# IRÖHM

# **Ultrasonic Welding of CYROLITE®**

# Ultrasonic Welding Study January 28, 2021

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# What is ultrasonic welding?

- 1. The process of joining 2 parts together using ultrasonic energy at high frequencies.
- 2. These mechanical vibrations generate heat at the joint surfaces, resulting in melting of the materials while additional force is applied.
- 3. The process stops resulting in a weld formation after cooling.





B) weld formation by diffusion and entanglement of polymer chains



# Ultrasonic welding in medical industry

Ultrasonic welding is a very common joining technique in the medical device industry.

## Pros:

- ✓ Overall cycle time is very low (<2 seconds)
- Energy efficient (low energy consumption)
- No additives and adhesives necessary
- No ventilation required
- Liquid and airtight welds
- Cleanroom compatible
- Can be easily automated and quality controlled

### Cons:

- Limited size of joint interface
- Special design needed (energy director)





# Phases of Ultrasonic welding process

# **Joint Design**





# **Welding Defects**





Conforming Weld: Homogeneous Mixture

#### Possible causes:

- Temperature at the joint too low
- No sufficient contact between top and bottom part
- Height differences in the joint area
- Not enough melt compression at the end of the process



# Equipment





## Controls

Parameters\* to be controlled / tested:

- Amplitude (20 μm, 25 μm, 30 μm)
- Welding Force (200 N, 300 N, 400 N)
- Welding Depth was kept consistent at 0.35mm due to test body design

\*The parameter determination was based on the Herrmann Ultrasonics experience values regarding the materials PMMA, SAN, PC and MABS provided with a corresponding trial frame.



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## Objective

Determination and optimization of the ultrasonic welding quality of different **CYROLITE**<sup>®</sup> grades to themselves and competitive materials.

### Procedure

Test specimens were molded, welded, then the quality of the welds were examined by microscope and tensile pull tested.





# **Materials**

Materials used in this study:

- CYROLITE<sup>®</sup> G-20 HIFLO
- CYROLITE<sup>®</sup> GS-90
- CYROLITE<sup>®</sup> Med 2
- MABS (medical grade)
- SAN (medical grade)
- PC (medical grade)

Material combinations tested										
	CYROLITE <sup>®</sup> G-20 HIFLO	CYROLITE <sup>®</sup> GS-90	CYROLITE <sup>®</sup> Med 2							
CYROLITE <sup>®</sup> G-20 HIFLO	×									
CYROLITE <sup>®</sup> GS-90		×								
CYROLITE <sup>®</sup> Med 2			×							
MABS		×								
SAN		×								
PC		×								



# CYROLITE® Characteristics of CYROLITE® Grades used for study

CYROLITE® ADVANCED MEDICAL ACRYLICS	CYROLITE® GRADE	Special Feature	Tensile Modulus ASTM D638 (psi)
PMMA-based copolymer	CYROLITE <sup>®</sup> G-20 HIFLO The high-flow solution for medical applications	High-Flow	7000
Transparent, impact modified	CYROLITE <sup>®</sup> GS-90 Easy flow and excellent γ-stability	Color stability after gamma sterilization	6800
PMMA-based copolymer	<b>CYROLITE<sup>®</sup> Med 2</b> Excellent chemical resistance	Extraordinary chemical resistance	5320
The Solar		•	-



## **Test Specimen**

Herrmann Ultrasonic test body "Hexagon 2.0" with a tongue and groove joint design was used.



# **Trial Setup**

#### **Optimized Test Matrix:**

	200 N	300 N	400 N
20 µm	X	X	X
25 µm	X	X	X
30 µm	X	X	X

- 10 Samples were tested from each matrix group (90 Parts)
- 6 Overall material combinations (540 Parts Total)

Welding Force

 Non-Optimized additional testing for competitive materials to themselves (30 Parts)

#### Analysis:

- The DoE-Experiment results were statistically analyzed
- Parameter groups with best average pull forces were extracted
- Based on best parameter groups, recommendations were created for amplitude and weld force

