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DVS – DEUTSCHER VERBAND FÜR SCHWEISSEN UND VERWANDTE VERFAHREN E.V.	**Welding of thermoplastics in series fabrication** Rotational friction welding of mouldings made of polyolefins (PE and PP)	DVS Technical Bulletin DVS 2218-2

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Contents:

1 Scope of application

The technical code applies to the rotational friction (FR) welding of components made of polyolefins, hereafter designated as PE or PP.

2 Procedural description

The fundamentals are described in the DVS 2218-1 technical code.

Welding machines which permit multi-stage pressures (different pressures during the welding and cooling phases) as well as triggering have been utilised in recent times in order to obtain high welding qualities.

The machines of the new generation offer additional technical possibilities. For example, the user can choose between the following operating modes:

– constant rotational speed and constant welding and joining forces
– constant rotational speed and variable welding and joining forces
– variable rotational speed and constant welding and joining forces
– variable rotational speed and variable welding and joining forces

It is thus possible to take better account of the material and the weld with regard to specific aspects and to optimise welding 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 Brief description of the PE and PP materials

Polyolefins are semi-crystalline plastics which have very good suitability for rotational friction welding. The material or the type should therefore be selected not only according to the requirements profile of the subsequent area of application but also according to the type-specific welding behaviour. The weldability of cross-linked polyolefins ranges from poor to non-existent. Material characteristics as well as type-specific properties are shown on the product data sheets and in the databases of the raw material manufacturers, e. g. CAMPUS database.

3.1 Polyethylene (PE)

According to ISO 1872-1 (DIN 16776-1), PE moulding materials are on the basis of polyethylene homopolymers and/or polyethylene copolymers. If necessary, fillers and/or reinforcing materials may be contained as well.

3.1.1 Polyethylene homopolymers

Depending on the polymerisation conditions, polyethylenes are created with different degrees of branching. The crystalline proportion and the density increase as the branching of the molecules decreases.

The melting temperature and the melt viscosity increase along with the density and the molar mass. Polyethylene becomes easier to weld as the melt viscosity rises. The density and the molar mass also influence the mechanical and thermal properties of the polyethylene.

PE-LD (density: 0.915 - 0.935 g/cm³) possesses a structure with long-chain branching. In contrast, PE-HD (density: 0.935 - 0.97 g/cm³) has a linear structure and exhibits a higher stiffness, hardness and heat distortion temperature.

In the case of PE, the resistance to stress cracking and the impact strength rise together with the molar mass – characterised by falling MVR/MFR values. In addition, the impact strength increases as the density decreases, i. e. with a rising degree of branching.

The molar mass distribution (MMD) has a major influence on the properties and the processing.

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3.1.2 Polyethylene copolymers

The copolymerisation of the ethylene leads to branched chain structures. This decreases the crystalline proportion, the melting temperature, the density and the stiffness and increases the resistance to stress cracking. The low-pressure process results in polyethylenes with lower densities such as PE-ULD, PE-VLD and PE-LLD (density: 0.88 – 0.93 g/cm³) and in PE-MD with a medium density (density: 0.93 – 0.94 g/cm³) which exhibit a linear structure with short-chain branching.

The high-pressure process gives rise to polar comonomers such as vinyl acetate (VA), acrylic acid (A) and acrylic ester which exhibit, for example, a flexibilising effect and higher adhesion to foreign materials.

Copolymers such as EVAC, EAA and EEA are characterised not only by the density and the MVR/MFR but also by the type and quantity of the comonomers.

3.1.3 Polymer mixtures (blends)

Polymer mixtures result from the mechanical incorporation of other polymers, e. g. PA. In most cases, so-called compatibility agents are still added for this purpose. The quality, type and concentration of the component(s) in the mixture influence the quality of the welded joint. Tests should be carried out in order to clarify the weldability.

3.1.4 PE with additives

Polyethylenes contain various additives such as stabilisers, colorants, antistatic agents, processing aids, flame retardants as well as possibly fillers and/or reinforcing materials too. Since these additives may influence the welding properties, the weldability must be established by tests here as well.

