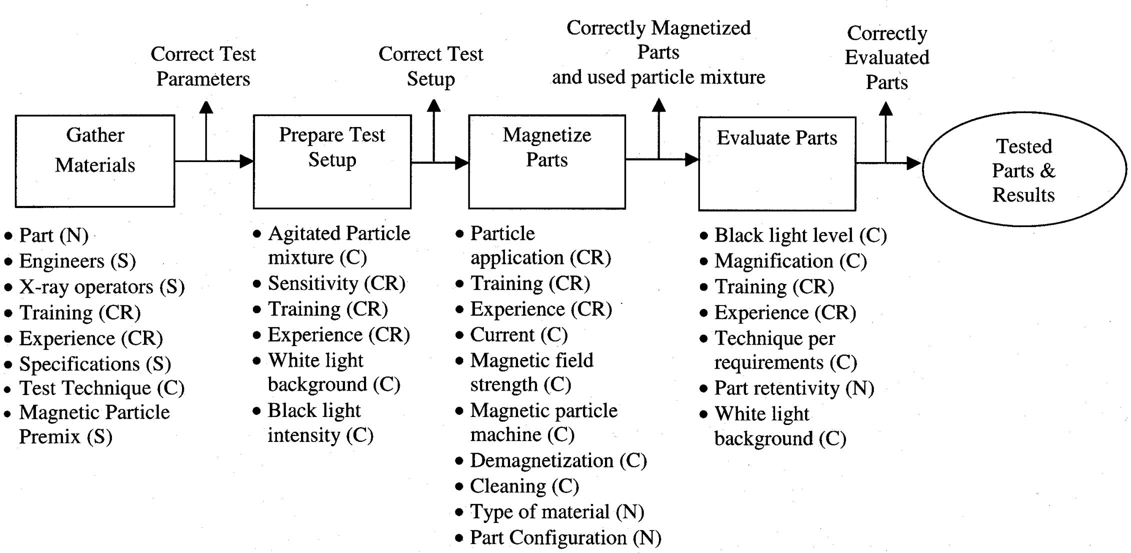
(As-is)



Level 2 Detailed Process Map

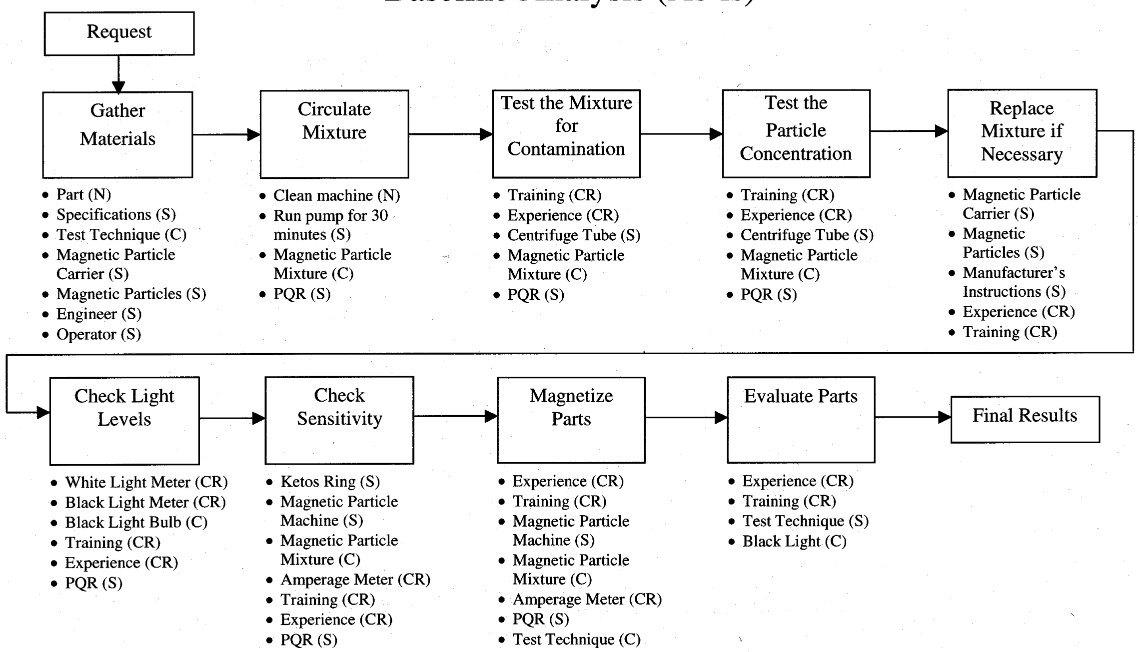
Perform Magnetic Particle Test

(New)



