Concept, design and testing of an ultrasonic tool used to process composite polymeric materials

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Keywords

Sonotrode, Titanium Grade 5, ultrasonic processing,

1. Structural configuration and analysis for the block ultrasonic Ti Grade 5 sonotrode using specialized software

Specialized ultrasonic TiGr.5 sonotrode, used to cut composite polymeric materials, 35 kHz, amplification report k=10,03

Exterior geometric dimensions of the block ultrasonic work tool, 35 kHz, imputed into the simulation specialized software, figure 1.

FILE GRAPH OPTION EQUATION HELP ABOUT M

SURFACE	TYPE	X_END	DIAMETER	ANGLE	RADIUS	MATERIAL
4e	ø Straight	86.50	10.00	0.00		Ti-6Al-4V bar, Para
3e	ø Arc	59.00	10.00		14.00	Ti-6Al-4V bar, Para
2e	ø Straight	45.00	38.00	0.00		Ti-6Al-4V bar, Para
1e	ø Straight	0.00	38.00	90.00		Ti-6Al-4V bar, Para
0e	--------	0.00	0.00	0.00		---

Figure 1. Exterior geometric dimensions of the block ultrasonic work tool, 35 kHz

The material used to build these block ultrasonic work tool, 35 kHz, mark titanium Grade 5 have acoustic and mechanical characteristics suitable for building, presented in the figure below. The variation of sound speed and fluency in the sonotrodes material, Ti Gr. 5, function to temperature is presented in diagram in figure 3.

MASTER MATERIAL PROPERTIES MENU

Information	
Material name	Ti-6Al-4V rod
≡Thin-wire wave speed	4555 m/sec at 24 °C
≡Modulus of elasticity	114.2 GPa
≡Density	4429 kg/m^3
Poisson's ratio	0.33
Q	26000

Figure 2. Mechanical and acoustic characteristics Ti Gr.5

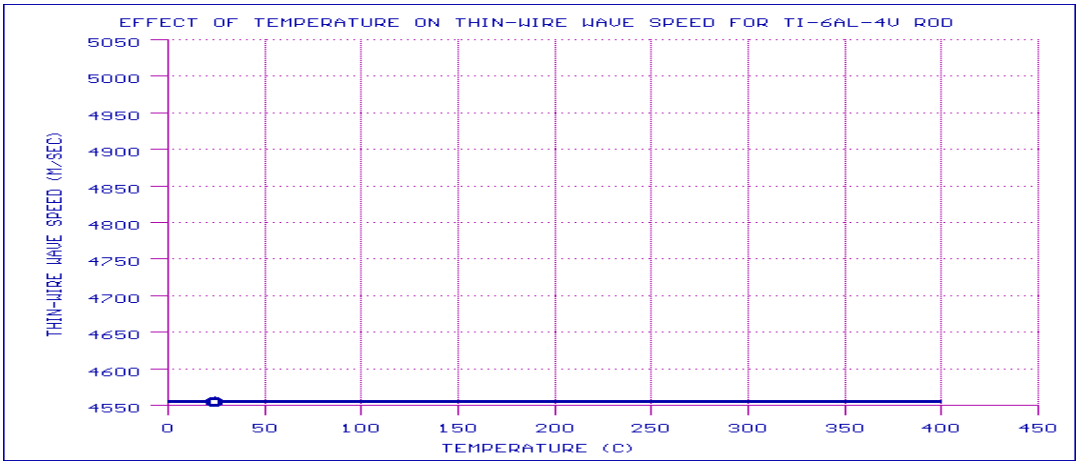


Figure 3. Variation of sound speed function temperature, Ti Gr.5

Figure 4 presents the elements that define a block ultrasonic working tool, 35 kHz , TiGr.5.

