Build a Usable Process Capability Database

A DATABASE OF THE RIGHT INFORMATION CAN HELP COMPANIES IMPROVE PRODUCT DESIGN.

By Anna Thornton, Analytics Operations Engineering Inc.

A basic tenet of design for Six Sigma is that designs must meet customer needs while being produced with high quality. A broad set of tools to support this goal, from quality function deployment to statistical process control (SPC) to robust design, have been developed over the past 40 years. The goal of these tools is to design a high quality product that is capable of being consistently manufactured. Unfortunately, the study of manufacturing and product development over the last 10 years has overlooked one key to achieving Six Sigma design: a systematic understanding of the expected variation introduced by processes across the organization.

Process capability data is critical to developing Six Sigma designs because product development teams need to design products that can be produced at a reasonable cost on existing equipment. Using process capability data is theoretically straightforward. Six Sigma, total quality management and variation reduction practices have generated reams of process capability data through capability studies and ongoing SPC and quality control activities. A company should be able to put these data sets into a database so the product development team can use the data to set tolerances, validate the tolerances, identify process improvement needs and track capability.

Unfortunately, the work involved in setting up and using a process capability database is often poorly understood and results in a database that is rarely used because insufficient thought is put into its design, implementation and support. To create a successful process capability database, the implementation team must:

- Get the right management support.
- Create the right data structure.
- Collect the right data.
- Use the data correctly.

Get the Right Management Support

It is important for management to allocate the necessary resources for planning, implementation, testing and ongoing support and then track and reward the use of the process capability data in product development. To understand both the costs and benefits of implementing a process capability database, management needs to learn the importance and value of using process capability to design more manufacturable products and the challenges involved in implementing such a system.

Organizations that underestimate the resources required to do the job right end up with unusable databases. Other organizations have well-designed databases that are not used because management does not emphasize the database's key role in the product development process.

Figure 1. **Sample Record**

Material	Stock	Process	Feature	Dimension	Lower limit	Upper limit	Machine	Operator number	Batch size	Mean	Standard deviation
2.2.3	3	2.2.1	2.1	2	-0.01	0.01	6A345	23451	20	2.002	0.004

Create the Right Data Structure

Organizations frequently fail to structure process capability databases so the right data can be found quickly by product development teams.

Designers usually know the part's specific feature type and dimension (the diameter of a hole), the material they will be using and a proposed manufacturing process (milling or hand drilling). They also frequently know the value of the dimension and the tolerance. But this is not how the way the data are typically recorded.

Process capability data are typically generated in association with a part number. Unless a designer is familiar with every available part, using part numbers to find the relevant capability data can be difficult. When collecting the process capability data, additional information (called descriptors) needs to be added to the data to enable the product team to intuitively access the data.

Process capability data are collected in a run, which consists of a collection of measurements on a batch of parts. The data in the run can be analyzed to determine the run's mean and standard deviation. Each run should have an associated descriptor that describes the relevant characteristics of the parts and processes that might influence the process capability. Descriptors typically include an index, and variable and attribute descriptors. Figure 1 shows an example of a record with a mean and standard deviation.

The index provides a structured method for describing the types of features a designer is interested in. For example, in machined parts, the designer may know the features, stock, materials and processes. (See Figure 2, p. 34, for an example of a typical indexing structure for machined parts.) Feature describes the geometry being created; material describes the material (chemical makeup and preprocessing); process describes the manufacturing process used to produce the feature; and stock describes the initial form of the material. The index may be different for other manufacturing technologies, such as gears.

Variable descriptors contain quantifiable information about the source of the process capability data, including the actual dimension of the feature and its allowable tolerance. For example, a hole diameter is 4.25 inches +/- 0.01. The batch size and machine settings such as feeds and speeds can also be considered variable descriptors.

Attribute descriptors contain information that can be enumerated, such as machine type, operator's name and manufacturing location. This information should be standardized before inclusion in the descriptors to ensure consistent encoding.

Organizations need to avoid several common pitfalls when creating the data structure. The most common is trying to create a one size fits all indexing scheme for the entire organization. One company we interviewed included assembly, composite, machining and injection molding in one indexing scheme. The result was millions of possible combinations of indexes, only a handful of which were valid.

Ideally, process capability databases should be partitioned so there is little or no overlap of the data between databases. One automotive organization, for example, divided its process capability into three separate systems with separate indexing schemes: prismatic (machined on milling machines), cylindrical (machined on lathes) and gears. It was unlikely the data on the gear machining could be used to validate the machining of an engine block.