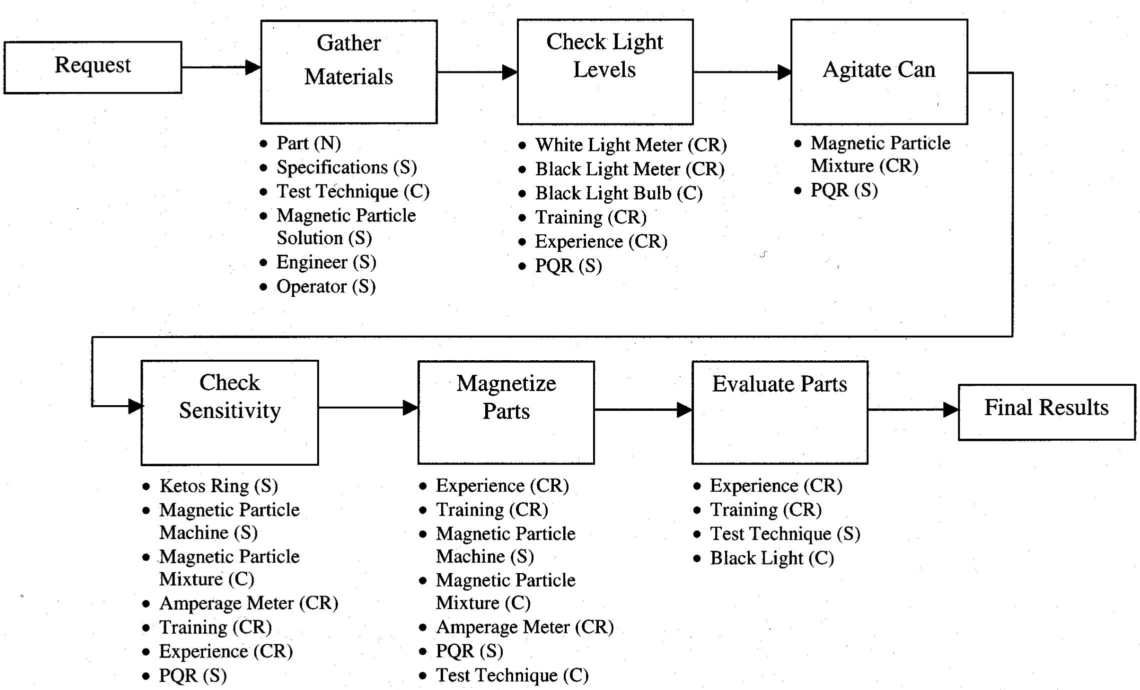
Magnetic Particle Process Map

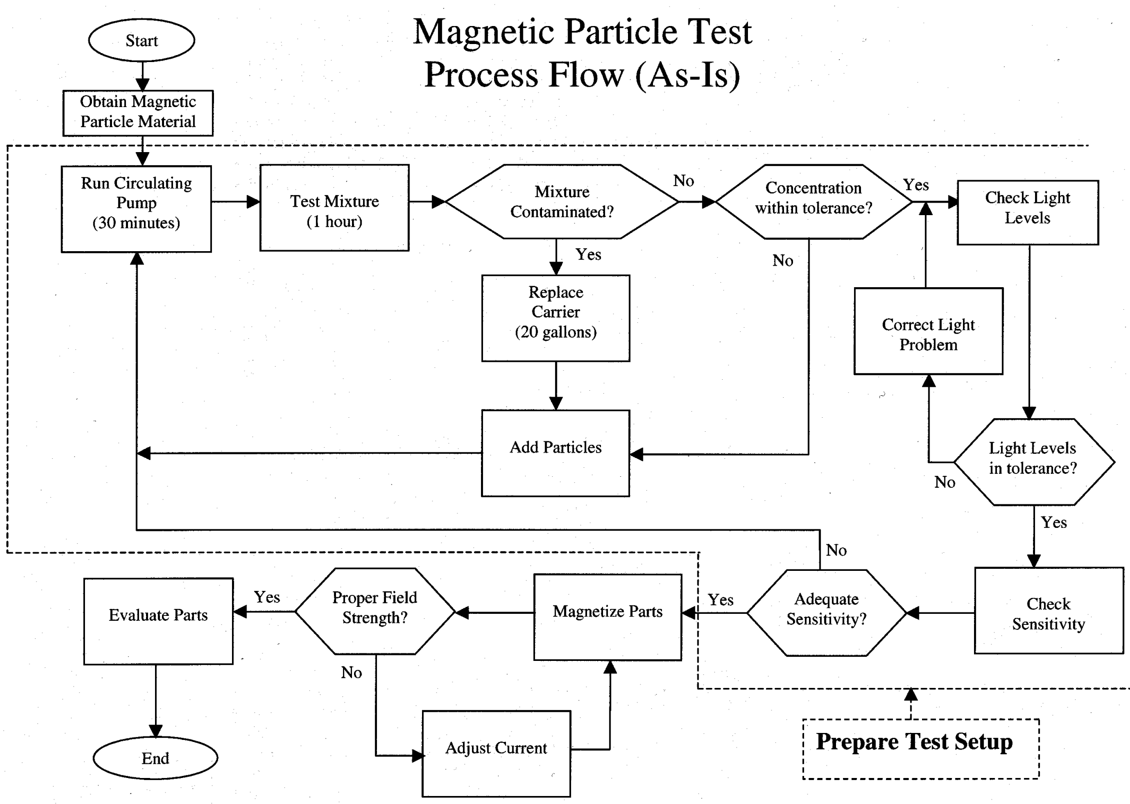
Baseline Analysis (As-is)

