DFSS Design for Six Sigma

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Abstract
With the application of Six Sigma respectively the DFSS method, IWC is aiming at bringing down the failure rate of products and increasing the optimisation level of the function requirements. Therefore analytical statistical methods are set up, which evaluate mathematically the function requirements. Furthermore the methods are also used to define process measurement categories, on which we can measure the customer requirements. Another goal is to shorten or to meet the set development times with reducing the prototype-iterations to a minimum. The better the work in the concept-phase is, the safer we are with prototyping. The process evaluation decides on the producibility and process capability of the individual parts. With the first sampling VDA we control the tolerance-range of drawings of individual parts and the process capability in the long run. The result leads to cost reduction, shortening of time to market and satisfied customers. In the following text we explain the process evaluation.

Process evaluation
In the process evaluation we decide which processes to use for the production of a specific watch component. Within this process we verify the process capability, whether the component is manufactured according to the tolerance requirements or not. Therefore the machine capability Cm has to be known.

- Verify the process capability for(Figure 1)
  - Components, OFD’s (Opportunities for defects)
  - Drawings, tolerances
- Verify the measurement capability for the control (Cpm and Gage R&R)
- Check the price evaluation, if there are different suppliers for the same process
- Check the optimization process → price- and quality improvements
- Knowledge of noise factors Z in the production (Taguchi)

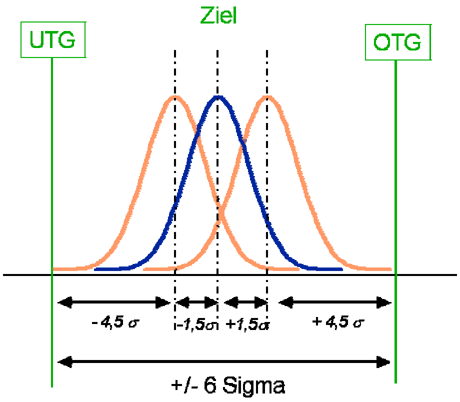

Figure 1: Average fluctuation of a process over a longer period of time

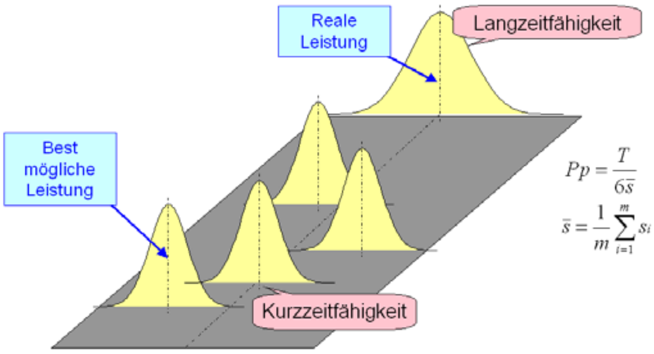

Figure 2: Short term capability and long term capability of a process with +/- 1.5σ average fluctuation

For the process capability of single parts we aim for Cp values > = 2.00
With a Cp value of 2.00, the Ppk value is 1.5. The long term capability varies from the average +/- 1.5σ.*(**Figure 2**)*

Example: Position tolerance +/-0.006 mm
In order to assure the long term capability of Cp=2.00 and Ppk of 1.5, the machine capability Cm has to be 2.00 with +/-0.004 mm. The Cmk may, with an average fluctuation of 1.5σ, not be under 1.5 [7].

$$Cp = \frac{T}{6s} = \frac{OTG - UTG}{6s} \quad (1)$$

$$T = Cp \cdot 6s \quad (2)$$

When Cp=2 then T = 12s

If we consider the long term capability, then Cmk turns into Ppk = 1.5

$$Cmk = \frac{(12-3)}{6} = 1.5 \quad (3)$$

To ascertain the machine capability Cm and Cmk, 30 parts have to be produced consecutively and measured. The tolerance field of the machine, results from a theoretical value of Cm=2 → T=2*6σ. This value has to be 1.5 times better than the plan tolerance. With the measurement capability it has to be considered that it must be 10 times more precise than the tolerance field. In our example 0.008 mm / 10 = 0.0008 mm [6].

