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(Non) Risky Business

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Thinking about and managing the risks of operating a job shop and machining parts is a straightforward process when using tools such as risk matrices and Failure Mode and Effects Analysis.

Running a machine shop and performing metalworking operations always involve safety, QC and financial risks. A coolant might cause health problems for workers or unexpected rust problems on machines. New tools might not cut as well as previous ones. A new machine tool might not provide as rapid a return on investment as expected.

While many risks are minor, every operator, inspection supervisor and shop owner experiences at least one or two that keep them up at night. They can clarify and lower these risks by using management tools such as risk matrices, Failure Mode and Effects Analysis (FMEA) and PosiTrol plans.

Simple Risk Matrix

The simplest risk management approach, one that can provide strategic insight, is the 2×2 risk matrix (Figure 1). The horizontal axis is degree of risk and the vertical axis shows the impact on the company if the risk becomes a reality. For one or more risk decisions, the user plots his best estimate of which quadrant the risk falls in. If it is a low-risk, low-impact decision, the user will probably take no significant action because even if the event happens, the impact is slight. At the other end of the scale, if the risk is relatively high and the probability of its occurring is also high, the user should take action.

The simple risk chart is a management tool for seeing the "big picture." Rankings are clearly subjective but provide an important initial risk examination. Impact can be charted in cost, percentage of rejected parts, number of accidents or other values.

Most users plot the risks first in general terms; then, if more detailed insight is needed, more specific values are plotted. This big picture takes little time to prepare because it does not require data.

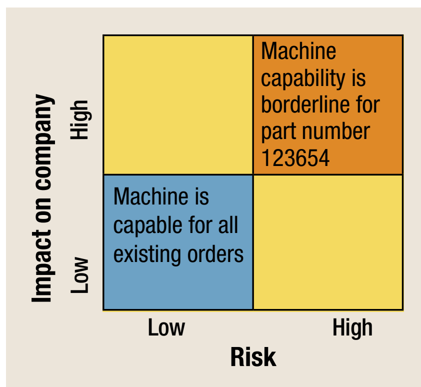


Figure 1: A simple 2×2 risk matrix provides a visual tool for clarifying risks.

It also documents that the user assessed the risks.

By preparing a simple risk matrix, a user begins to ask a key question: "What kinds of risk do I believe might be real?" As a result, the user makes a list of things he considers risks, and then collects data. This begins the risk assessment process. The shop owner who wants or needs a new 8-axis machine tool will list concerns such as: “Will it take the heavy cuts I need without wearing out over the 7 years I have to pay for it? Can I find and keep operators who can program this 8-axis machine? How much can I trust the builder to diagnose machine problems over the phone because my staff cannot troubleshoot and I cannot afford major downtime?”

An engineer considering the purchase of a multiaxis EDM to cut heavy parts unattended to close tolerances and fine surface finishes must consider the potential for customer rejection of a new surface appearance. He also might ask: “Can the proposed run time work for 0.003"-dia. brass wire instead of the 0.005" wire typically used on this new machine? Can my operators handle the fine wire without it becoming a bird’s nest? Can both Joe and Tom operate a new machine like this?” Some of these questions can clearly be answered before a machine is purchased, but others will not become obvious until the machine is used in production.