Group	*	Ampitude	Trigger Force	Weld Force 1	Depth RPN	2	D	TP	1	E	Ppeak	RPN	ABS	v	Pend	r	RPN+	мст	Failure CODE	Date	Time	strength	average	min	max	standard deviation
2 Terlu GS90	28 28 28 28 28 28 28 28 28 28 28 28 28 2	1 20 2 20 3 20 4 20 5 20 6 20 7 20 8 20 9 20 0 20	198 198 198 198 198 198 198 198 198 198	300 300 300 300 300 300 300 300 300 300	0 0,35 0 0,35	1 1 1 1 1 1 1 1 1 1 1 2	1 1070776 2 1070778 3 1070778 4 1070779 5 1070780 6 1070780 8 1070781 7 1070782 8 1070783 9 1070784 0 1070785	107,12 107,12 107,12 107,12 107,12 107,12 107,12 107,12 107,12 107,12 107,12	0,188 0,197 0,201 0,201 0,2201 0,220 0,193 0,204 0,204 0,232 0,199	108 110 116 129 117 121 111 111 111 126 116	1.088 1.105 1.059 874 1.131 1.155 1.090 1.105 1.105 1.105 1.105	0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.35	107,2 107,2 107,2 107,2 107,2 107,2 107,2 107,2 107,2 107,2	1,9 1,8 1,7 1,7 1,7 1,7 1,8 1,8 1,8 1,7 1,5 1,9	566 429 483 693 670 551 544 483 628 681	20.030 20.045 20.041 20.037 20.032 20.046 20.028 20.049 20.042 20.042 20.033	0,39 0,38 0,41 0,46 0,42 0,42 0,42 0,42 0,42 0,44 0,39 0,44 0,42	2,188 2,095 2,074 2,098 2,103 2,103 2,064 2,076 2,129 2,096		25.08.2019 25.08.2019 25.08.2019 25.08.2019 25.08.2019 25.08.2019 25.08.2019 25.08.2019 25.08.2019 25.08.2019 25.08.2019 25.08.2019	09:48:14 09:49:37 09:49:50 09:49:12 09:49:12 09:49:31 09:49:31 09:49:40 09:49:51 09:50:33 09:50:18	2251 2204 2195 2316 2312 2131 2247 2204 2133 2190	2217,49	2131,1	2315,05	61,28
1 Lustran 0590	361 363 364 364 366 366 366 366 366 366 370	1 20 2 20 3 20 4 20 5 20 5 20 5 20 5 20 7 20 8 20 8 20 9 20	132 132 132 132 132 132 132 132 132	200 200 200 200 200 200 200 200 200 200	0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.35	1	1 1071064 2 1071065 3 1071066 4 1071067 5 1071068 6 1071069 7 1071070 8 1071070 8 1071071 9 1071072 0 1071073	106,85 106,65 106,65 106,65 106,65 106,65 106,65 106,65 106,65	0,295 0,278 0,282 0,280 0,283 0,283 0,283 0,286 0,288 0,288 0,268 0,268 0,303 0,27	125 118 115 120 121 108 112 122 112	579 535 544 588 543 530 545 531 566 508	0,35 0,35 0,35 0,35 0,35 0,35 0,35 0,35	106,74 106,74 106,76 106,75 106,74 106,72 106,73 106,73 106,73 106,73	1,2 1,3 1,2 1,2 1,2 1,2 1,4 1,3 1,2 1,3	479 499 527 489 526 452 409 383 468 392	20.045 20.042 20.033 20.040 20.037 20.047 20.060 20.062 20.041 20.062	0,45 0,44 0,44 0,45 0,44 0,44 0,44 0,43 0,44 0,43	2,149 2,12 2,124 2,119 2,123 2,138 2,113 2,124 2,169 2,111		08:10:2019 08:10:2019 08:10:2019 08:10:2019 08:10:2019 08:10:2019 08:10:2019 08:10:2019 08:10:2019 08:10:2019 08:10:2019	145354 145403 145417 145423 145423 145437 145447 145500 145515 145524 145524	2114 2478 2238 2439 2309 2351 2448 2158 2019 2187	2274,02	2018,65	2477,5	148,04
1 Makrol n-GS90	45 45 45 45 45 45 45 45 45 45 45 45 45	2 20 3 20 4 20 5 20 6 20 6 20 7 20 8 20 9 20 9 20 0 20 1 20	132 132 132 132 132 132 132 132 132 132	200 200 200 200 200 200 200 200 200 200	0 0,35 0 0,35	1	1 1071164 2 1071165 3 1071165 4 1071167 5 1071167 5 1071168 6 1071169 7 1071169 7 1071170 8 1071171 9 1071172 0 1071173	105,73 106,73 106,73 106,73 106,73 106,73 106,73 106,73 106,73 106,73	0,561 0,501 0,502 0,497 0,483 0,521 0,521 0,521 0,521	202 177 174 203 176 167 177 182 171 173	471 499 485 482 486 488 508 488 488 488 475 488	0,35 0,35 0,35 0,35 0,35 0,35 0,35 0,35	106,77 106,77 106,76 106,76 106,76 106,76 106,76 106,76 106,76 106,76	0,6 0,7 0,7 0,7 0,7 0,7 0,7 0,7 0,7 0,7 0,7	320 310 314 296 294 296 309 316 295 307	20.068 20.068 20.070 20.070 20.069 20.069 20.069 20.069 20.069	0,45 0,45 0,45 0,46 0,45 0,45 0,45 0,45 0,45	2,624 2,577 2,581 2,518 2,568 2,532 2,549 2,595 2,546		10.10.2019 10.10.2019 10.10.2019 10.10.2019 10.10.2019 10.10.2019 10.10.2019 10.10.2019 10.10.2019 10.10.2019	11:03:39 11:04:37 11:04:52 11:05:01 11:05:20 11:05:43 11:05:52 11:06:05 11:06:13 11:06:37	3889 3875 3813 3245 3822 3302 3859 3871 3846 3888	3810,98	3302,13	3945,13	173,29
	Material combinations (top part / bottom part)																									
					G-20 G-20	) HI ) HI	FLO FLO		GS- GS-	90 90			Med Med	2 2		l	MAB 3S-9	S 0		G	SAN S-90	D		GS	РС 5-90	
	Ar	nplitu [µm]	ide			25			20-2	25		2	20-3	30			20				20			20	-30	)