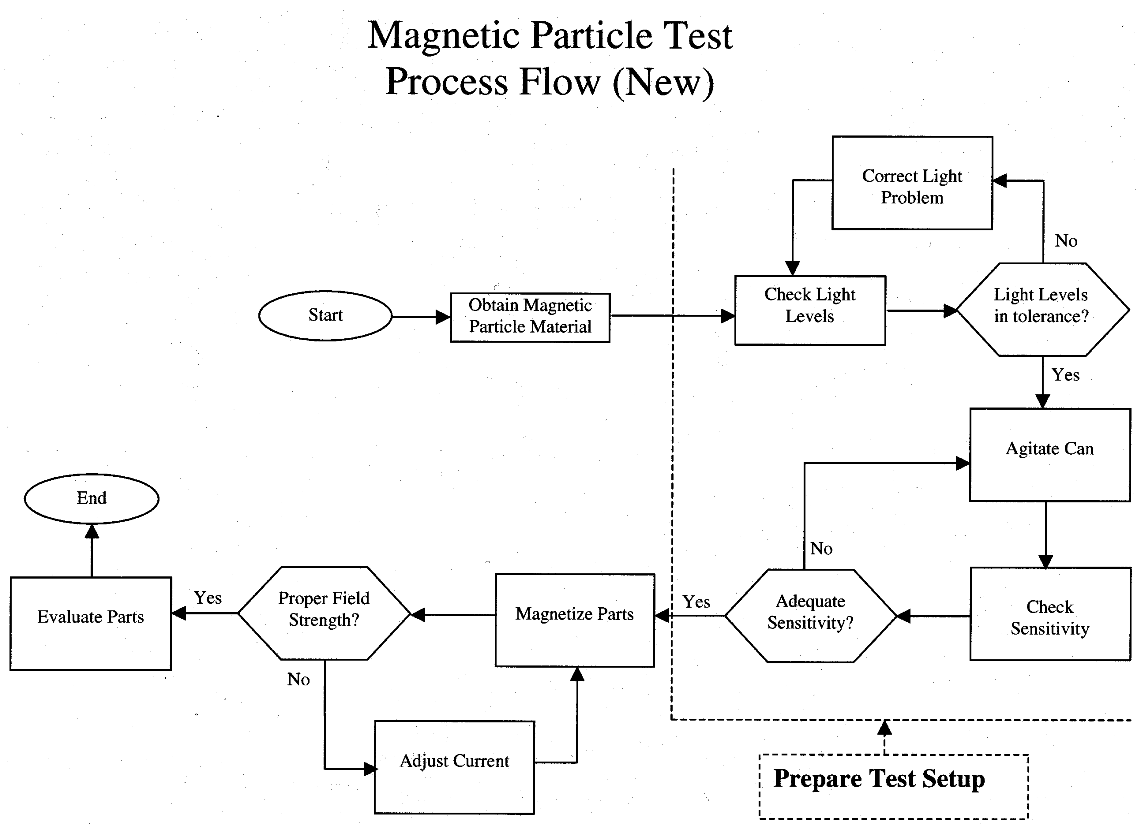


Magnetic Particle Process Map

Baseline Analysis (New)




