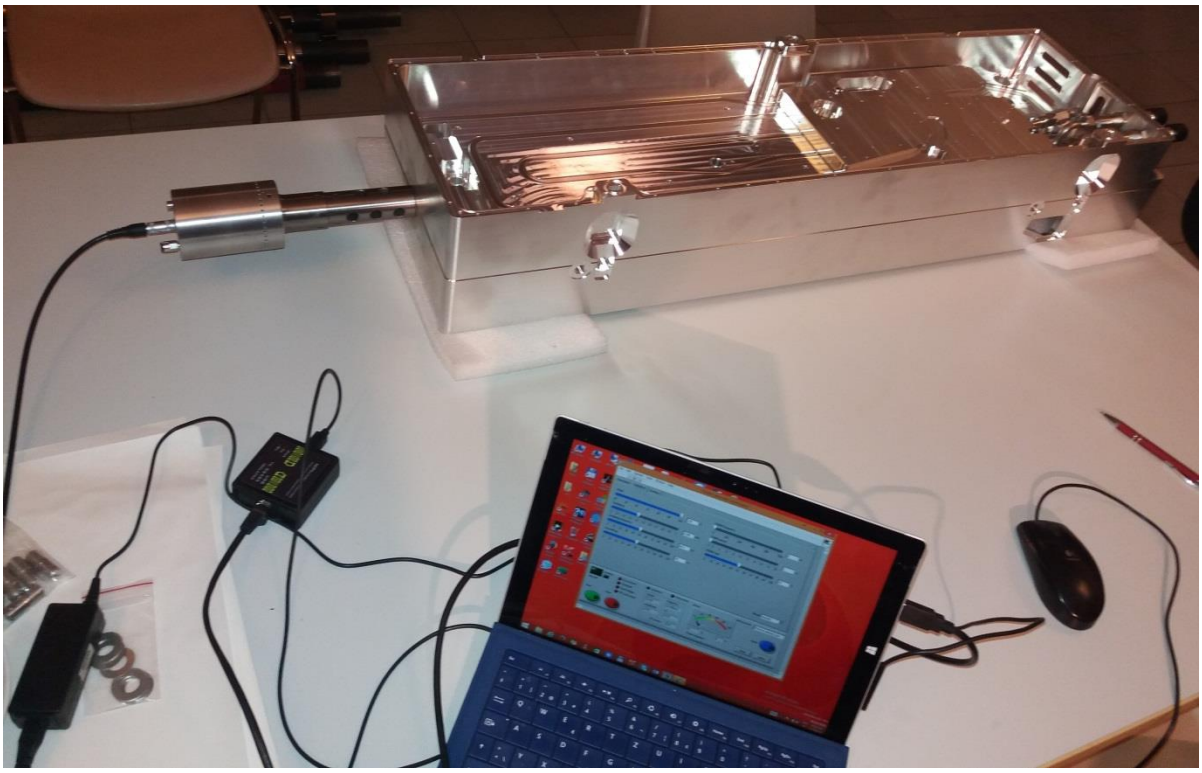
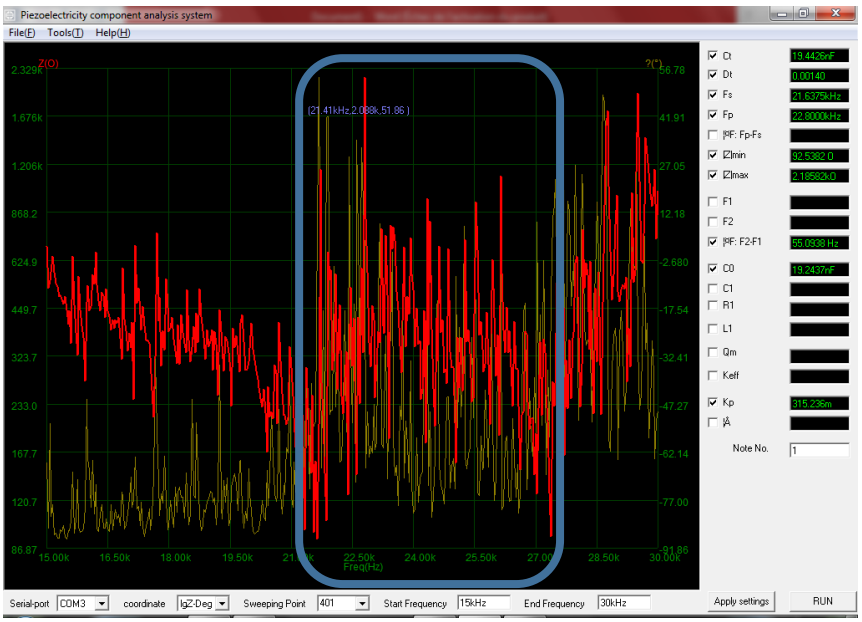
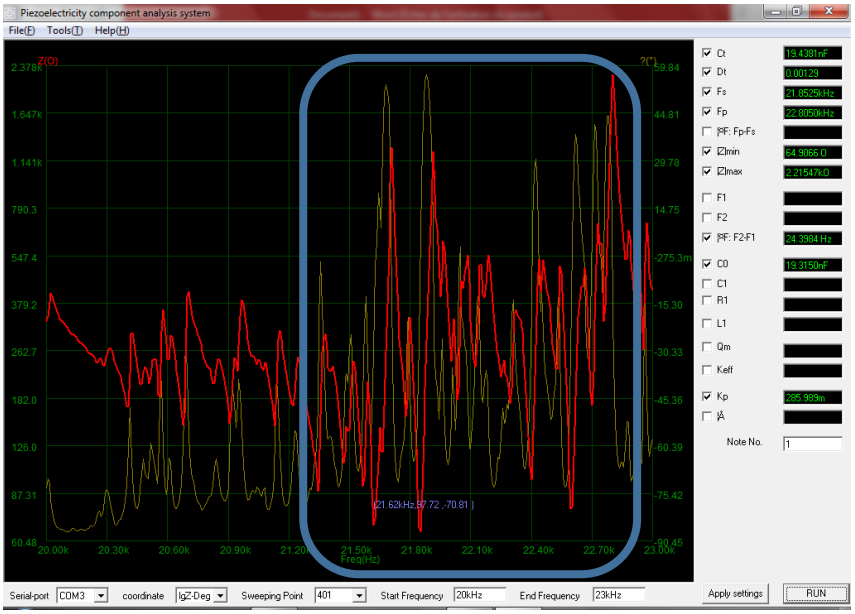
MMM Residual Stress Removal