3.2 Polypropylene (PP)

According to ISO 1843-1 (DIN 16774-1), PP moulding materials are thermoplastic moulding materials on the basis of propylene homopolymers and/or propylene copolymers. There are homopolymers with high or low crystalline proportions, block copolymers, random copolymers as well as elastomer-modified and filled and/or reinforced types. Good welding qualities can be achieved with all of these.

3.2.1 Polypropylene homopolymers

Mouldings made of homopolymers are characterised by a higher stiffness, hardness and heat distortion temperature. The melting temperature range begins at 160°C. The different types are defined by their MVR/MFR values.

3.2.2 Polypropylene copolymers

In the case of copolymers, a distinction is made between block copolymers (PP-B), random copolymers (PP-R) and (PP-Q) polypropylenes with a high melt strength. Copolymers possess higher toughnesses than homopolymers and comparable MVR/MFR values. Random copolymers exhibit higher transparency and a decreased wider melting range.

The different types are defined by their MVR/MFR values and their toughnesses. The polyolefins are semi-crystalline plastics which have very good suitability for rotational friction welding.

3.2.3 Elastomer-modified PP

In most cases, the elastomer-modified PP moulding materials contain ethylene/propylene rubber (EPM or EPDM) as the elasticiser. They are characterised, in particular, by a high impact strength in cold conditions, a sufficient stiffness in hot conditions, compatibility with fillers and reinforcing materials as well as good processability.

3.2.4 PP with fillers and/or reinforcing materials

Polymers reinforced/filled with glass fibres, natural fibres, chalk or talc exhibit a higher stiffness, hardness and heat distortion temperature but, in most cases, a lower impact strength than the unfilled matrix. Glass-fibre-reinforced types with chemical coupling are characterised by a high mechanical strength, stiffness and heat distortion temperature. The orientation of the glass fibres in the moulding influences these properties and the distortion. Therefore, it is necessary to check the weldability in most cases.

3.3 PP with additives

Additives such as foreign polymers, colorants, plasticisers, antistatic agents, processing aids and flame retardants influence the properties of PP, depending on the added quantity. Preliminary tests for the weldability are advisable here as well.

3.4 Welding-relevant properties of polyolefins, Table 1

Table 2. Properties of polyolefins (PE and PP) for FR welding.

PE, PP type	Structure	Density g/cm³	Modulus of elasticity N/mm²	Melting temperature °C	Melt viscosity MVR /MFR
PE-LD	Homopolymer	0.915 -0.926	140 – [illegible] 160 – 255	105 – 113 104 – 113	0.1 -8 3) 15 – 250 3)
PE-LLD	Homopolymerisat lin.	0.88-0.927	140 – [illegible]	121 – 124	0.6 – 11 3)
PE-MD	PE with a medium density	0.93 – 0.944	380 – 800	125 – 128	0.7 – 1.0 2)
PE-HD	PE with a high density	0.935-0.97	[illegible] – 1900 [illegible] -17[illegible]0	121 – 137	0.1 – 8 1) 11 – 42 1)
PP-H	Homopolymerisat	0.898-0.[illegible]	[illegible] – [illegible]600 1100 – 1600	150 – 175	0.5 – 12 4) 15 – 60 4)
PP-B	Block polymer, medium flowability	0.89 – 0.912	[illegible]50 – 1650 1050 – 1700	160 – 175	0.8 – 9 4) 12 – 45 4)
PP-Q	High melt strength	0.89 – 0.90[illegible]	400	160 – 170	0.8 – 20 4)
PP-R	Random polymer	0.895 – 0.905	700 – 1200	140 – 170	1.2 – 14 4)
PPEPDM-copolymer	PP copolymer	[illegible]896 – 0.915	350 – 1010		5 – 8 4)

1) cm³/ At. 190°C/2.16 kg /10 min
2) cm³/ At 190°C/5 kg /10 min
3) cm³/ At 190°C/2.16 kg/10 min (MFR)
4) cm³/ At 230°C/2.16 kg/10 min