Q-DAS GmbH | Stephan Sprink| October 2014

User-specific and Task-related Data Analysis and Presentation of Results

Companies amass a huge amount of data as a basis for process evaluation and any associated process improvement. These data include measurement and test data, process parameter values and other types of information generated in production and in measurement and test processes. Depending on their tasks and responsibilities in a company, the respective users want to gather different kinds of information from the same data pool. These different kinds of information shall support employees in their daily work, e.g. in documenting processes and in taking specific corrective action based on this process documentation.

Basis for a Correct Analysis of Data

The correct calculation of desired statistics and their presentation in graphics provide the basis for each data analysis. Especially the presentation of results has to meet various requirements depending on the tasks and responsibilities of the company's respective employee. Q-DAS software products define these crucial specifications in the evaluation strategy, a kind of pattern determining how to calculate statistics and defining process requirements (meets / conditionally meets / does not meet decision criterion). In addition to individual company-specific specifications, users may select common standards, company guidelines and standards of technical associations integrated into the software. Graphics help to present the calculated statistics in a way that users are immediately able to identify any crucial process information.

You have to apply specific filter and selection criteria to any data derived from a comprehensive data pool in order to analyze these data statistically. Before defining a project, it is crucial to clearly determine any descriptive header data and additional information that shall be stored together with the measured value, process parameter value and test data. In general, the more descriptive information you store together with the actual measured value, the more flexible any subsequent data analysis based on filter and selection criteria will become. However, the other side of the coin is that you have to monitor, process and provide the growing amount of data permanently. The AQDEF data format (Advanced Quality Data Exchange Format) by Q-DAS is a recommended standard established by a work group including members of different companies from various industries. This format guides you through the process of defining a suitable data basis for the analysis of data. The AQDEF format reflects many years of experience gained by all the companies involved.

The Same Data from Different Perspectives

The following article illustrates how to get the different kinds of information you need from the same data pool by using Q-DAS products and how to apply them to evaluate and improve processes. We use two different approaches in this example. The first data analysis focuses on the different types of parts and the second approach examines how production (processes) is (are) organized.

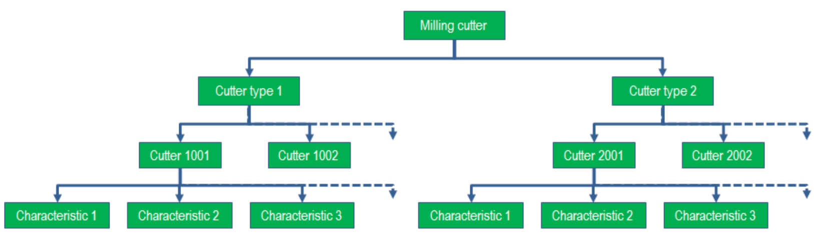

Figure 1: Part type structure

A milling cutter serves as an example. Two different types of this milling cutter are produced (cutter type 1 and cutter type 2). There are “x” individual versions of each type of cutter available; they vary e.g. in hole depth or width/depth of slot. A number clearly identifies the different cutter versions. The characteristics and specifications of each specific milling cutter depend on the respective type of cutter. Obviously, this approach represents the structure of products and thus refers to the parts to be produced.

In order to produce these milling cutters, the cutters are processed in different operations of the manufacturing process.