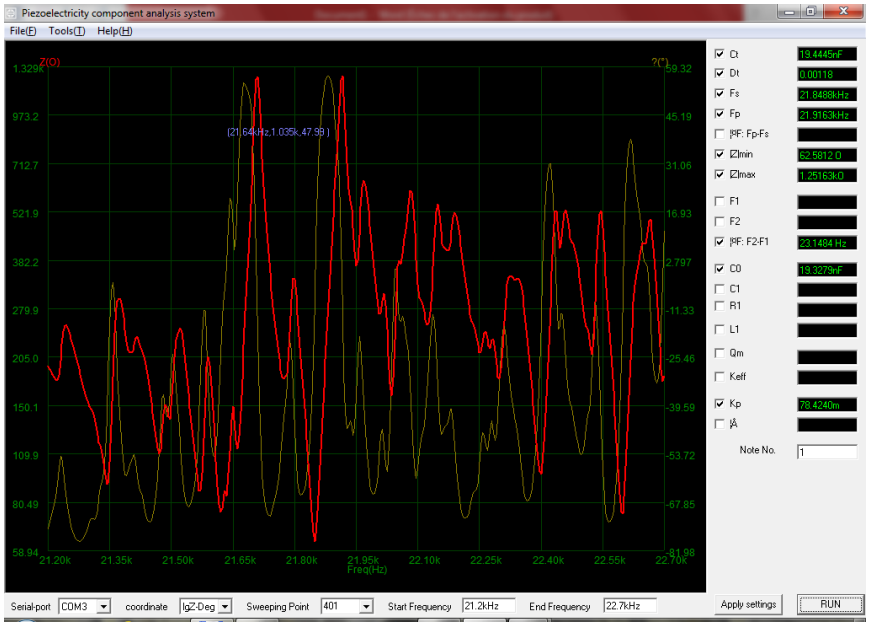
For initial scanning, it is very useful to have an Impedance Network Analyzer. First, we make Impedance-Phase-Frequency scanning in a larger frequency interval (here from 15 kHz to 30 kHz). We can roughly see that dominant resonant modes are between 21 and 27 kHz. We try to be closer to 20 kHz, since ultrasonic transducer used for this processing has 20 kHz as its resonant frequency (when not loaded or when operating in air).