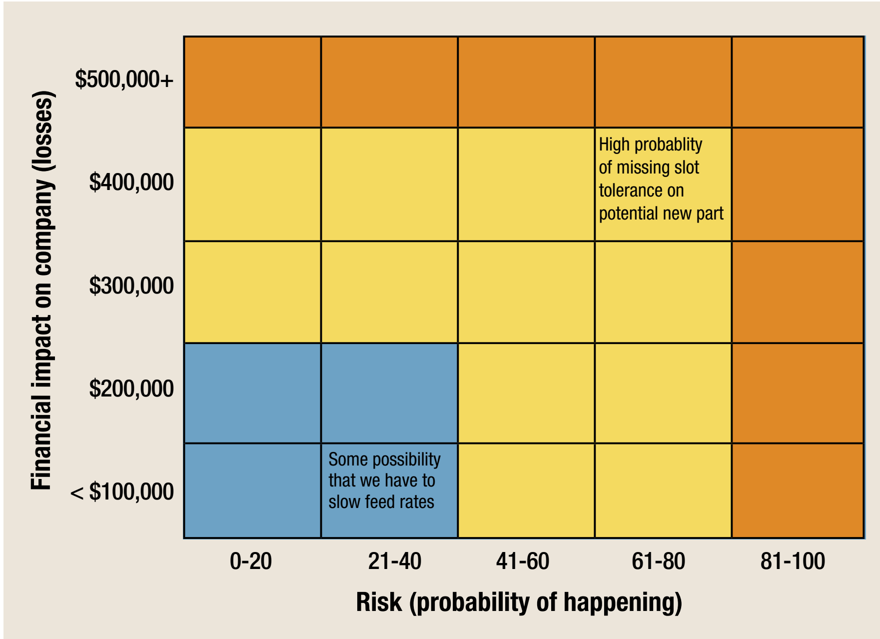


Figure 2: A more detailed risk matrix.

Another more involved approach is to use a larger matrix (Figure 2). The two axes are the same as in Figure 1, but the matrix provides more risk

Original FMEA before machine order

Step No.	Function	Potential failure modes	Potential failure effects	SEV	Potential causes of failure	OCC	Possible solutions	DET	RPN
1									
2	Install machine	Installation takes 5 weeks or more	Slows delivery of existing big order	6	Manufacturer does not meet his commitment	6	None	6	216
3				6	We are not ready when machine arrives	4	Tom is coordinating	3	
4	Operate machine	Operators cannot run machine	Cannot meet delivery schedule	8	Operators not capable of thinking in 8-axis logic	6	Have four operators who likely can run machine	3	144
5		Cannot find other operators in city	Cannot meet delivery schedule	6	Shortage of machinists	8	None	4	192
6			Cannot grow business	7	Shortage of machinists	8	None	4	224
7		No capable CNC programmer in-house	Cannot grow business	7	Shortage of 8-axis capable programmers	6	Order first program with machine order	2	84
8	Keep machine operational	Seller fails to provide timely machine repair	Slows delivery of orders	5	Seller staff overloaded	5	None	8	200
9				5	Seller staff not capable of some timely repairs (knowledge)	4	None	8	160
10	Keep machine loaded with work	Work not coming in as expected	Machine payback needs not met	8	Local companies not familiar with our machine abilities	4	Order book tells load/ open house planned for local community	2	64
11			Machine payback needs not met	8	No out of town companies know about us	5	Order book tells load/ open house planned for local community	4	160
12			Machine payback needs not met	8	Only have medium-size runs—need longer runs	5	None	6	240
13			Machine payback needs not met	8	Major order cancelled	5	None	9	360

Figure 3: Original FMEA of risks for purchasing an 8-axis machine tool.

discrimination. Both of these approaches take someone's "gut feel" about risk and display it so others can evaluate it. A risk matrix helps communicate ideas and generate additional questions.

Using FMEA

FMEA is one of the most common approaches to analyzing and preventing risk. Typically used to prevent certain risks from happening, it is part of many safety procedures, new product introductions, problem solving and quality improvement processes. It is one of the Six Sigma approaches to quality and is widely used by large companies to prevent and solve problems.

Figure 3 is a typical FMEA format. Only a few considerations are shown here; users will likely think of many more. It typically takes more than one page to capture all the considerations that can reduce risk to an acceptable level.

In this example, the owner believes his job shop would benefit from purchasing an 8-axis machining center and using it for medium-volume part runs. The machine tool requires CNC programs prepared by a capable programmer as well as machinists who can envision how the cutting tools will interact when one or more settings are changed. That is a challenging assignment considering that front, back and side tool turrets must work together and some part dimensions are functions of other dimensions.