Collect the Right Data

No matter how good a data structure is, if it is not populated with appropriate and usable data, the database will be useless. A number of tasks are involved in ensuring the process capability data in the database is complete and usable.

The first task is to select the data updating approach. Today, most organizations manufacture at multiple sites and in multiple companies. This design anywhere/build anywhere philosophy makes it difficult to understand a company's true capability. When designing a database for such a scenario it is tempting to try a real-time database that can access the current capability at any location as the parts come off the line, but this approach creates a data quality and IT nightmare. The logistics in combining multiple legacy databases while ensuring high quality data turns this into a monumental task.

Instead, many companies opt for a metadatabase where the capability data are regularly collected, cleaned and uploaded to a central location. While the data may be six months old, most machine capability will not change sufficiently in that timeframe to justify the headaches involved in implementing in a real-time system.

The second step is to choose what data to include. The implementation team should take a data inventory at all manufacturing sites to determine the process capability data that is available, its quality and how it is indexed. When choosing the data to include, the team should follow this simple guideline: If the data are not likely to be used in future products or cannot be used by a design team, don't include them. For example, a factory may keep an SPC chart on temperature because controlling temperature is critical to controlling quality. However, variability in the resultant dimension, not temperature, would be what's of interest to design.

The implementation team should then compare the available data to the index structure to determine the unpopulated areas of the database. Critical holes may need to be filled through capability studies.

Once the data are collected, the team must clean them. Errors in keying and special cause variation as well as errors in indexing need to be fixed before the data are uploaded. The team also needs to ensure the data are in statistical control. Otherwise, the results could be skewed by special causes of variation.

Finally, the team needs to plan to enhance the database and determine how to keep the capability information up to date.

Figure 2. **Sample Index Structure**

Material
- 1.0 Thermoplastic
  - 1.1 ABS polymer
  - 1.2 Acetal
  - 1.3 Acrylic
  - 1.4 Elastomer, TPE
  - 1.5 Ethylene vinyl acetate
  - 1.6 Nylon
  - 1.7 Polycarbonate
  - 1.8 Polyester, TP
  - 1.9 Polyethylene
- 2.0 Metals
  - 2.1 Steel
    - 2.1.1 Stainless
    - 2.1.2 Low alloy
    - 2.1.3 Carbon
    - 2.1.4 Tool
  - 2.2 Iron
    - 2.2.1 Alloy cast
    - 2.2.2 Ductile
    - 2.2.3 Gray cast
    - 2.2.4 Malleable
    - 2.2.5 White cast
  - 2.3 Aluminum
  - 2.4 Copper alloy
  - 2.5 Titanium

Process
- 1.0 Thermoplastic molding
  - 1.1 Injection
  - 1.2 Extrusion
  - 1.3 Thermoform
  - 1.4 Roller
  - 1.5 Transfer
  - 1.6 Compression
  - 1.7 Vacuum
  - 1.8 Dipped
  - 1.9 Pressure
  - 1.10 Rubber
- 2.0 Machining
  - 2.1 Boring
  - 2.2 Milling
    - 2.2.1 End of cutter
    - 2.2.2 Side of cutter
    - 2.2.3 Kellering
  - 2.3 Sawing
  - 2.4 Shearing
  - 2.5 Turning
- 3.0 Forming
  - 3.1 Stretch
  - 3.2 Brake
  - 3.3 Rolling
  - 3.4 Swagging

Stock
- 1.0 Angle
- 2.0 Bar
  - 2.1 Flat
  - 2.2 Hex
  - 2.3 Round
  - 2.4 Square
- 3.0 Casting
- 4.0 Coil
- 5.0 Extrusion
- 6.0 Pellets
- 7.0 Plate
- 8.0 Strip
- 9.0 Tube
  - 9.1 Round
  - 9.2 Square
  - 9.3 Rectangle

Feature
- 1.0 Chamfer
  - 1.1 Angle
  - 1.2 Depth
- 2.0 Hole
  - 3.1 Depth
  - 3.2 Diameter
- 3.0 Open profile
  - 3.1 Contour
  - 3.2 Position
- 4.0 Pocket
  - 4.1 Length
  - 4.2 Depth
  - 4.3 Width
  - 4.4 Position
- 5.0 Rib
  - 5.1 Height
  - 5.2 Depth
  - 5.3 Position
  - 5.4 Thickness