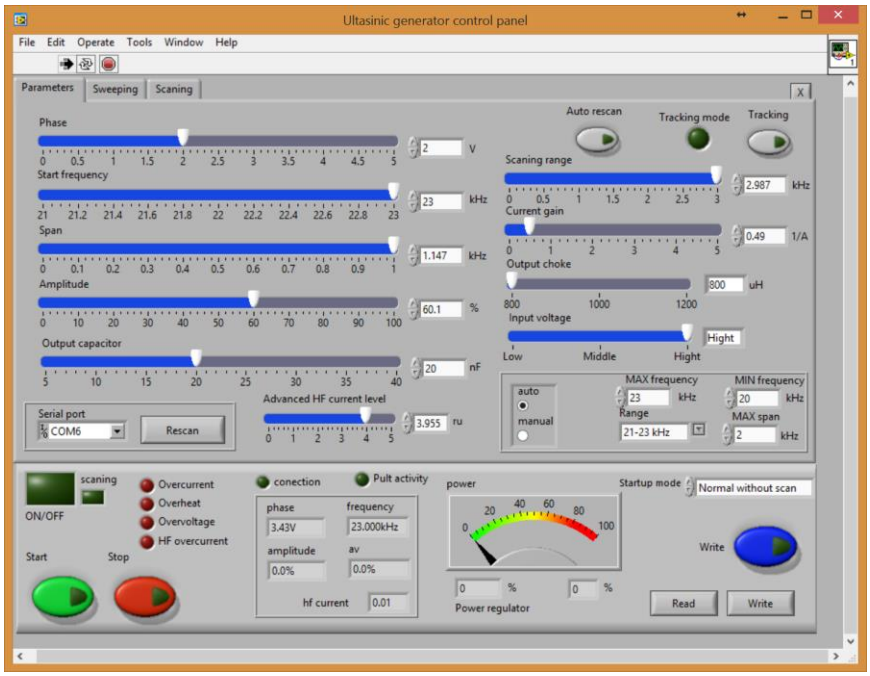
Now we shorten the scanning interval (from 20 to 23 kHz). Again we roughly see that group of dominant resonant modes is between 21.2 and 22.7 kHz. Here we also try to select group of resonant modes closer to 20 kHz (since applied ultrasonic transducer is optimal for frequencies close to 20 kHz).



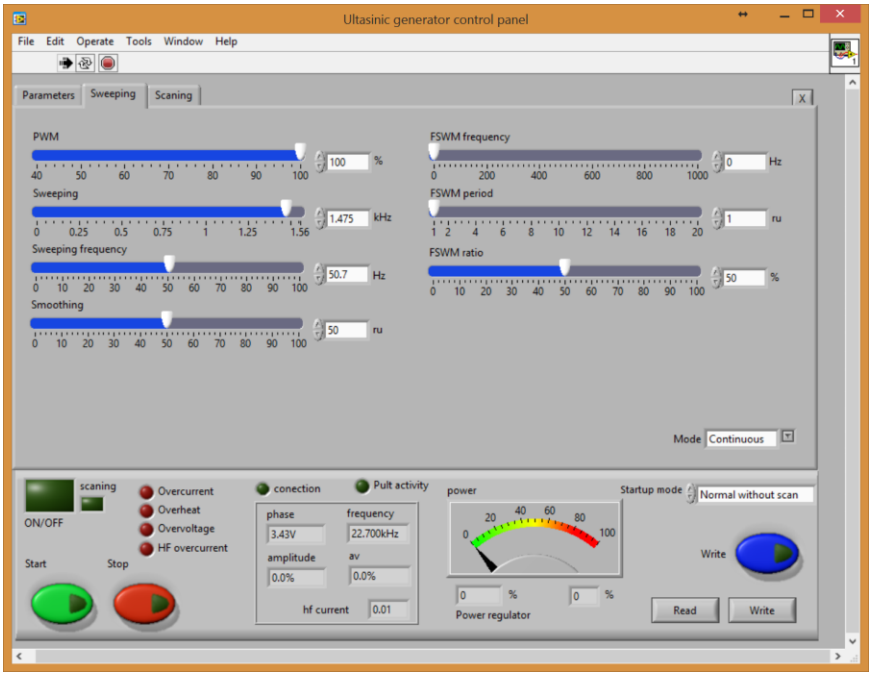
Now we select (visually, by intuition, and trying to be closer to 20 kHz reference) that our frequency sweeping interval will be from 21.2 and 22.7 kHz. The length of this interval is 1.5 kHz. In this frequency interval, we will apply frequency modulation (sweeping) until 1.5 kHz. Repetition rate or periodicity of applied frequency sweeping interval will be selected between 1 and 50 Hz. This is the speed of sweeping. For driving big, massive metal objects, it is not recommendable to select very high speed of sweeping (for instance 100 Hz), since big metal masses have certain inertia, and would not follow very high sweeping speed. Until 50 Hz repetition, it is empirically known that frequency sweeping will have good, measurable effects regarding stress relief.