> *In the FMEA, the likelihood of using an undersized tool was rated at six and the ability to accurately detect it using the shop's typical practice for sourcing endmills is less than 50 percent, so it is rated at six.*

The intent is to reduce risk before ordering the machine. The owner has done some investigation, but is still bothered by four issues (called "functions" in Figure 3).

The shop will be loaded with work during the intended installation, and if installation is delayed by more than 2 days, some orders will not be finished on time due to congestion and downtime. Rumors indicate that the seller has not always completed installation as required. The shop has no control over the seller's ability to install the machine correctly and on time.

The owner judges the severity (SEV) of installation delays to be a six on a one-to-10 scale, with one being low severity. He judges the likelihood of a significant delay occurring (OCC) to be a six. With no way to control delays, he rates his ability to detect (DET) a problem ahead of time, with one being high ability and 10 being no ability, as a six. When the severity (6) is multiplied by the likelihood of occurrence (6) and the result is multiplied by the ability to detect it before it happens (6), the Risk Priority Number (RPN) is 216.

The owner lists the issues he can foresee that might delay installation and makes his best estimate of SEV, OCC and DET for each. A high number for SEV and OCC indicates significant impact.

keyword

QA, QUALITY ASSURANCE; QC, QUALITY CONTROL: Terms denoting a formal program for monitoring product quality. The denotations are the same, but QC typically connotes a more traditional postmachining inspection system, while QA implies a more comprehensive approach, with emphasis on "total quality," broad quality principles, statistical process control and other statistical methods.

—CTE Metalworking Glossary

In this example, the owner is using FMEA to forecast problem areas. FMEA can also be used to solve technical problems after they have occurred. As seen here, the RPN values vary from 64 to 360. The 360 value represents the largest potential impact on the shop, so that is the first place the owner should begin searching for ways to reduce risk. He should begin by discussing with his staff ways to prevent loss of major orders.

After developing solutions for preventing order loss, the owner should work on getting longer runs. Many automotive parts manufacturers use 8-axis machines that, like screw machines, produce the same part for an entire year. Long orders reduce the need for programmers and ensure that the machine is always fully loaded.

Note that for line 13, the biggest cause of the high-risk number is the inability to detect ahead of time that orders will be canceled. That risk can be reduced with contracts requiring advance notice of cancellation or penalty payments when they do happen. With those clauses in place, SEV and DET ratings are lowered, and the RPN falls to a much lower number. The owner will modify the FMEA to reflect the new values and continue doing so until he is satisfied that the risk levels are low enough to proceed, or he decides that they are too high to proceed. Reducing risk is the real purpose of an FMEA.

Figure 4 describes the application of FMEA to a partmaking process. In this instance, the workpiece material is expensive and hard to obtain. The company has some experience with it but is concerned about a narrow slot that requires endmilling. The part has a tight tolerance and is at the outer limits of the shop's capabilities. As he estimates the cost and considers how the shop would make the part, the shop manager populates the FMEA with these two major concerns. He then asks the staff to review the results and discuss preventive actions.

Endmilling 0.010"-wide slots is challenging in any material. A limited num-

Initial FMEA

Step No.	Function	Potential failure modes	Potential failure effects	SEV	Potential causes of failure	OCC	Possible solutions	DET	RPN
1	Maintain 0.010"-wide slot requirements	0.0002" width over high limit (OHL)	Mating part too loose	10	Endmill deflection	5	Operator feed rate	6	300
2				10	Endmill deflection	5	Operator axial DOC too deep per pass. Change DOC	1	50
3				10	Wrong endmill	3	Tool stocker bin placement	5	150
4				10	Part material movement	2	None	8	160
5		0.0002" width under low limit (ULL)	Mating part will not fit	10	Wrong endmill	5	Tool stocker bin placement	5	250
6				10	Endmill ULL	6	Receiving tool inspection	6	360
7	Maintain 32µin. R_a finish on walls	Roughness exceeded	Not known but customer will reject	8	Chip caught under teeth	7	None	10	560
8				8	Feed too fast	5	Operator feed rate	6	240
9				8	Material hard spots	2	Lot sample hardness	8	128

