Butt-Fusion of Glass-Fiber Reinforced Polyethylen Pipes (PE-GF)

General:

Since 2005, helical extruded pipes made of PE-GF have been used in the market for pressure application. Worldwide many projects have been realized in various diameters and for pressure applications up to 16 bar. The pipes are produced by the Krah Comtruder®-Technology, which guarantees a homogenous distribution of the chopped glass-fibers and the coupling-agent in the polyethylene-matrix. The international available standards for pipes DN/ID 400 until DN/ID 4000 are ASTM F 2720/ASTM 2720M, DIN SPEC 19674 and ISO/CD 29561 is still in process.

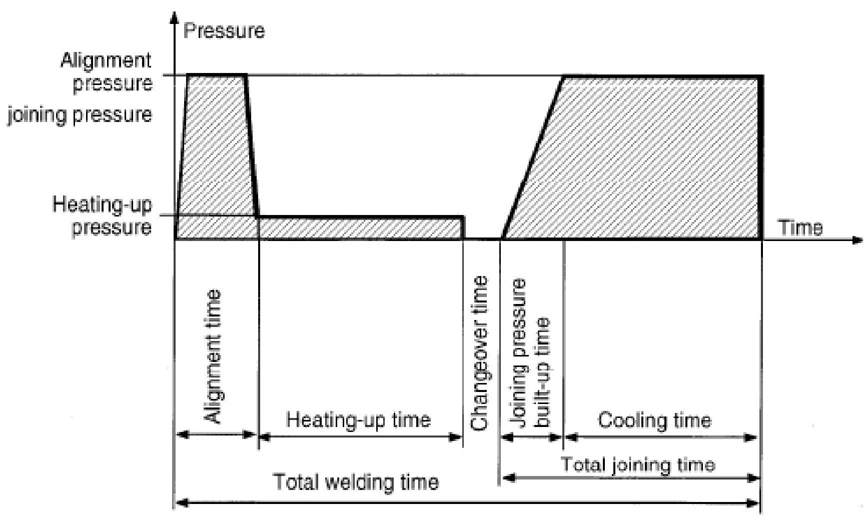
Mostly used in the market is the PE-GF 200 with a MRS-class 20 MPa, based on 20 % Glass Fibers, 2 % Coupling agent and 78 % polyethylene matrix of PE 100.

Joining of this kind of pipes is done either by the typical Krah-Electrofusion-Technology or by Butt-Fusion.

The Butt-Fusion-process

For standard Polyethylene Pipes the Butt-Fusion process is standardized in DVS 2207. Also the Butt-Fusion process for helical extruded PE-GF-pipes is following the rules of DVS2207 in general issues, especially regarding preparation of welding, quality control and general requirements for training and equipment.

The welding parameters themselves, must be adapted regarding temperature-and pressure profile:



Welding temperature (heated tool temperature)	235 °C

1	2	3	4	5	
Nominal Wall Thickness	Alignment	Heating-up	Changeover	Joining	
	Bead height on heated tool at the end of the alignment time (alignment with 0.30 N/mm²)	Heating-up time = 10 x wall thickness (heating-up with ≤ 0.02 N/mm²)		Joining Pressure Build-up time	Cooling time under Joining pressure P=0.30 N/mm² ± 0.01
[mm]	[mm] minimum	[sec]	[sec] maximum	[sec]	[min] minimum
7 … 12	1.5	70 … 120	6 … 8	6 … 8	10 … 16
12 … 19	2.0	120 … 190	8 … 10	8 … 11	16 … 24
19 … 26	2.5	190 … 260	10 … 12	11 … 14	24 … 32
26 … 37	3.0	260 … 370	12 … 16	14 … 19	32 … 45
37 … 50	3.5	370 … 500	16 … 20	19 … 25	45 … 60
50 … 70	4.0	500 … 500	20 … 25	25 … 35	60 … 80

Recommended values for heated tool butt welding of pipes made of PE-GF200 at an outside temperature of 20°C and moderate air-flow, according technical catalogue of Krah AG

Welding factor

To determine the welding factor an international well-respected institute in Belgium was instructed and authorized to verify the short- and long-term behavior of butt-fusion-joints:

- Test Product is a helical extruded pipe (Krah-pipe) with solid pipe wall.
- The used Polyethylene Raw Material is PE 100 (Hostalen CRP 100, Lyondell-Basell)
- Internal Diameter / Nominal Diameter = 500 mm
- Wall thickness = 33 mm
- Pipe Producer = Krah AG
- Place and Date of Production = Schutzbach, Germany, 2013
- Butt-Fusion = Henze GmbH, Germany, 2013

The determination of the welding factor is done according DVS rules. The investigation contains the following steps:

a) Determination of tensile strength for non-welded specimen:

Reference test piece No.	Thickness mm	Width mm	Maximum load (at break) N	Tensile stress at break σ_p (MPa) Short term
1.1a	5,98	9,96	1695	28,46
2.1a	5,99	9,91	1584	26,68
3.1a	5,99	9,97	1660	27,80
4.1a	5,99	10,00	1692	28,25
Mean tensile stress				**σ_p = 27,80**

b) Determination of tensile strength for butt-welded specimen:

Reference test piece No.	Thickness mm	Width mm	Load at break N	Tensile stress at break σ_{bf} (MPa) Short term
1	5,93	9,93	1678	28,50
6	5,98	9,97	1599	26,82
11	5,99	9,97	1672	28,00
16	5,99	9,96	1693	28,38
21	5,98	9,94	1628	27,39
26	5,98	9,91	1632	27,54
Mean tensile stress				**σ_{bf} = 27,77**

c) Calculation of short term welding factor:

$$f_Z = \frac{\sigma_{bf}}{\sigma_p} = 0{,}999$$

f_Z = *shortterm welding factor*

σ_{bf} = *tensile strength of buttwelded specimen*

σ_p = *tensile strength of non buttwelded specimen*

d) Determination of durability for non-welded specimen (parent material)

Reference test piece No.	Thickness mm	Width mm	Long term tensile strength σ_p (N/mm²)	Maximum load N	Creep rupture time (h)
3.1b	6,03	10,09	22,2	1351	2845
4.1b	6,01	10,03	22,2	1338	2696
5.1	5,88	10,00	22,2	1305	3102
6.1	5,91	10,03	22,2	1316	3019
7.1	5,97	10,02	22,2	1351	2874
Mean creep rupture time until failure: 2.907 h					

e) Determination of durability for welded specimen (series 1)

Reference test piece No.	Thickness mm	Width mm	Long term tensile strength σ_w (N/mm²)	Maximum load N	Creep rupture time (h)
13	6,02	10,08	17,8	1080	3245
18	6,03	9,91	17,8	1064	3296
23	6,04	10,06	17,8	1082	2902
28	6,07	10,04	17,8	1085	3319
Mean creep rupture time until failure: 3.191 h					

f) Determination of durability for welded specimen (series 2)

Reference test piece No.	Thickness mm	Width mm	Long term tensile strength σ_w (N/mm²)	Maximum load N	Creep rupture time (h)
15	6,01	10,10	17,8	1080	3212
20	6,02	10,02	17,8	1074	3296
25	5,94	10,10	17,8	1068	2702
30	5,98	10,07	17,8	1072	3019
Mean creep rupture time until failure: 3.057 h					

g) Verification of long term welding factor:

It should be verified that long-term-welding factor is ≥ 0.8 as it is given for standard Polyethylene pipe materials. Therefore the stress level for welded specimen is reduced by 20% from 22.2 to 17.8 MPa.

To confirm the welding factor of minimum 0.8, the determined duration for welded specimen has to reach at minimum the same time as for the parent material!

$$t_p = duration\ \ non\ welded\ \ specimen$$
$$t_p = 2907\ \ h$$
$$t_{w1} = duration\ \ welded\ \ specimen\ \ series\,1$$
$$t_{w1} = 3191\ \ h$$
$$t_{w2} = duration\ \ welded\ \ specimen\ \ series\,2$$
$$t_{w2} = 3057\ \ h$$

$$t_{w1} \geq t_p$$
$$t_{w2} \geq t_p$$
$$\Rightarrow f_S \geq 0{,}8$$

Conclusion:

The butt-welding process is applicable and proper for welding of PE-GF pipes!

The determined results of testing the butt welded specimens fulfill the requirement similarly to well-known Polyethylene specimens.

The short-term welding factor is 0.99 and shows no significant loss of strength by butt-welding.

The long-term welding factor is larger than 0.8 and provides a lot of safety, especially if it is considered, that the axial stress in pipes because of inner pressure is only 50% of the circumferential stress!

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