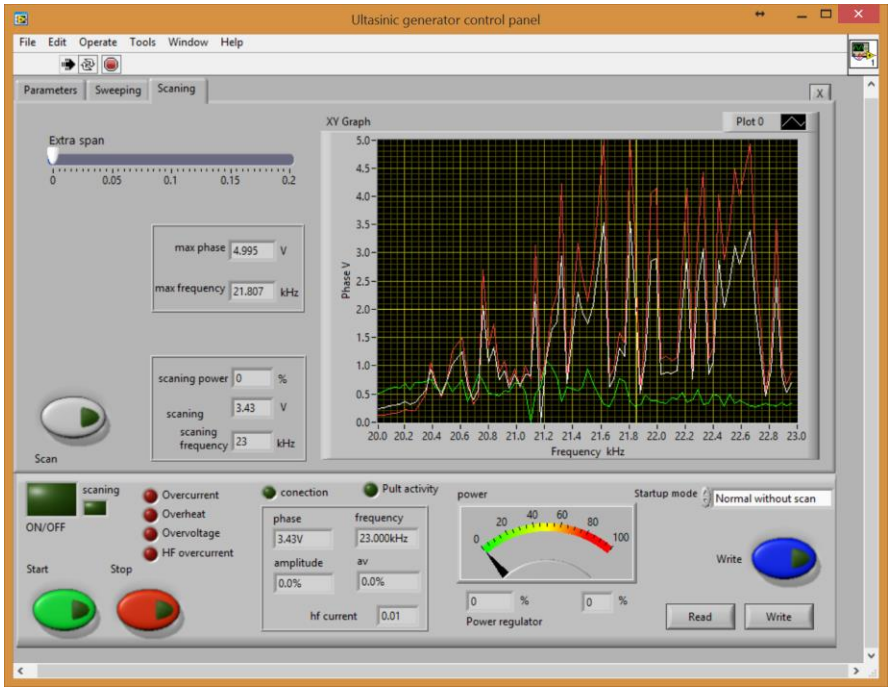
If we do not have Impedance Network Analyzer, we will perform all scanning and settings using only AMMM ultrasonic generator. Let us make initial generator settings as on the picture below.