Figure 4: Initial FMEA for part with a small slot that requires endmilling.

ber of companies make the required cutting tools, which can easily deflect and break. Cutters from one supplier can cut differently than cutters from another. To make matters worse, the roughness specification and the tolerance limit create two conflicting limitations. In this instance, a 32µin. R_a finish and a 0.0002" width tolerance probably mean that the finish needs to be better than 32µin. R_a to hold the tolerance. Slower feeds or smaller DOCs to impart finer finishes cause other machining problems on some materials.

In this shop, machine operators are allowed to override programmed feed rates if they think they can improve productivity or cutter life or solve operating problems. Also, a stocker typically places tools in bins without inspecting them. One part per lot is typically measured for hardness during incoming material inspection.

However, in milling the part with the small slot, one of the biggest problems is the potential for applying an undersized cutter. Because the slot tolerance is tight, the cutter-width tolerance must be held even tighter. Traditional tool inspection using micrometers is not adequate. In the FMEA, the likelihood of using an undersized tool was rated at six and the ability to accurately detect it using the shop's typical practice for sourcing endmills is less than 50 percent, so it is rated at six. The shop manager knows of some solutions to several of these issues, but he discovers that the biggest risk in the process is having a chip caught under a cutter tooth, which leaves a long out-of-spec area on the finished part. An inspector cannot see into a 0.010"-wide

Revised FMEA

Step No.	Function	Potential failure modes	Potential failure effects	SEV	Potential causes of failure	OCC	Possible solutions	DET	RPN
1	Maintain 0.010"-wide slot requirements	0.0002" width over high limit (OHL)	Mating part too loose	10	Endmill deflection	5	Operator feed rate override locked out on tape	1	50
2				10	Endmill deflection	5	Operator axial DOC too deep per pass. Change DOC	1	50
3				10	Endmill deflection	5	Receiving tool inspection marks tool ID on shank	1	50
4				10	Wrong endmill	3	Endmill work instructions specify to check marking on endmill	1	30
5				10	Part material movement	2	None	8	160
6		0.0002" width under low limit (ULL)	Mating part will not fit	10	Wrong endmill	5	Receiving tool inspection marks tool ID on shank	1	50
7				10	Wrong endmill	3	Endmill work instructions specify to check marking on endmill	1	30
8				10	Endmill ULL	6	Receiving tool inspection instructions requires super micrometer	2	120
9	Maintain 32µin. R_a finish on walls	Roughness exceeded	Not known but customer will reject	8	Chip caught under teeth	7	Use high-pressure coolant	4	224
10				8	Feed too fast	5	Operator feed rate override locked out on CNC program	1	40
11				8	Material hardspots	2	Sample hardness three places on every part	4	64

Figure 5: Final FMEA for part with a small slot shows solutions that limit risk.

slot or insert a traditional measuring tool, so surface finish has a high DET value. That is a more difficult problem to solve.

Figure 5 shows the lead man's solutions, including locking out operator feed rate changes, having the tool inspector use a super micrometer and mark the tool's ID on the shank, having operators check the marking on endmills, sampling hardness in three places on every part and using high-pressure coolant. While there are still issues, the risks are reduced by his selected items. Most of the preventive measures are simple shop controls.

For example, high-pressure coolant does not eliminate all chips under the cutter's teeth, but appropriate endmill fluting helps resolve this issue. Having places for chips to easily evacuate also helps.

If these measures are insufficient, the shop may need to employ miniature, rotating EDM electrodes. That requires a special EDM that most shops do not have. Sourcing the slot to another shop may be the best solution. A revised FMEA would show this as a solution.