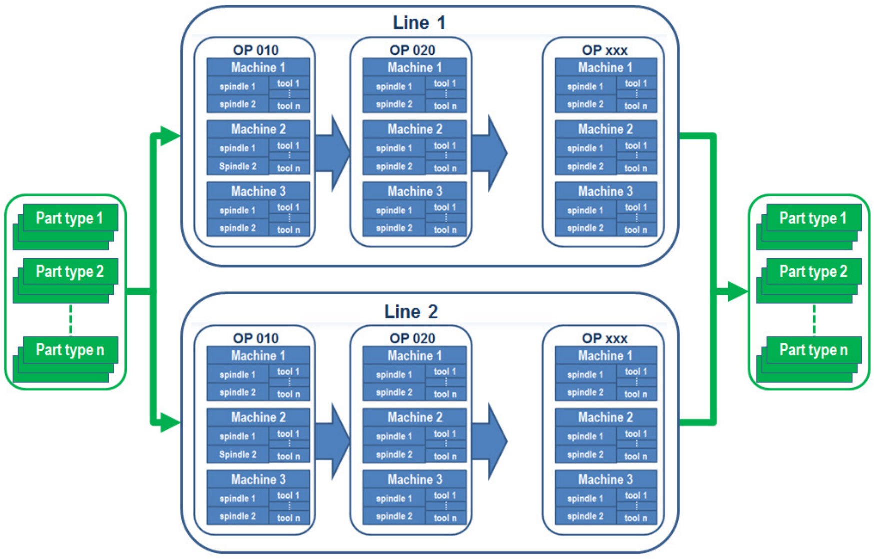

Figure 2: How the different part types run through the manufacturing process

There are two parallel production lines in the manufacturing process, i.e. similar part types either run through production line 1 or line 2. Each line includes a series of consecutive operations (operation 010 … operation xxx). In each operation, one of several identical machines (machine 1 …) produce the respective parts (depending on the respective capacity). Each machine has got two different spindles and the required tools (tool 1 … tool n) to produce the characteristics. Every time an operation is completed, samples are taken at regular intervals and the parts are measured.

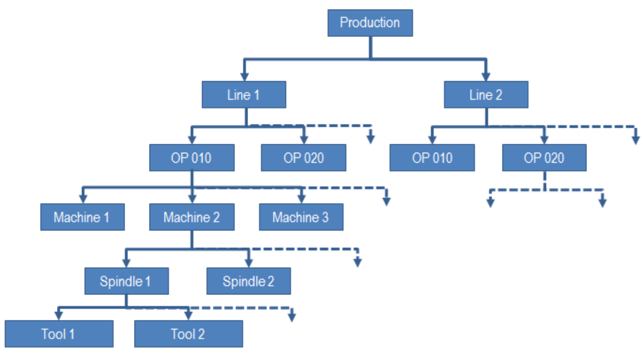

Figure 3: Structure of how the manufacturing process is organized

The way the different elements of the manufacturing process are organized leads to a high variety with respect to how a part runs through the manufacturing process (which way it takes).

Combining the Part Type Structure and the Structure of the Manufacturing Process

The next task is to combine these two structures (part types and the way the production is organized). Which part types might run through which line / operation / machine and which spindle / tool is used to produce them? We quickly obtain a complex tree structure underlining the high variety once again.

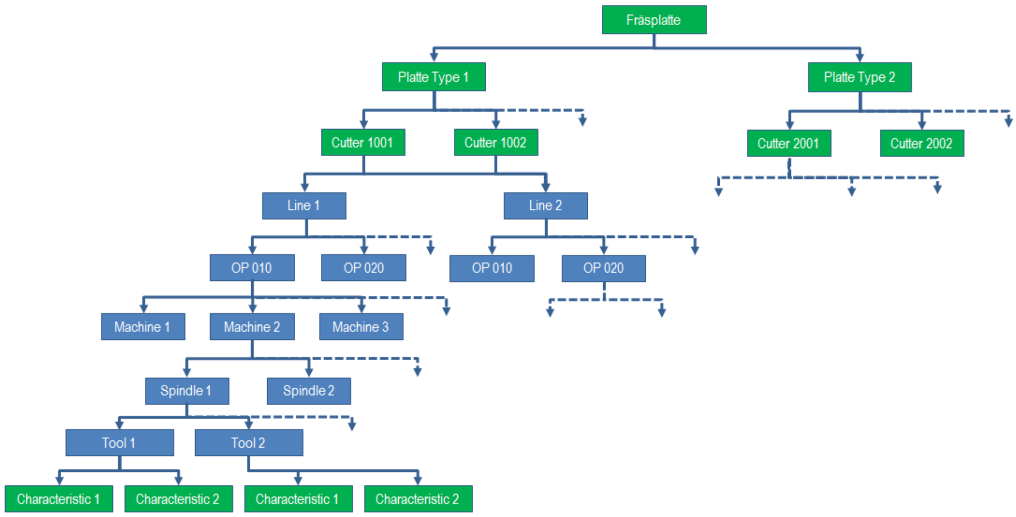

Figure 4: Part type structure and manufacturing process structure combined

Every aspect referring to the part is displayed in green whereas all the elements presenting the structure of the manufacturing process are shown in blue.