Magnetic Particle Test
Process Flow (As-Is)
Start
Obtain Magnetic Particle Material
Run Circulating Pump (30 minutes)
Test Mixture (1 hour)
Mixture Contaminated?
No
Yes
Concentration within tolerance?
Yes
No
Check Light Levels
Replace Carrier (20 gallons)
Correct Light Problem
Add Particles
Light Levels in tolerance?
No
Yes
No
Evaluate Parts
Yes
Proper Field Strength?
Magnetize Parts
Yes
Adequate Sensitivity?
Check Sensitivity
No
Adjust Current
End
Prepare Test Setup


Magnetic Particle Test
Process Flow (New)
Correct Light Problem
No
Start
Obtain Magnetic Particle Material
Check Light Levels
Light Levels in tolerance?
Yes
Agitate Can
End
No
Evaluate Parts
Yes
Proper Field Strength?
Magnetize Parts
Yes
Adequate Sensitivity?
Check Sensitivity
No
Adjust Current
Prepare Test Setup

Magnetic Particle Testing
Failure Mode Effects Analysis (FMEA)

	Process Step or Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Plans	PS	PO	PD	PRPN
1	Prepare Test Setup	Too low of concentration	Time Delay	2	Pump not run long enough	3	Callout in PQR	5	30	Replace with spray cans		1	1	5	5
2				2	Pump failure	1	Training on operation	5	10						
3				2	Particles not manually dislodged from tank wall	4	Training on operation	5	40	Replace with spray cans		1	1	5	5
4				2	Not enough particles in tank	4	Training on operation	5	40	Replace with spray cans		1	1	1	1
5		Too high of Background	Time Delay	4	Too many particles added	4	Training on operation	5	80	Replace with spray cans		1	1	5	5
6				2	Inexperience	2	Requirement to train with certified operator and become certified	5	20						
7		Contaminated Mixture	Time Delay	5	Outside contaminant introduced in system	2	Hood and curtain around tank	5	50	Replace with spray cans		1	1	1	1
8		Incorrect Sensitivity	Possible inaccurate results	5	Too many particles added	2	Training on operation	5	50	Replace with spray cans		1	3	5	15
9				4	Too few particles added	4	Training on operation	5	80	Replace with spray cans		1	1	5	5
10				4	Inadequate training	1	Requirement to train with certified operator and become certified	5	20						
11				4	Lack of experience	1	Requirement to train with certified operator and become certified	5	20						
12				4	Incorrect machine operation	3	Training on operation	5	60						
13				4	Contamination	1	Hood and curtain around tank	5	20						
14				2	Ketos ring not properly cleaned	5	Callout in PQR	4	40						
15		Too much white light	Possible missed indications	4	Meter not calibrated	1	Training on operation	4	16						
16				4	Meter damaged	1	Training on operation	4	16						
17				4	Inadequate training	1	Requirement to train with certified operator and become certified	5	20						
18				4	Inexperience	1	Requirement to train with certified operator and become certified	5	20						
19				4	Light Curtain not closed	2	Training on operation	4	32						
20				4	Light Curtain not in good repair	3	Training on operation	3	36	Check curtain before using machine	Include in training and recertification	2	1	5	10
21		Too low of Black Light level	Possible missed indications	4	Meter not calibrated	1	Training on operation	4	16						
22				4	Meter damaged	1	Training on operation	5	20						
23				4	Inadequate training	1	Requirement to train with certified operator and become certified	5	20						
24				4	Inexperience	1	Requirement to train with certified operator and become certified	5	20						