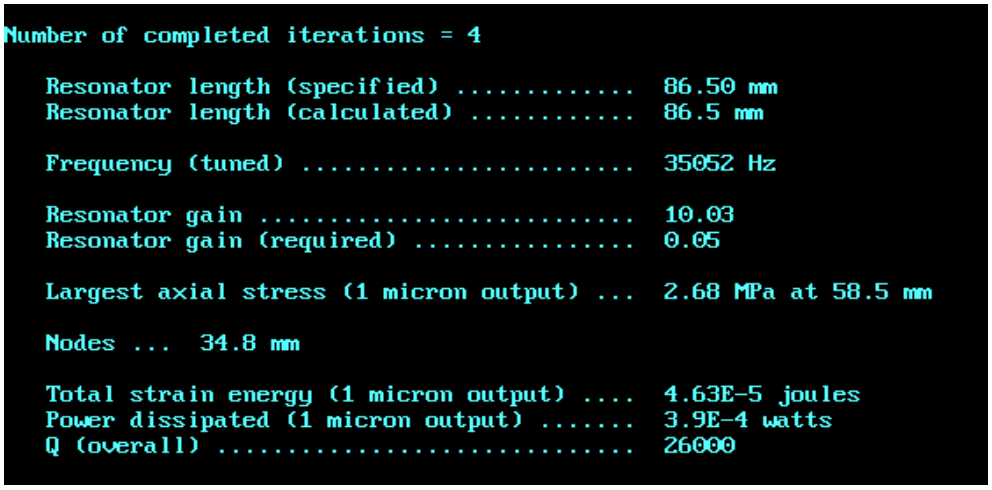


Figure 4. Defining elements for block sonotrode, 35 kHz, Ti Gr.5

Axial tensions representations highlighted after the simulation, reaching 2,68 Mpa, at X= 58,5 mm for 1 micron amplitude, is presented in figure 5.

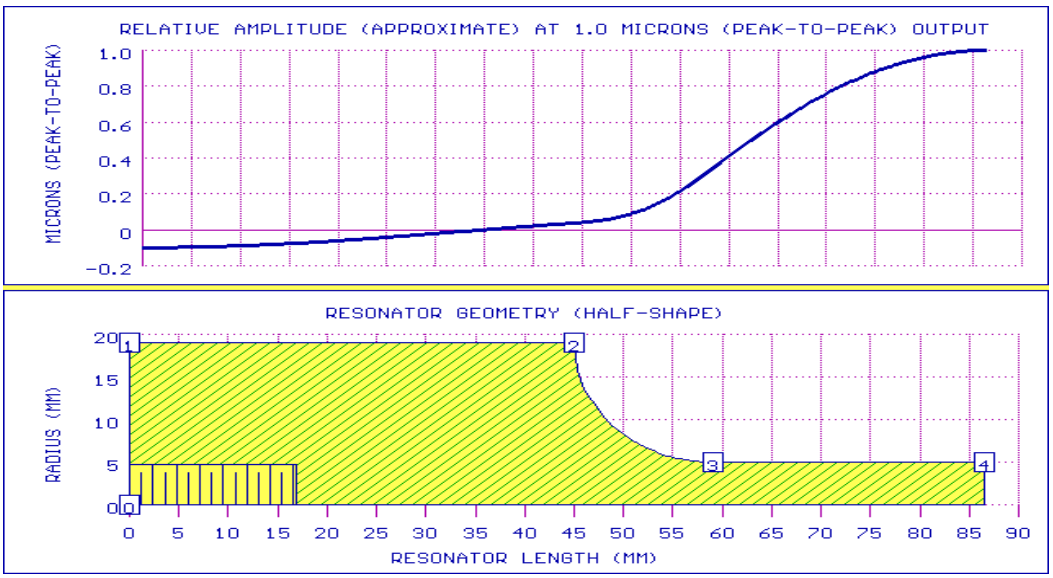


Figure 5. Axial tensions for block sonotrode, 35 kHz, Ti Gr.5

Vibration amplitude variations all along the sonotrode highlight a zero vibration knob at coordinates' X= 34,8 presented in figure 6.

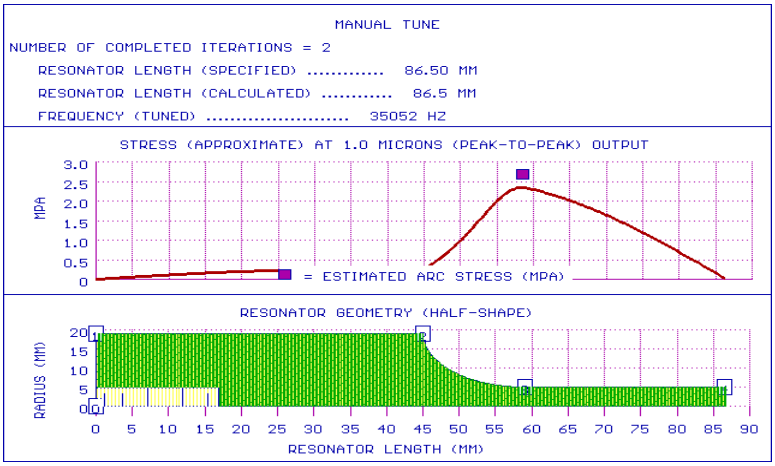


Figure 6. Vibration amplitude variations at 35 kHz for a TiGr.5 sonotrode

Deformation cumulated energy - in volume and linear, in the internal structure of the block sonotrode of 35 kHz, Ti Gr.5has a maximum value of 4,6 10^{-5} Joules, for 1 micron amplitude, presented in the diagram from figure 7.