200-400 300-400 200-400 200-400



200-300

200-400

# Results: Andrew Sneeringer



# Top-part: CYROLITE<sup>®</sup> G-20 HIFLO

**RESULTS:** 





Bottom-part: CYROLITE<sup>®</sup> G-20 HIFLO



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# **Results welding CYROLITE® G-20 HIFLO with CYROLITE® G-20 HIFLO**

# **Cross section test body**



#### **DoE Results:**

#### **Recommendation for welding:**

Amplitude: 25 µm Welding Force: 200-400 N



Unwelded

Welded Homogeneous

**Break Point** 



# Top-part: CYROLITE<sup>®</sup> GS-90

# **RESULTS:**





Bottom-part: CYROLITE<sup>®</sup> GS-90



# **Results welding CYROLITE® GS-90 with CYROLITE® GS-90**

# **Cross section test body**

**DoE Results:** 



Unwelded

Welded Homogeneous **Break Point** 



25

Amplitude [µm]

Amplitude: 20-25 µm Welding Force: 300-400 N



30

# Top-part: CYROLITE<sup>®</sup> MED 2

# **RESULTS:**





Bottom-part: CYROLITE<sup>®</sup> MED 2



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# Results welding CYROLITE<sup>®</sup> Med 2 with CYROLITE<sup>®</sup> Med 2

# **Cross-section test body**





Welding Force: 200-400 N



# Top-part: MABS

# **RESULTS:**





Bottom-part: CYROLITE<sup>®</sup> GS-90



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# **Results welding MABS with CYROLITE® GS-90**

# **Cross section test body**



#### **Recommendation for welding:**

Amplitude: 20 µm Welding Force: 200-400 N





Unwelded

Welded Homogeneous Break Point



# Top-part: SAN

# **RESULTS:**





Bottom-part: CYROLITE<sup>®</sup> GS-90



# **Results welding SAN with CYROLITE® GS-90**

# **Cross section test body**



Unwelded





**Primary Break Point** 

Welded Homogeneous DoE Results:



#### **Recommendation for welding:**

Amplitude: 20 μm Welding Force: 200-400 N



# Top-part: **PC**

# **RESULTS:**





Bottom-part: CYROLITE<sup>®</sup> GS-90



# **Results Welding PC with CYROLITE® GS-90**

# **Cross-section test body**



Unwelded

Welded Homogeneous







#### **Recommendation for welding:**

Amplitude: 20-30 µm Welding Force: 200-300 N



# Summary of Ultrasonic Welding of CYROLITE<sup>®</sup> with MABS, SAN and PC



			Tensile Strength (MPa) Comparison			
G-20 HIFLO	GS-90	Med 2		MABS	SAN	PC
48.3	43.4	36.7		48	74.5	75
			-			



# **Recommendations for Ultrasonic Welding of CYROLITE®**

	Material combinations (top part / bottom part)											
	G-20 HIFLO G-20 HIFLO	GS-90 GS-90	Med 2 Med 2	MABS GS-90	SAN GS-90	PC GS-90						
Amplitude [µm]	25	20-25	20-30	20	20	20-30						
Welding Force [N]	200-400	300-400	200-400	200-400	200-400	200-300						



# **Overview of Ultrasonic Welding Study: Weldability Matrix**

Weldability matrix									
	CYROLITE <sup>®</sup> G-20 HIFLO	CYROLITE <sup>®</sup> GS-90	CYROLITE® Med 2						
CYROLITE <sup>®</sup> G-20 HIFLO									
CYROLITE <sup>®</sup> GS-90									
CYROLITE® Med 2									
MABS									
SAN									
PC									
GOOD Welding Combination / Strength									

0

Not tested



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### CYROLITE<sup>®</sup> Acrylic Copolymer





Vistability

STERILE R

STERILE R

STERILE R

STERILE R

STERILE R

00

# **CYROLITE**<sup>®</sup>

# Introducing the world's most advanced medical acrylics

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