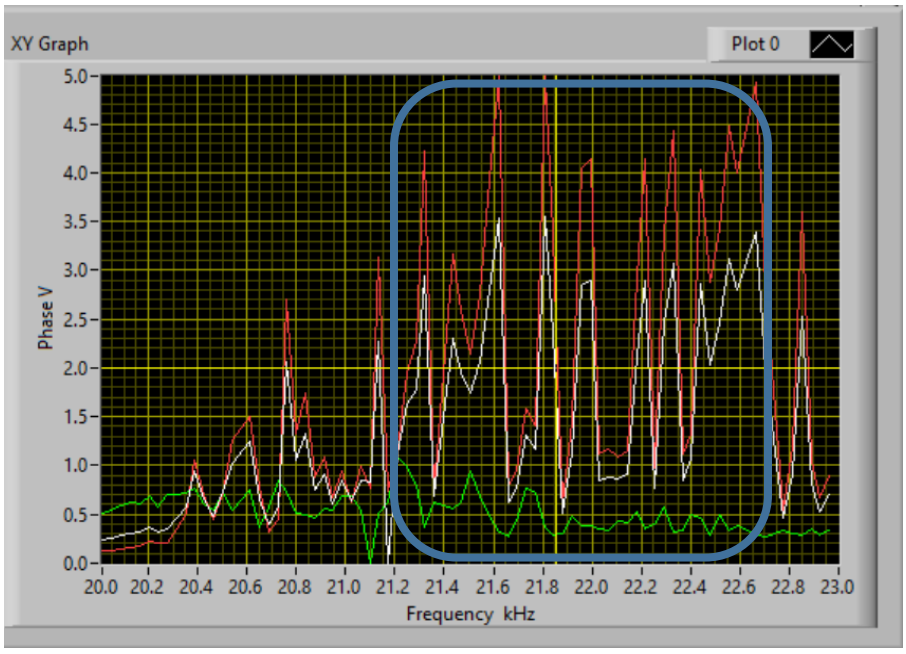
On the second, sweeping parameters software Tab we will temporarily select Continuous operating mode (meaning no sweeping, no modulation), as on the picture below. Practically, all sweeping parameters are deactivated (or irrelevant) when we select Continuous operating mode.

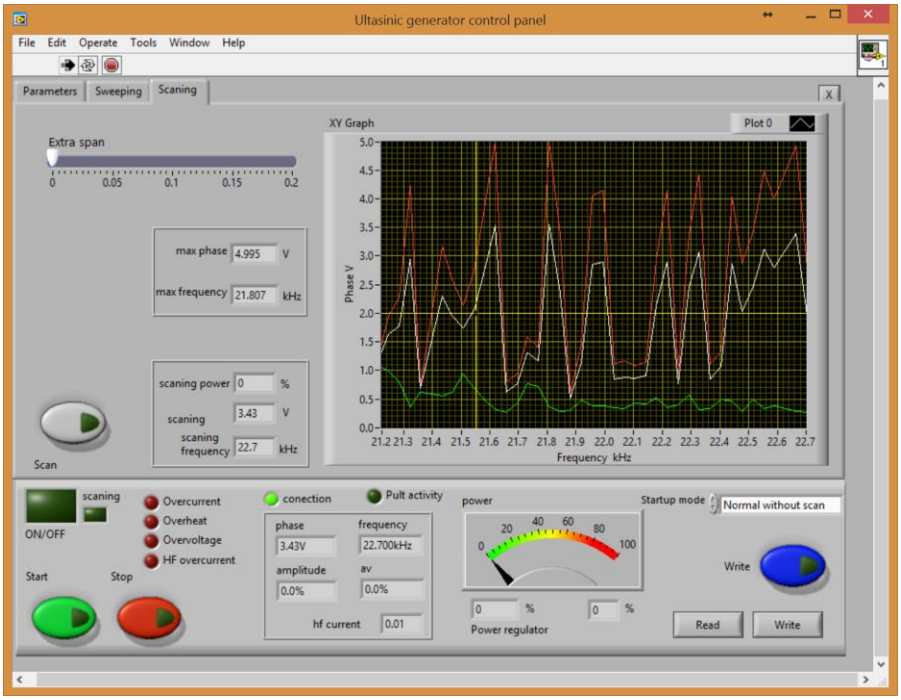


Now we make scanning using AMMM generator, from 20 to 23 kHz. We will get similar scanning picture as when using Impedance Network Analyzer, and from this picture we can select group of dominant resonant modes.