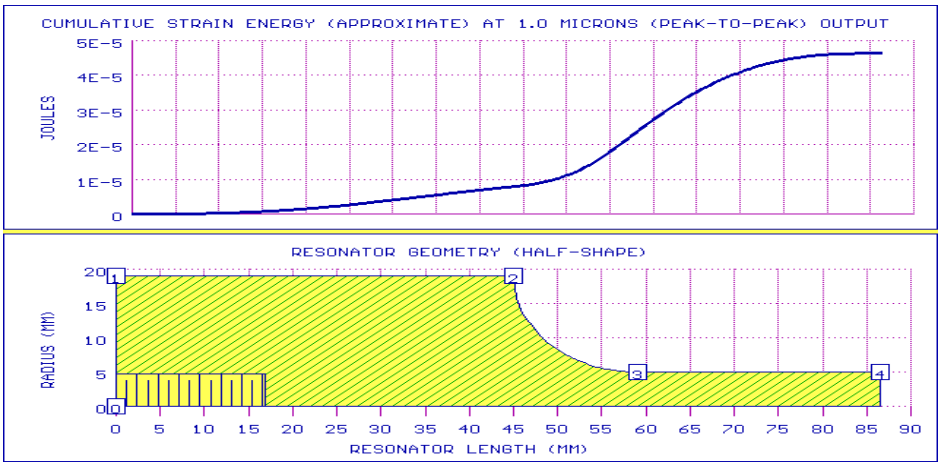


Figure 7. Cumulated deformation energy at a frequency of 35 kHz sonotrode TiGr.5

Cumulated energy loss- linear and in volume, in the internal structure of the ultrasonic work tool at 35 kHz, has a minimum value of 3,9 10^{-4} watt, for 1 micron amplitude, d is presented in the diagram from figure 8.

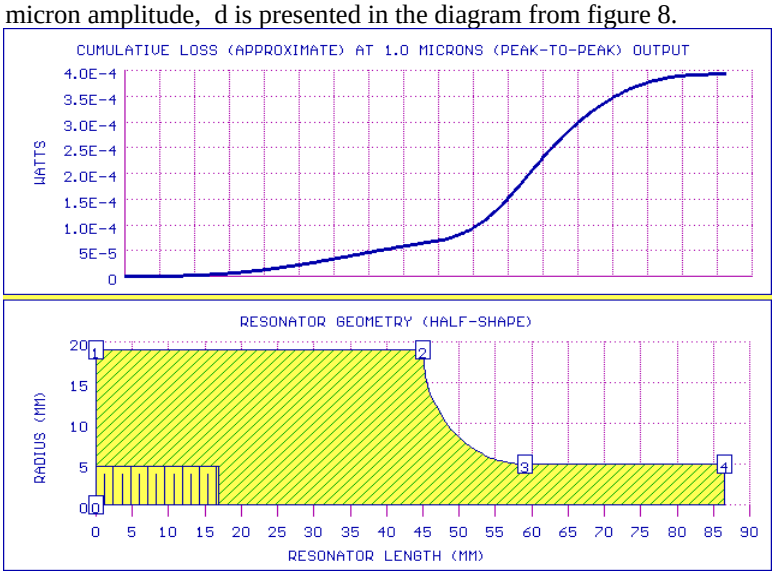
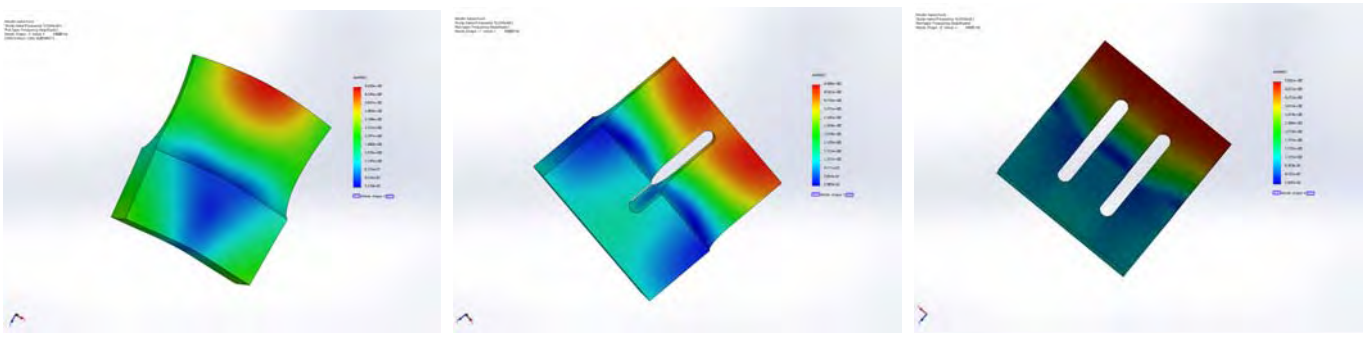