In case you want to analyze the data later, you have to be able to select the desired data based on the single elements of this structure. Relating to figure 4, this would be a top-down analysis (vertical view) of all data of a certain cutter type irrespective of its line, operation and machine (line 1 or line 2, machine 1, 2 or 3 of an operation, etc.). Only if the consolidated result of the highest level of data compression deviates from the demanded specification, you must analyze the data of the subjacent levels. As an example, you might find out that machine 2 of operation 020 causes problems.

The same options for data analysis must be available for a horizontal view of the collected information. This is rather the perspective relevant to employees responsible for the manufacturing process. Depending on their tasks and responsibilities, they want to know how the machines of their operation are working irrespective of the cutter type they produce. These employees often use an evaluation / presentation of results that does not focus on any specific cutter type. The option to get additional more detailed analyses (spindle, tool ...) must be available, too.

A vertical and horizontal view should be provided, i.e. you have to add additional information to the measured data in order to perform all required evaluations. As mentioned before, the AQDEF format forms a good basis for applying K-fields (information carriers in this data format) in a reasonable way.

Examples of Evaluation Options

The following screenshots show the different evaluation options described above and illustrate the presentation of results depending of the respective point of view (part type structure or structure of the manufacturing process). Of course, these examples are not fixed but they depend on the selected K-fields, the filter and selection criteria and the respective graphics. Users can configure and generate them based on their individual requirements.

Analyzing Data Based on their Part Type

The Q-DAS software products evaluate characteristics whose results can be summarized at different levels or, if required, may be displayed with even more details. The following graphic shows a data analysis referring to the different types of parts, i.e. in principles it combines the green elements of the flow chart representing the part types with the structure of the manufacturing process (figure 4).

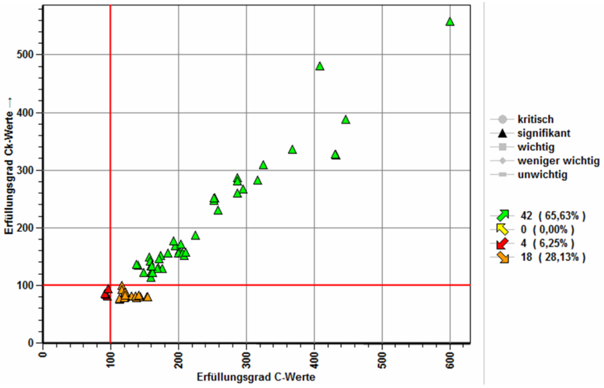

Figure 5: Performance degree of all characteristics of the selected part types

You load all part types of the milling cutter (see e.g. structure above) produced in a certain period from the database and display the cumulated evaluation results of the characteristics (see figure 5).

The result indicates that 65.63% of all characteristics of the selected part types meet the process requirements (target capability index and target minimum capability index). However, 6.25% of all characteristics neither fulfill the requirements of the target capability index nor the target minimum capability index. Though 28.13 % of all characteristics meet the requirements of the target capability index, they do not satisfy the demands of the target minimum capability index.

The following table is often used in management reports in order to provide a short and comprehensive overview of the total status of product quality. You might even use it to compare periods (e.g. current month compared to the previous month), a comparison that clearly shows the effects of any corrective action you have taken.

50,00%	0 50 100	4		42	65,63%	0 50 100
25,00%	0 50 100	2		0	0,00%	0 50 100
25,00%	0 50 100	2		22	34,38%	0 50 100
0,00%	0 50 100	0		0	0,00%	0 50 100
100,00%	0 50 100	8		64	100,00%	0 50 100

Figure 6: Summary of the number of part types and characteristics

The single characteristics belong to a certain part type, of course, so it is important to know whether the processes o.k. / n.o.k. mainly refer to a specific part type or whether both process results occur for all types of parts.

You may even weight parts to summarize the evaluation results of the single characteristics at the part type level. This helps you to find out how many part types meet the requirements and how many do not. The table displayed below (figure 6) shows the 64 characteristics corresponding to a total of eight part types. The overall result of this graphic is that two part types do not satisfy demands, two types meet the requirements only conditionally and four types of parts fulfill them.