Webco reviews a PFMEA template, which shows each work center's potential failures against the new part's requirements. New needs are added to the existing PFMEA, so the document becomes a living guide to the issues Webco has addressed for all parts.

FMEA Requirements

Michael Miller, quality manager for Webco Manufacturing Inc., Olathe, Kan., a trucking and construction equipment supplier, said its customers require Webco to use a process FMEA (PFMEA) to identify potential problems before it begins making a product.

Webco reviews a PFMEA template, which shows each work center's potential failures against the new part's requirements. New needs are added to the existing PFMEA, so the document becomes a living guide to the issues Webco has addressed for all parts. The company revises the PFMEA every quarter to add any new problems. Problems are fixed as soon as they occur, and Webco then turns to the PFMEA to address new issues.

For example, Webco addresses questions such as, "What can go wrong with our welding of heavy plate fabrications?" Some of the answers include, "The operator can use the wrong machine settings; they can put a part on wrong (wrong position); or they can put the wrong part on."

The PFMEA then describes actions needed to prevent that problem on any part or specific parts as needed. When the PFMEA review and control

Page: 1 of 1	**PosiTrol Plan**		Plan Date:	Nov. 11, 2006
Part No.	321456-103		Rev. Date:	
Process	Slot milling	**Machine**	Hurco 350	**FMEA?:** Yes
Control	**Variables to control to reduce risk/Control quality**			
	Variable #1	Variable #2	Variable #3	Variable #4
What	Feed rate	Tool sharpness	Radial depth	Endmill configuration
How	CNC program and operator feed rate override locked out	Change tool frequently and log changeouts	Use finish pass of 0.0005"	1) Limit to Richards Micro Tool Co. Tool No. 879-0031 on work instructions 2) Add "no substitutes" on tool requisition
Who	Machining center operator	Machining center operator	Machining center operator	1) Manufacturing engineer 2) Manufacturing engineer
When	First part onward	Every 30 minutes	At program prep time	Release of initial work instruction and tool requirements
Use SPC?	No	Yes	No	No
SPC type		Run chart of machine minutes between changes		
PosiTrol owner	Tim Miller			

Figure 6: PosiTrol plan to control cutter runout of endmilled slot on part No. 321456-103.

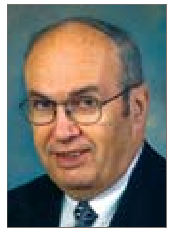
plans are finished, Webco writes its shop routing.

The PosiTrol Plan

Part of the FMEA process involves controlling all identified risks. The FMEA sheet provides the general solution, which the user implements in more detail. One of the most useful approaches to defining risk controls is the PosiTrol plan, first developed and published by Mario Perez-Wilson as part of his 1989 "Machine/Process Capability Study." It is designed to prompt specific actions to prevent a quality (or risk) attribute from exceeding acceptable limits. It uses a chart to define "who, what, how and when" for every issue (Figure 6). This chart is generally used by machinists, but risk issues can involve other shop personnel as well. The listed actions are placed in work instructions, programmed in the CNC and put on an order request for purchased endmills. An SPC chart is prepared and added to the work instructions.

Managing risk is critical to every business. We all manage risk every day, even if we are not aware of it. Formalizing the process using easy-to-use spreadsheets can go a long way toward identifying serious risks. At the very least, this process will prompt discussion about how to handle perceived risks, and at best the process will clarify and lower risks to key processes and business plans. CTE

Editor's Note: The author would appreciate hearing of other approaches that readers use for risk assessment. Several examples of FMEA applications can be found on the Internet, and there are several books that provide more detail. Scoring sheets in the examples used in this article were all easily prepared on Excel spreadsheets.



About the Author: *Dr. LaRoux K. Gillespie has a 40-year history with precision part production as an engineer and manager. He is the author of 11 books on deburring and 200 technical reports and articles on precision machining. He can be e-mailed at laroux1@myvine.com.*