Figure 8. Cumulated energy loss at frequency 35 kHz sonotrode TiGr.5sonotroda TiGr.5

2. Finite element analysis for TiGr.5 sonotrode, used to process composite polymeric materials, 35 kHz, amplification report k=10,03

Finite element analysis for TiGr.5 sonotrode, in three constructive variations, block type figure 9 a, with a equalizing slot 9 b, and respectively 9 c, with two equalizing slots, it highlights an even repartition of amplitude leaving the ultrasonic work tool.

Constructive solution 9 c. was considered to be optimal, thus it was developed, ultra-acoustic calibrated, then tested regarding its technic and technological processing performances. It was mounted on an hybrid ultrasonic cutting equipment used to process composite polymeric materials.



a b c

Figure 9. Sonotrode constructive solutions Ti.Gr.5 , 35 kHz, amplification report k=10.03s

Figure 10 presents a Ti.Gr.5 ultrasonic cutting tool at 35 kHz, mounted on the hybrid ultrasonic processing equipment used on composite polymeric materials.

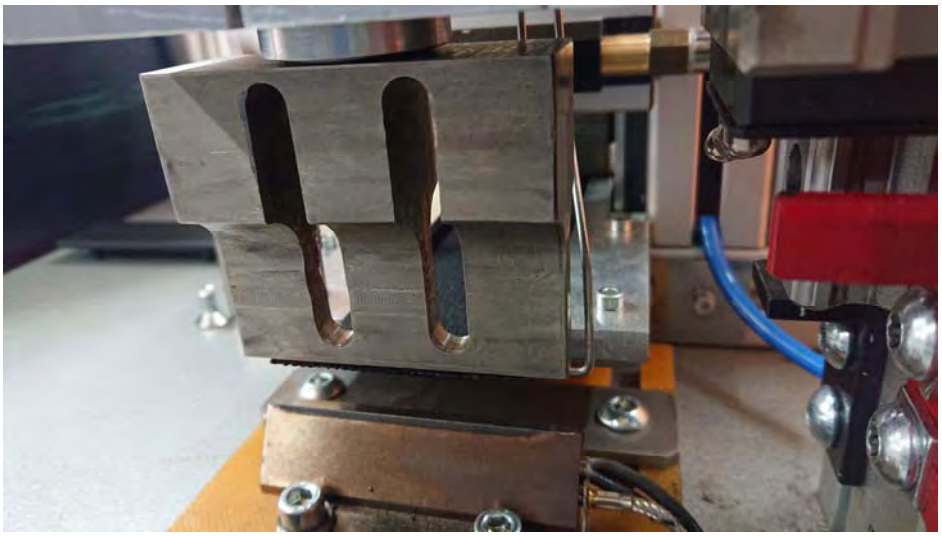


Figure 10. Sonotrode Ti.Gr.5 , 35 kHz, mounted on the hybrid ultrasonic processing equipment used on composite polymeric materials

3. Equipment and material used for experiments

3.1 Technical characteristics of the specialized equipment used to cut composite polymeric materials, using 35 kHz:

- Current: 240 V / 50 Hz
- Automatic and step by step operation;
- Technological parameters adjustment is done on a touchpad PLC, HMI programming.
- Maximum material length: 5 m
- Pressing force: 6.5 bar
- Ultrasonic processing time (force steeling time [1 s], processing time [3-5 s], retain time [3-5 s];
- Technological program saving mode YES
- Welding parameter monitoring YES

Ultrasonic module:

- Ultrasonic Generator: 1200W, 35 kHz;
- Piezoceramic Convertor 35 kHz;
- Booster 2:1 35kHz;

- Technological system action: electric + electro-pneumatic
- Compressed air pressure: 3,0 - 6,5 bar
- Productivity: 5 s / process cycle / processed material length: 315 mm
- Loading manual/automat;
- Unloading: automat gravitational