Platte Typ 1					
Operation 010	Teilnr.	K1111_1001	Teilebez.	Platte 1001	60 100
Operation 020	Teilnr.	K1111_1001	Teilebez.	Platte 1001	60 100
Operation 010	Teilnr.	K1111_1002	Teilebez.	Platte 1002	60 100
Operation 020	Teilnr.	K1111_1002	Teilebez.	Platte 1002	60 100
Platte Typ 2					
Operation 010	Teilnr.	K2222_2001	Teilebez.	Platte 2001	60 100
Operation 020	Teilnr.	K2222_2001	Teilebez.	Platte 2001	60 100
Operation 010	Teilnr.	K2222_2002	Teilebez.	Platte 2002	60 100
Operation 020	Teilnr.	K2222_2002	Teilebez.	Platte 2002	60 100

Figure 7: Summary of results per part type

On the next level it is important to identify the single part types and to see the overall result of the respective type. According to the structure of products and the structure of the manufacturing process assumed in this article, you take measurements from the parts of the different cutter types (cutter type 1 and cutter type 2). These measurements are taken in the assumed operations 010 and 020. What first strikes you when looking at the compressed characteristic results at the part type level is that cutter 2002 does not meet the requirements neither in operation 010 nor in operation 020. So you have to take a closer look at these characteristic results.

Teilnr.	K2222_2002	Teilnr.		K2222_2002				Operation 010
2	Merkmal 2	10,000	10,300	10,08660	0,0450	C_p = 1,20	C_{pk} = 1,03	
3	Merkmal 3	100,550	100,720	100,64779	0,0182	C_p = 1,55	C_{pk} = 1,32	
4	Merkmal 4	26,315	26,585	26,42228	0,0289	C_p = 1,70	C_{pk} = 1,11	
6	Merkmal 6	4,000	4,370	4,08161	0,0426	C_p = 1,57	C_{pk} = 1,03	
Teilnr.	**K2222_2002**	**Teilnr.**		**K2222_2002**				**Operation 020**
2	Merkmal 2	15,000	15,300	15,09388	0,0485	C_p = 1,11	C_{pk} = 1,03	
3	Merkmal 3	101,580	101,720	101,64774	0,0182	C_p = 1,28	C_{pk} = 1,24	
4	Merkmal 4	36,295	36,585	36,41638	0,0296	C_p = 1,61	C_{pk} = 1,17	
6	Merkmal 6	6,000	6,370	6,08814	0,0451	C_p = 1,25	C_{pk} = 0,99	

Figure 8: Overview of the characteristics n.o.k. of selected part types

Now, you only focus on the single characteristics of the part types that do not meet the process requirements, i.e. you go down one level.

By using the filter functionalities of the table you may filter out all bad characteristics. These characteristics need an in-depth analysis. In order to be able to evaluate these characteristics more thoroughly, you have to take a closer look at the raw value chart. We use characteristic 6 as an example, i.e. a characteristic n.o.k. (see figure 8).

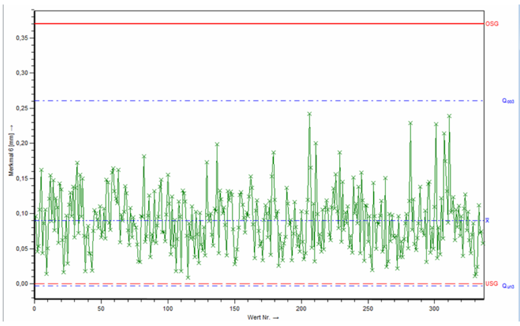

Figure 9: Raw value chart of a single characteristic

This presentation of results is always affected by many influences from production and you thus have to consider the way the manufacturing process is organized when you examine the data and you must analyze the respective characteristic in detail. Since there is a certain number of different machines that might produce a characteristic in a specific operation, you first have to allocate the original values to the corresponding machine of the respective operation. It is reasonable to display the result in a graphic.

