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DVS – DEUTSCHER VERBAND FÜR SCHWEISSEN UND VERWANDTE VERFAHREN E.V.

Welding of plastic series parts – Quality assurance and testing

DVS

Technical Code DVS 2230-1

Contents:

1 Scope of application

The technical code applies to the welding of parts made of thermoplastics in series fabrication with the following joining processes: heated tool, vibration, ultrasonic, rotational friction and high-frequency welding.

In this respect, the quality-assuring measures before, during and after the welding process are dealt with especially. Technological details such as design, process engineering and joining technology can be taken from the DVS technical codes which relate to the various processes and are listed in Section 10.

2 Fundamentals and definitions of terms

According to DIN 55350, "quality" is the "condition of a unit with regard to its suitability for meeting stipulated and prerequisite demands". Comprehensive quality assurance includes the personnel management, the logistics, the fabrication sequence and all the other fields involved in the production.

Corresponding to the quality requirements, the design of the joining parts must be geared to the following demands, e.g.:

- load-bearing capacity of the weld
- leak tightness
- appearance
- dimensional accuracy (shrinkage, distortion and moulding cavities)
- melt flash and formation of particles
- component damage

Furthermore, it is imperative to pay attention to the individual process-specific prerequisites of the individual series welding processes.

Often, reference is also made to joining. This is the case wherever a thermoplastic is joined with another material, e.g. chipboards, cardboard, textile fabrics etc. Mechanical clawing occurs in this respect.

2.1 System FMEA

FMEA means "failure mode and effect analysis". This serves to minimise the risks and the costs. It is applied not only in the case of safety-relevant systems but also wherever failures are disturbing and may have expensive consequences. The system FMEA designation has gained acceptance with the latest refinement and is composed of a product FMEA and a process FMEA.

The system FMEA and the product or design FMEA consider the possible failure types of whole products. If required, the consideration extends as far as individual components.

In the case of the system FMEA process, the manufacturing process is described and structured on the basis of the five system elements involved, i.e. person, machine, material, environment and method (procedure). Process steps are regarded as the tasks of these system elements. If necessary, the analysis is made right up to the design data of the fabrication facilities.

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2.2 Investigation into the testing material capability

In order to evaluate and monitor the product quality, it is necessary to select suitable testing methods whose capability must be proven. The testing material capability guarantees the possibility of correctly displaying the fluctuations arising in the course of a process. Since the testing material itself is subjected to fluctuations, it must be stipulated whether these are smaller than the fluctuations to be expected from the process. For this purpose, the device-induced scattering behaviour of the testing facility is investigated in utilisation conditions at the utilisation location with a normal or a masterpiece within the framework of the investigation into the testing material capability (repeat measurements). The results of the investigations are characteristic values for the capability which are a measure of the accuracy and the repeat precision.

2.3 Investigation into the machine capability

The investigation into the machine capability (frequently also designated as the investigation into the short-time capability) should serve to check, above all, any influences of the fabrication facility on the product quality. Thus, the influences exerted by the person, the material, the method and the environment should be excluded if possible. The result supplied by the investigation into the machine capability is a provisional statement about the suitability of the machine/tool/moulding combination. No alterations to the process may be made during the random sampling.

The characteristic value for the short-time (machine) capability c_m provides information about the extent to which the scattering of the measured values exploits the tolerance specified for the characteristic. It is calculated as follows:

$$c_m = \frac{T}{6 \cdot s}$$

s = standard deviation of a random sample from the values for the characteristic
T = tolerance for the characteristic

In order to establish the characteristic values, reference should be made to > 50 parts which have been taken from the process successively and have been numbered consecutively. After the determination of the selected values for the characteristic, their standard deviation *s* can be calculated as follows:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

In addition, the characteristic value for the machine capability Cmk takes account of the position of the mean in the tolerance range:

$$Cmk = \frac{ULV - \overline{x}}{3 \cdot s} \quad \text{or} \quad Cmk = \frac{\overline{x} - LLV}{3 \cdot s}$$

where: ULV - LLV = T

ULV = upper tolerance limit of the characteristic
LLV = lower tolerance limit of the characteristic
$\overline{x}$ = arithmetic mean of the values for the characteristic

A processing facility is capable when the following applies to the lower amount of both the relationships:

$Cmk \geq 1.67$

This is a value which is customary in the automobile industry today.

2.4 Investigation into the process capability

The investigation into the process capability is a long-term investigation which also takes account of influences which exert an effect on the fabrication process from the outside during a lengthy operating time. The objective of the investigation into the process capability is to prove that the fabrication process to be investigated can satisfy the quality requirements set on it in the long term.

The investigation is conducted using several single random samples which are taken at process-dependent intervals. At least 20 random samples each consisting of five parts are necessary for an assured starting basis.

The following relationships are applicable:

$$C_p = \frac{T}{6 \cdot \sigma} \quad \text{where:} \quad \sigma = \frac{\overline{s}}{a_n}$$

$$\overline{s} = \frac{\sum_{j=1}^{m} s_j}{m}$$ = mean of the standard deviations of the random samples

m = number of random samples
n = number of parts per random sample

The factor a_n serves to estimate the standard deviation of the population from the standard deviation of a single random sample and is dependent on the scope of the random samples n.

The assignment can be taken, for example, from a table:

n	2	3	4	5	6	7	8	9	10
a_n	0.798	0.886	0.921	0.940	0.952	0.959	0.965	0.969	0.973

Corresponding to the investigation into the short-time capability, the following applies to the characteristic value for the process capability:

$$Cpk = \frac{ULV - \overline{\overline{x}}}{3 \cdot \sigma} \quad \text{or} \quad Cpk = \frac{\overline{\overline{x}} - LLV}{3 \cdot \sigma}$$

where: $\overline{\overline{x}} = \frac{1}{m}\sum_{i=1}^{m}\overline{x}_i$ = grand mean of the single random samples for the values for the characteristic

The following applies to capable processes:

$Cpk \geq 1.33$

This is a value which is customary in the automobile industry today.

With regard to welding processes, it is frequently the case that only one minimum value is defined for one characteristic (LLV) and the result must not be lower than this minimum value, e.g. weld strength or bursting pressure level. In these cases, the characteristic value should only be established in relation to the lower limiting value (LLV):

$$Cmk = \frac{\overline{x} - LLV}{3 \cdot s} \geq 1.67$$

$$Cpk = \frac{\overline{\overline{x}} - LLV}{3 \cdot s} \geq 1.33$$

A normal distribution of the characteristics is assumed in these calculation formulae. If the actual distribution deviates from this, it is necessary to utilise correction functions.

2.5 Process regulation and process monitoring

Process and fabrication monitoring is understood to refer to all the operations which allow the process to be controlled/regulated using information about the process state so that the quality characteristics of the manufactured products are kept within stipulated limits. Different procedures can be applied in this connection, e.g. statistical process control (SPC) and continuous process control (CPC).

2.6 Prerequisites for production suitable for series

Irrespective of the utilised welding process, fundamental prerequisites are necessary for quality-assured production in order to exclude any systematic errors. Before series fabrication begins, it must therefore be checked whether the process is subjected to systematic influences. If this is not the case, the process is under statistical control. Statistical control means that the scattering of the quality characteristics is now subjected to random influences alone. A process under statistical control can be managed and predicted. Fig. 1 shows a process which does not proceed in a controlled way at the beginning, characterised by its extremely fluctuating mean position and distribution width. Measures which reduce the random influences have been taken with an increasing time. This serves to improve the position and width of the distribution, i.e. the distributions are narrower and identical in the last stage.