3.2 Composite polymeric materials characteristics

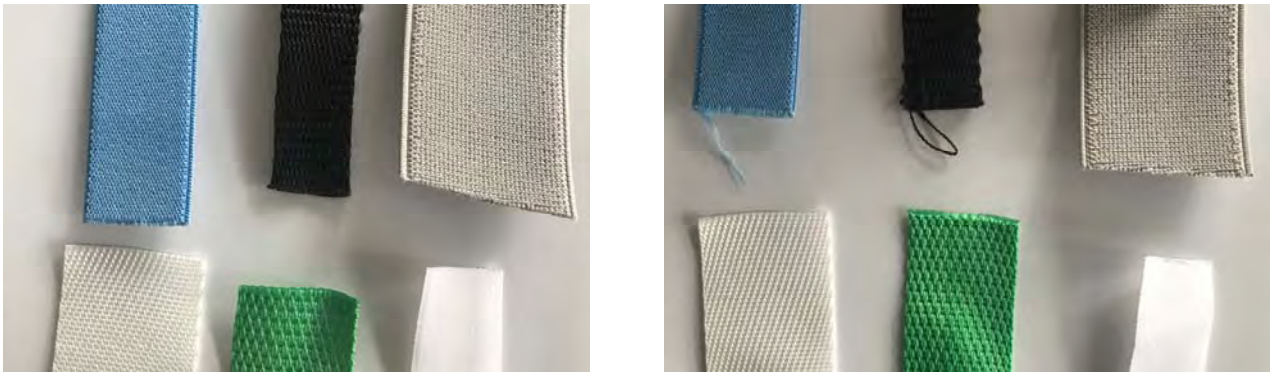
- Textile strip characteristics: Elastic CHRIS - Natural Rubber - rubber threads, sensitive to light, heat, greases, oils, acid bases, is recommended to keep them in dark and dark rooms. Over time, they age (especially by oxidation), lose their elasticity and become brittle.
- Length of sample: 315 mm
- Max. textile Width:60 mm

With this equipment and ultrasonic cutting tool we can process a various range of composite polymeric materials, function to specific adaptations, to each type of textile strip characteristics. Experiments presented were conducted on:

Polyester - properties for filament yarns and polyester short fibers:

- Tensile: 25-65 (textile filament yarn); 70-95 (technical filament yarns);
- 120◦C - temperature limit until the fiber losses its resistance;
- Stability to light: very good;
- Max. Effort elongation (%): 15-30 (textile filament yarn); 8-20 (technical filament yarns);
- Melting point: 228° C;
- Dimensional (wet) stability: very good;
- Painting capacity (without accelerator): weak;
- Repeated bending strength (cycles): 1775;
- Dimensional stability (dry): good;
- Electric discharge time (s): 2.

Figure 11 presents textile strips processed by using the hybrid ultrasonic processing technology and the Ti Gr. 5 ultrasonic cutting tool, congruent, left hand side, and on the right hand side samples processed by conventional processing technologies, inconsistent.



a b

Figure 11. Congruent samples, left hand side. Inconsistent samples right hand side

This hybrid technology has a clean, environmental friendly cut, materials that are processed can be safely used in the food, medical, textile and so on.

Conclusion

After proper investigations we can safely conclude that the ultrasonic titanium Grade 5 sonotrode is clearly suitable to safely process composite polymeric materials. It can be extended to sorts of typo-dimensions of composite polymeric materials that vary in texture and size

References

[1]. Yan Wang, Bin Lin Shaolei, Wang Xiaoyan Cao, (2014), Study on the system matching of ultrasonic vibration assisted grinding for hard and brittle materials processing. International Journal of Machine Tools and Manufacture, Volume 77, February 2014, Pages 66-73.

[2]. J.A. Gallego-Juárez, G. Rodriguez, V. Acosta, E. Riera (2010), Power ultrasonic transducers with extensive radiators for industrial processing. Ultrasonics Sonochemistry, Volume 17, Issue 6, August 2010, Pages 953-964.

[3]. Alex Patist, Darren Bates, (2008), Ultrasonic innovations in the food industry: From the laboratory to commercial production –. Innovative Food Science & Emerging Technologies, Volume 9, Issue 2, April 2008, Pages 147-154.

[4]. Nicușor-Alin Sîrbu, Octavian Victor Oancă, Emilia Florina Binchiciu, Gabriela-Victoria Mnerie, Darius Graur, (2018), Method and technologies for cutting and sealing composite polymeric materials, The 9th International Conference "Innovative technologies for joining advanced materials", TIMA 18, 1 - 2 November 2018, Timișoara, Romania

[5]. Joel B. Harley, Jose M. F, Moura , (2012), Scale transform signal processing for optimal ultrasonic temperature compensation –. IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Volume: 59 Issue: 10, 2012.

[6]. J. Sackmann, K. Burlage, C. Gerhardy, B. Memering, S. Liao. W. K. Schomburg, (2015), Review on ultrasonic fabrication of polymer micro devices-. Ultrasonics, Volume 56, February 2015, Pages 189-200.