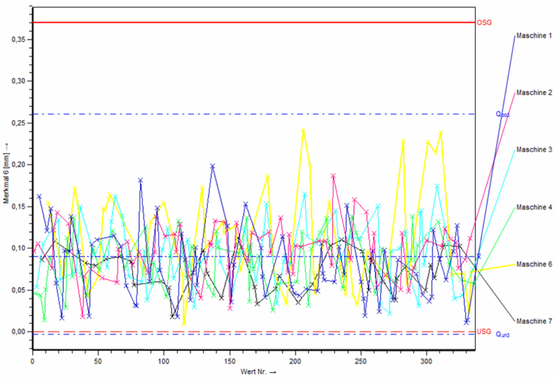

Figure 10: Raw value chart showing values allocated to the respective production machine

The graphic clearly shows that the measured values of parts machine 6 produces (yellow line) show the most significant variation. So it is reasonable to go down one level by selecting measured values of machine 6 only. Machine 6 includes different spindles which makes it possible to allocate the measured values to the different spindles.

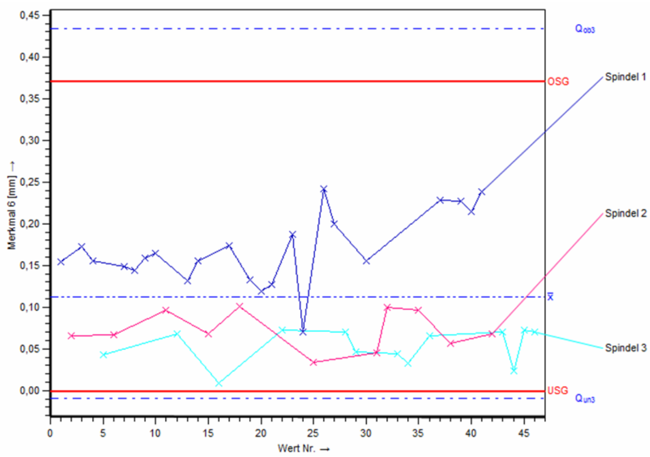

Figure 11: Raw value chart showing values of machine 6 allocated to the different spindles

Even though the measured values of spindle 2 and spindle 3 might show an acceptable variation, they are too close to the lower specification limit. By contrast, the values of spindle 1 are rather centered but they show a high variation. Based on this information you may take specific corrective action in order to optimize the process in case of this characteristic.

Analyzing Data Based on the Way the Manufacturing Process Is Organized

Employees responsible for the manufacturing process or single shop floor areas (lines, operations, production machines) rather analyze data from a different perspective. They need precise information about how to optimize their production, machine or even their tools in order to obtain the highest possible quality. This approach pushes the analysis of data based on the part types in the background and focuses on the production facilities. However, even in this case you can use a top-down analysis.

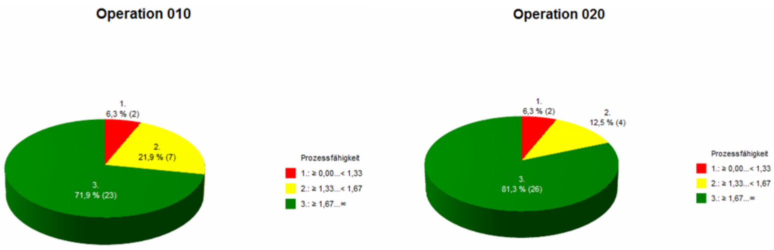

Figure 12: Compressed results allocated to the respective operation

This compact pie chart shows the evaluation results of all characteristics of operation 010 and operation 020. The graphic displays the cumulated results but the results do not have any reference to the part types. This presentation of results does not provide any specific information helping you take improvement actions since it focuses on an overall summary.

By going down one level you focus on the characteristics of a specific operation. These are characteristics 1, 2 and 3 of operation 010 in this example.