25				4	Too high of white light level	2	Callout in PQR	5	40						
26				4	Weak blacklight bulb	2	Callout in PQR	5	40						
27	Magnetize Parts	Too low of magnetic field	Possible missed indications	2	Current setting too low	5	Specified in technique and Callout in PQR	4	40						
28				4	Improper use of pie gage	2	Training on operation	4	32						
29				4	Inadequate training	1	Requirement to train with certified operator and become certified	5	20						
30				4	Inexperience	1	Requirement to train with certified operator and become certified	5	20						
31				2	Machine failure	1	Training on operation	5	10						
32				4	Current meter not calibrated correctly	1	Training on operation	4	16						
33				4	Incorrect current called out in technique	2	Training on operation	4	32						
34		Too high of magnetic field	Possible Masked indications	2	Current setting too high	4	Specified in technique and Callout in PQR	5	40						
35				4	Improper use of pie gage	2	Training on operation	4	32						
36				4	Inadequate training	1	Requirement to train with certified operator and become certified	5	20						
37				4	Inexperience	2	Requirement to train with certified operator and become certified	5	40						
38				4	Machine failure	1	Training on operation	5	20						
39				4	Current meter not calibrated correctly	1	Training on operation	4	16						
40				4	Incorrect current called out in technique	3	Callout in PQR	4	48						
41	Evaluate Parts	Incorrect Interpretation	Incorrect Results	5	Too low of black light level	1	Training on operation	5	25						
42				5	Too high of white light level	1	Training on operation	5	25						
43				3	Improper magnification	3	Training on operation	4	36						
44				5	Inadequate training	1	Requirement to train with certified operator and become certified	5	25						
45				5	Inexperience	1	Requirement to train with certified operator and become certified	5	25						
46				5	Incorrect technique	1	Callout in PQR	4	20						
47				5	Missed indications	1	Requirement to train with certified operator and become certified	4	20						
48				5	Too much background	1	Requirement to train with certified operator and become certified	5	25						

Magnetic Particle Process ABM Analysis (As-is)

Step	Process Steps	Resources Used			Summary Cost		
		Labor (hrs)		Supplies	Labor$ (base)	Material$ (base)	Total Cost
		436S	838H				
1	Gather Materials Verify Technique with Specification	0	0.2		$4.60	$0.00	$4.60
2	Circulate Mixture Clean Palette Run Pump for 30 minutes	0	0.7		$16.10	$0.00	$16.10
3	Test the Mixture for Contamination Draw and let 100 ml sample settle for 1 hour	0	0.1		$2.30	$0.00	$2.30
4	Test the Particle Concentration If concentration is too low, add particles If concentration is too high, remove some solution and add carrier Circulate for 30 minutes Draw and let 100 ml sample settle for 1 hour	0	1	Particles and/or Carrier	$23.00	$16.95	$39.95
5	Replace Mixture if Necessary Put new mixture in machine if contaminated	4.5	3.5	Carrier and Particles	$244.08	$316.00	$560.08
6	Check Light Levels Perform Background Light Check Perform Blacklight Level Check Replace Blacklight Bulb if necessary	0	0.5	Black Light Bulb	$11.50	$100.00	$111.50
7	Check Sensitivity Setup with Ketos Ring Run Ketos Ring at 4 current levels and observe number of holes detectable If sensitivity fails, start on step 1 again Demagnetize Ketos Ring Clean Ketos Ring	0	0.5	Alcohol	$11.50	$1.00	$12.50
8	Magnetize Parts Setup using part Check magnetic field strength with pie gage Magnetize part using wet continuous method	0	0.3		$6.90	$0.00	$6.90
9	Evaluate Parts Put parts under blacklight Evaluate per test technique and specification using magnification if specified Demagnetize parts Clean parts	0	0.5		$11.50	$0.00	$11.50
	Totals	4.5	7.3		$331.48	$433.95	$765.43

Magnetic Particle Process ABM Analysis (New)

Step	Process Steps	Resources Used			Summary Cost		
		Labor (hrs)		Supplies	Labor$ (base)	Material$ (base)	Total Cost
		436S	838H				
1	Gather Materials Verify Technique with Specification Get supply of aerosol cans	4.5	0.2		$168.18	$80.00	$248.18
2	Check Light Levels Perform Background Light Check Perform Blacklight Level Check Replace Blacklight Bulb if necessary	0	0.5	Black Light Bulb	$11.50	$100.00	$111.50
3	Check Sensitivity Setup with Ketos Ring Run Ketos Ring at 4 current levels and observe number of holes detectable If sensitivity fails, agitate can for a longer period Demagnetize Ketos Ring Clean Ketos Ring	0	0.5	Alcohol	$11.50	$1.00	$12.50
4	Magnetize Parts Setup using part Check magnetic field strength with pie gage Magnetize part using wet continuous method	0	0.3		$6.90	$0.00	$6.90
5	Evaluate Parts Put parts under blacklight Evaluate per test technique and specification using magnification if specified Demagnetize parts Clean parts	0	0.5		$11.50	$0.00	$11.50
	Totals	4.5	2		$209.58	$181.00	$390.58