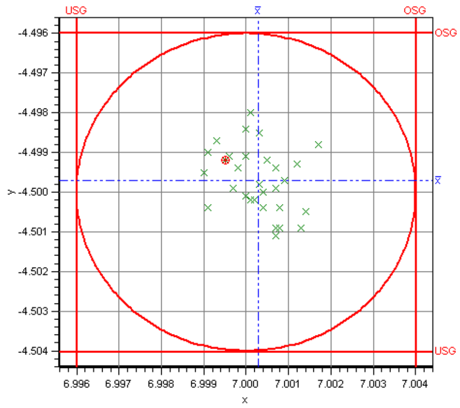

Figure 3: Position measurement of 30 equal parts (produced on an Almac) in the short term capability (QS-Stat)

Merkm.Nr.	Merkm.Bez.	$\bar{x}$	s	Index	Index	
1	Position 1			P_o	P_{ok}	--- 900
1	x	4.99896	0.00050895	C_m 2.62	C_{mk} 1.94	
1	y	7.49868	0.00062150	C_m 2.15	C_{mk} 1.44	

Figure 4: Evaluation of the process capability Cp and average fluctuation Cpk (QS-Stat)

Excel© or special statistic software like QS-Stat© [4] (figure 4) can be used for the evaluation of the measurement values. The evaluation of a position tolerance can also represented graphically (figure 3).

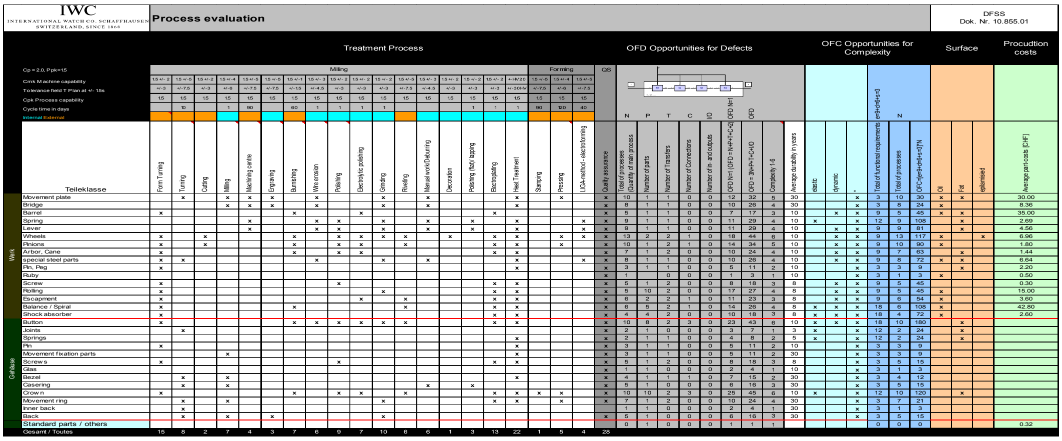

Figure 5: QFD Matrix of the part families and processes for their production, process capability and tolerance field.

There are 11 different processes for the production of movement wheels. The number of processes are in connection with the cycle time and the complexity (OFD Opportunities for Defects) of the parts (figure 5).

The process evaluation helps us to check the tolerance fields of each part antecedent and also evaluates the feasibility/process capability. The functions of the parts have to be simulated or calculated beforehand, if the number of processes are very high. FEM for springs, tooth profile for wheels etc.
The matrix chart gives us an overview of all used processes and capabilities. It provides an application for the industrialization and supply engineering and shows the competence of verticalized processes.

Results

IWC has started with DFSS in 2003. The pilot project was the movement with the minute split memory. The project was successfully introduced at the SIHH in 2004. The development and industrialization incl. the homologation took 13 months.

List of references

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