Merkm.Nr.	Merkm.Bez.	USG	OSG	$\bar{x}$	s	Index	Index	Gesamtbeur	Werteverlauf Einzelwerte	Histogramm Einzelwerte
				Operation 010						
1	Merkmal 1	9,980	10,220	10,09159	0,00584	P_p = 3,38	P_{pk} = 2,14	↑		
1	Merkmal 1	12,050	12,150	12,09126	0,00407	C_p = 2,99	C_{pk} = 2,48	↑		
1	Merkmal 1	14,075	14,110	14,09123	0,00386	C_p = 1,87	C_{pk} = 1,80	↑		
				Operation 010						
2	Merkmal 2	0,000	0,470	0,09752	0,0466	C_p = 1,89	C_{pk} = 1,08	↓		
2	Merkmal 2	5,000	5,470	5,09496	0,0472	C_p = 1,84	C_{pk} = 1,05	↓		
2	Merkmal 2	10,000	10,300	10,08660	0,0450	C_p = 1,23	C_{pk} = 1,12	↓		
				Operation 010						
3	Merkmal 3	98,434	98,904	98,64687	0,0202	C_p = 3,88	C_{pk} = 3,52	↑		
3	Merkmal 3	99,534	99,804	99,64887	0,0197	C_p = 2,28	C_{pk} = 1,94	↑		
3	Merkmal 3	100,550	100,720	100,64779	0,0182	C_p = 1,55	C_{pk} = 1,32	↓		

Figure 13: Characteristics of operation 010

The graphic combines equal characteristics (e.g. an identical borehole on all milling cutters possibly produced with the same tool) of all part types in case they have the same specifications. As an example, characteristic 1 of cutter 1001 is considered to be the same characteristic as characteristic 1 of cutter 1002 in case of equal tolerances. The responsible employees are just interested in how to evaluate and possible modify the process in case a problem occurs.
When the tolerances are not equal, the characteristics are analyzed separately in this table. This is the reason why the same characteristics are listed several times in the summary graphic (depending of the specification limits LSL and USL).
You will notice that characteristic 2 does not meet the requirements at all in operation 010 (figure 13). Since operation 010 can include different machines, it might be helpful to allocate the characteristics to the production machines that produced them.

Merkm.Nr.	Merkm.Bez.	USG	OSG	$\bar{x}$	s	Index	Index	Gesamtbeur	Werteverlauf Einzelwerte	Histogramm Einzelwerte
				Operation 010						
2	Merkmal 2 (Maschine 1)	0,000	0,470	0,08542	0,0468	C_p = 1,67	C_{pk} = 0,61	↓		
2	Merkmal 2 (Maschine 2)	0,000	0,470	0,10401	0,0342	C_p = 2,29	C_{pk} = 1,01	↓		
2	Merkmal 2 (Maschine 3)	0,000	0,470	0,10110	0,0419	C_p = 1,87	C_{pk} = 0,80	↓		
2	Merkmal 2 (Maschine 4)	0,000	0,470	0,08871	0,0360	C_p = 2,17	C_{pk} = 0,82	↓		
2	Merkmal 2 (Maschine 6)	0,000	0,470	0,11823	0,0663	C_p = 1,32	C_{pk} = 1,03	↓		
2	Merkmal 2 (Maschine 7)	0,000	0,470	0,07636	0,0290	C_p = 2,70	C_{pk} = 0,88	↓		
4	Merkmal 4 (Maschine 6)	6,215	6,685	6,40684	0,0459	C_p = 1,71	C_{pk} = 1,39	↓		
5	Merkmal 5 (Maschine 7)	9,980	10,220	10,09577	0,0165	C_p = 2,44	C_{pk} = 1,73	↓		
6	Merkmal 6 (Maschine 1)	0,000	0,370	0,07914	0,0432	C_p = 1,43	C_{pk} = 0,61	↓		
6	Merkmal 6 (Maschine 2)	0,000	0,370	0,09725	0,0313	C_p = 1,97	C_{pk} = 1,04	↓		
6	Merkmal 6 (Maschine 3)	0,000	0,370	0,09512	0,0379	C_p = 1,63	C_{pk} = 0,84	↓		
6	Merkmal 6 (Maschine 4)	0,000	0,370	0,08321	0,0333	C_p = 1,85	C_{pk} = 0,83	↓		
6	Merkmal 6 (Maschine 6)	0,000	0,370	0,11277	0,0636	C_p = 0,83	C_{pk} = 0,80	↓		
6	Merkmal 6 (Maschine 7)	0,000	0,370	0,07181	0,0248	C_p = 2,49	C_{pk} = 0,97	↓		
8	Merkmal 8 (Maschine 6)	6,265	6,635	6,41013	0,0454	C_p = 1,36	C_{pk} = 1,07	↓		