Use the Data Correctly

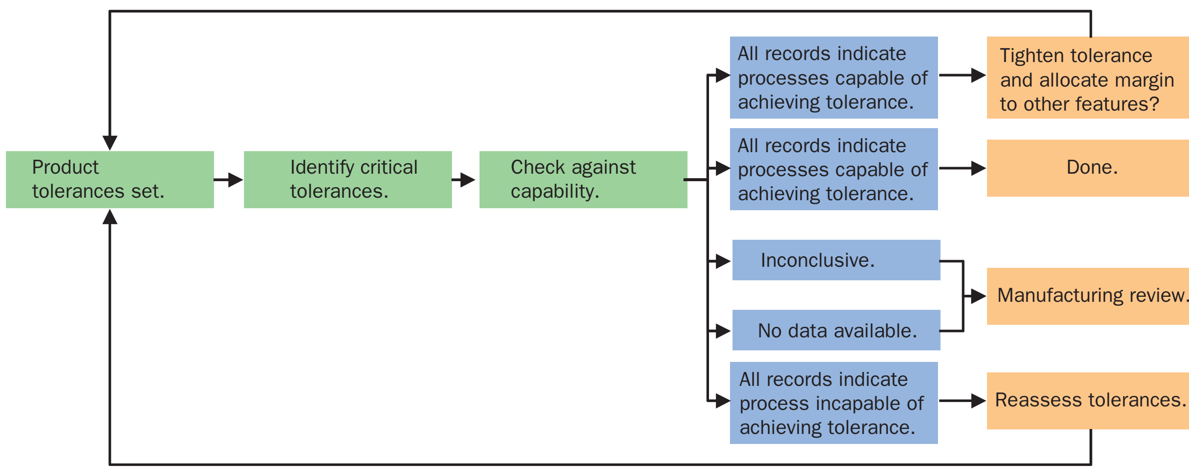
Once the process capability database has been designed and populated, it is necessary to ensure it will be used. There are two ways the database can be used during design:

1. Reactively to validate tolerances.
2. Proactively to set tolerances.

Figure 3 shows how the database is used within the product development process. First the important tolerances should be identified. There can be hundreds of tolerances on a part, but only a fraction of them are truly critical to the product's function and cost. Once the critical tolerances have been determined, the database can be queried with one of four results:

1. **All records indicate the process is capable.** Because

Figure 3. **Use of Process Capability Data**



the same feature, material and process combination has been produced multiple times, the database will likely return multiple records. If all the records indicate the process is capable, then the product development team can consider the tolerance validated.

2. **All records indicate the process is too capable.** If the process has a $C_{pk} > 2$, the product development team should consider tightening the tolerance and allocating the extra margin to another feature in the tolerance chain that has a lower C_{pk}.
3. **All records indicate the process is incapable.** If all the records returned indicate the feature cannot be produced at the appropriate quality and have a $C_{pk} < 1$, the product development team will need to reevaluate the tolerance or the processes used to produce it.
4. **Inconclusive response, or no records returned.** If the records come back with some processes capable and some incapable, or if the index is not populated, manufacturing experts should be consulted to provide the capability.

The fourth scenario is critical to keep in mind. The process capability database will not replace manufacturing or process engineering, so this functional group still needs to be involved in the product development process. However, the database will allow the product development team to focus its efforts on only those tolerances in which the capability is unclear or in which function or cost improvements can be achieved, allowing the skills and expertise of the manufacturing and process engineering functions to be better applied.

Teams should also remember past performance does not guarantee future performance. The data in the database represent surrogate data, and small changes in part geometry or processing can have a dramatic impact on capability. Understanding the differences between new parts and parts produced in the past is critical to avoiding quality issues in production. The validation of critical tolerances should be reviewed by a process engineer.

Design teams have a wonderful opportunity to improve future designs if their companies define and use databases that document manufacturing experience. A correctly developed process capability database can be intuitive and beneficial in achieving Six Sigma designs. But as with any well-designed product, the returns are often proportional to the effort invested.

BIBLIOGRAPHY

Braha, Dan, *Data Mining for Design and Manufacturing: Methods and Applications*, Kluwer Academic Publishers, 2001, pp. 505-518.

Kern, Daniel, "Forecasting Manufacturing Variation Using Historical Process Capability Data: Applications for Random Assembly, Selective Assembly and Serial Processing," Ph.D. thesis, MIT, 2003.

Kern, Daniel, and Anna Thornton, "Structured Indexing of Process Capability Data," Computers and Information in Engineering Conference, Montreal, 2002.

Tata, Melissa, and Anna Thornton, "Process Capability Usage in Industry: Myth vs. Reality," Design for Manufacturing Conference, Las Vegas, 1999.

Thornton, Anna, *Variation Risk Management*, John Wiley and Sons, 2003.

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