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Welding of thermoplastics in series fabrication

Rotational friction welding of mouldings and semi-finished products made of polyamides (PAs)

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Contents:

1 Scope of application

This technical code applies to the rotational friction welding (code designation: FR) of mouldings and semi-finished products made of polyamides, hereinafter designated as PAs.

2 Procedural description

The fundamentals of rotational friction welding are described in DVS 2218-1 and DVS 2218-2. Welding machines which permit multi-stage pressures (different pressures during the welding and cooling phases) as well as triggering are utilised in order to obtain high weld qualities.

The machines of the new generation offer additional technical possibilities with the following operating modes:

– constant rotational speed and constant welding force
– constant rotational speed and variable welding force
– variable rotational speed and constant welding force
– variable rotational speed and variable welding force

It is thus possible to take better account of the material and the weld with regard to specific aspects and to optimise the weld qualities even further.

Moreover, modern friction welding machines are equipped with a diagnosis system (information about sources of defects in the machine) in order to:

– collect the operating data
– collect the process data
– handle the process data right up to statistical quality control
– elaborate data documentation

3 Description of the materials to be welded

3.1 Polyamide types

Polyamides (PAs) are high-quality thermoplastics which are predominantly utilised for technical components. They are ha to resilient plastics which may be modified with reinforc mate-rials and/or fillers or with other additives in order to improv the mechanical and thermal properties.

A distinction must be made between semi-crystalline yamide and amorphous (semi-aromatic) polyamides. emi-cr ine PAs are available as homopolyamides or co olya les and as cast polyamides. In this respect, the latte are main ed for thick-walled mouldings and semi-finished p ducts. A hou ous PAs are transparent and are characterised b lower roces ing shrinkage, good dimensional stabilit her glass tra ition temperature in part and somewha lower moisture a orption. They also include polymer mixture (bl ds) a d modifications from polyamides.

In order to improve (for xamp) the impact strength, the heat distortion temperature r the s ness, the polyamides can be mixed with a numbe f other p lasticisers. Depending on the proportion o foreign components, these are called modified polyamides or, e case of a higher foreign proportion, polyamide mixtures (bl ds). The welding behaviour is also influenced by the change in the ove properties.

3.2 Additives

Depending on thei type and quantity, additives influence the welding beh ior and t e joining weld strength. The additives include fillers and reinfo ing materials, e. g.:

– glas or c bon fibres
– gla s nonw ns or mats
– gla beads
– chalk
– ma
– qua flour
– metal owders

DVS, Tech ical Comm ee, Working Group “Joining of Plastics”

Orders to: DVS Media GmbH, P. O. Box 10 65, 40 10 Düsseldorf, Germany, Phone: +49(0)211/1591-0, Telefax: +49(0)211/1591-150

Other additives are, e. g.:

– additives
– colorants (pigments, dyes and carbon black)
– nucleating agents
– lubricants
– stabilisers
– elasticisers
– demoulding aids (release agents)

3.3 Welding-relevant properties of polyamides

The table shows properties of unreinforced polyamides which may be used for welding. Merely in the case of PAMXD6 were the values of a material reinforced with 30% glass fibre included since this material is only available in the trade as reinforced material.

4 Material-related factors influencing the welding behaviour

4.1 Softening and plasticising behaviour (flow behaviour)

Polyamides exhibit high melting temperatures and relatively low coefficients of friction. The heat arising during friction welding is proportional to the product of the friction time, the friction pressure and the circumferential speed. This product must reach a minimum value in order to plasticise the material surface. After the initial friction phase has finished, the melt temperature then changes only slightly.

The possible friction welding speeds are located in a wide range but only a narrow joining pressure range belongs to a certain rotational speed. The pressure and the rotational speed should be chosen in such a way that plasticised melt is formed very quickly and only a small abrasion quantity arises. An excessive joining pressure dispels the melt from the joining weld and leads to a rising melting-off rate. Because of its low viscosity, polyamide forms only a very thin melt coat.

Table 2. Influence of the viscosity on the flow behaviour.

Low-viscosity PA	Steep-flanked conical weld	Double conical weld
Circumferential speed [m/s]	1.0 – 1.6	1.6 – 2.6
Joining pressure in the weld [MPa]	1.5 – 1.8	0.6 – 1.2
Joining path [mm]	3.0 – 4.0	1.0 – 2.0
Medium-viscosity PA		
Circumferential speed [m/s]	1.0 – 1.6	2.0 – 2.6
Joining pressure in the weld [MPa]	1.2 – 2.2	0.6 – 1.2
Joining path [mm]	1.0 – 2.0	2.0 – 3.0

4.2 Additives

The information provided in DVS 2218-1 and DVS 2218-2 as well as the additives listed in Section 3.2 apply to additives.

Table 1. Properties of polyamide types for FR welding.

PA type	Chemical structure	Group[1)]	Density g/cm³	Modulus of elasticity[2)] MPa	Water absorption[3)] %	Melting temperature °C	Melt viscosity MVR (2[illegible] 5 kg
6	Polycaprolactam	s	1.10 – 1.14	1,100 – 3,500 / 1,000 – 2,500	2.5	220	6 – 350
66	Polyhexamethylene adipamide	s	1.12 – 1.14	2,600– 3,600 / 1,000 – 2,800	2.5	[illegible]55	[illegible] – 150
610	Polyhexamethylene sebacamide	s	1.06 – 1.08	2,400 / 1,500	1.4	2[illegible]	30 – 120
612	Polyhexamethylene dodecaneamide	s	1.01 – 1.02	2,300 / 1,500	1.3	[illegible]210	60 – 200
11	Poly-11 aminoundecaneamide	s	1.01 – 1.04	1600/ 1000	1.0	175 – 187	172 – 186
12	Polylaurolactam	s	1.01 – 1.02	1,300 – 1,600 / 1,200	0.9 – [illegible]	172 – 180	36 – 160
46	Polytetramethylene dipamide	s	1.18	3,300 / 1,000	3.7	295	
6/66	Copolymer consisting of PA6 and 66	s	1.13	2,200 / [illegible]000	3.[illegible]	296	60
66/6	Copolymer consisting of PA66 and 6	s – a	1.13	[illegible]000 / 1,100	1.8	243	110
6/6T	Copolymer consisting of PA6 and polyhexamethylene terephthalamide	s	1.18	[illegible]500 / 3,[illegible]		295	20 – 30[4)]
PAMXD 6-GF30	Poly-m xylylene dipamide	s	1.[illegible]	4,800	0.2	235 – 245	

1) s = semi-crystalline, a = amorphous
2) 1st value = dry, 2nd value = conditioned
3) standard atmosphere (23°C / 55% relative humidity)
4) 10 min / 365°C / 5 kg