Figure 14: Selected characteristics n.o.k. allocated to the respective production machines applied in operation 010

Even this graphic does not indicate any main errors for characteristic 2 with regard to any specific production machine. The only obvious fact is that the potential capability is least for characteristics produced by machine 6. A separate analysis of characteristic 2 produced by production machine 6 also confirms this assumption.
Since every machine includes different spindles, it is reasonable to allocate the values of characteristic 2 produced by production machine 6 to the single spindles. Maybe this will help you gain the required additional knowledge of the process.

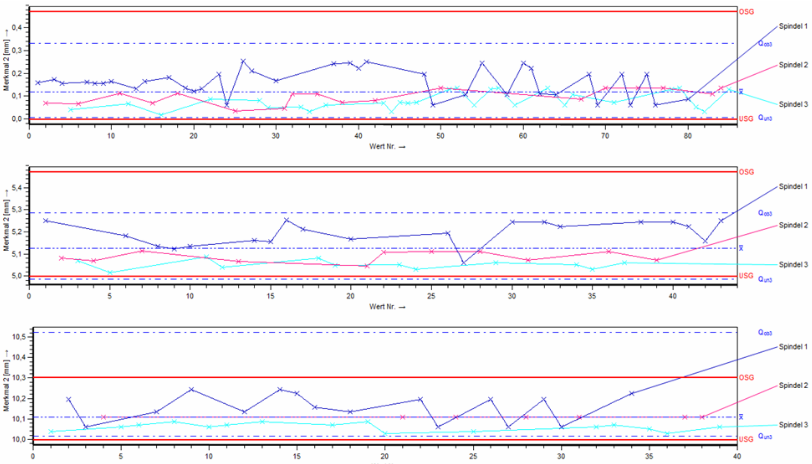

Figure 15: Values of characteristic 2 produced by production machine 6 allocated to the single spindles

Another approach to analyze the data based on the way the production is organized is to examine the single tools. There is a strict allocation defining which tool is used to manufacture which characteristics and which spindle might be applied.

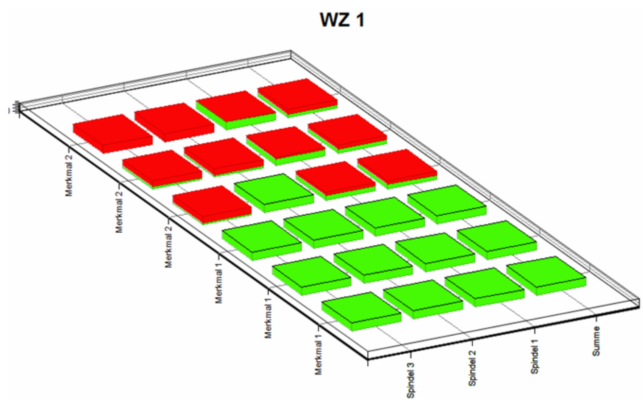

Figure 16: Tool WZ 1 allocated to the respective characteristics with different specifications and spindles

The same tool WZ 1 can be applied to produce characteristic 1 and characteristic 2. Characteristic 1 and characteristic 2 are listed several times in the graphic because each of these characteristics has a different specification. Even this graphic shows that the problem with characteristic 2 persists; however, you are not able to find a specific cause of the problem. Maybe the selected specification limits for characteristic 2 are too narrow, i.e. the manufacturing technology is not always able to meet the process capability requirements.

Conclusion

Depending on the function and task of employees in a company, they have to examine the data from a different perspective and thus analyze the data in different ways. The most common perspective to examine the measured data is the analysis based on the part types and most measuring programs of measuring machines installed in companies work according to this approach. However, especially production-related employees rather need a data analysis based on the way the production is organized and do not need any reference to the part types. The decisive factor is data quality, of course, i.e. the additional descriptive information you can pass on when generating data (measurement process). The specification of the data format AQDEF already considers most of these requirements with the result that Q-DAS software products provide a task-related and user-specific analysis and presentation of data.

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