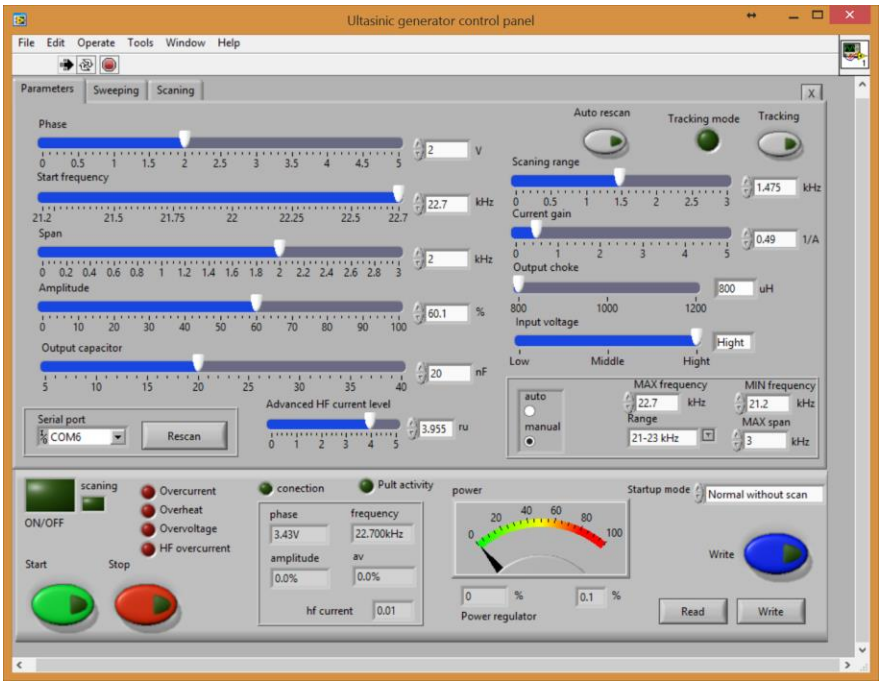


Again, visualy and roughly we select frequency interval from 21.2 and 22.7 kHz to be our frequency sweeping interval, as presented on the pictures below. Sweeping interval will be 1.5 kHz = 22.7 – 21.2 kHz. Based on such selection, we will make other generator settings.

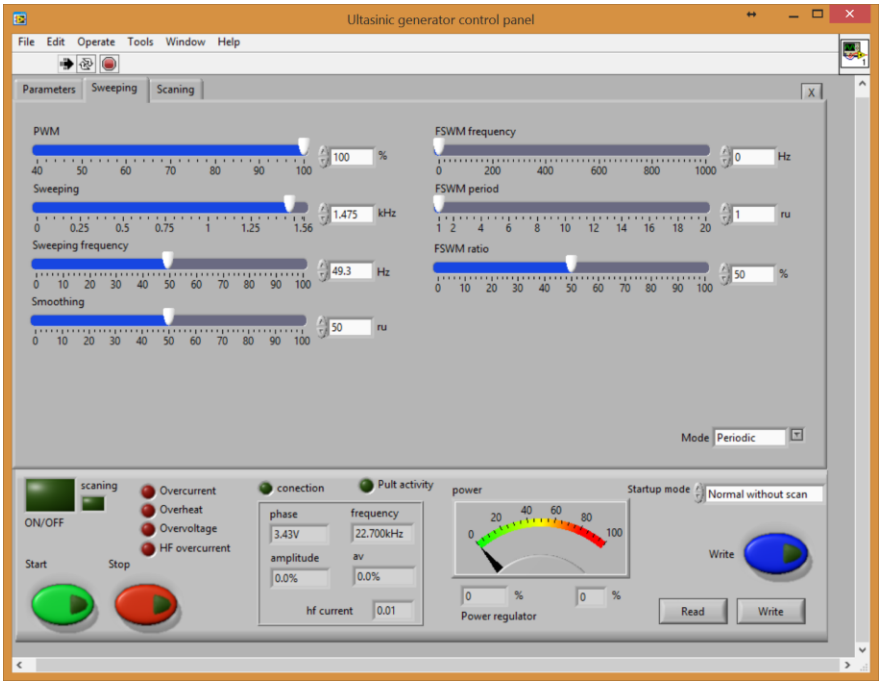




Let us now make AMMM generator settings. We select operating frequency interval from 21.2 until 22.7 kHz (where start frequency is 22.7 kHz, and generator will periodically sweep towards lower frequencies for maximal frequency duration of 1.5 kHz. We select frequency Span to be little bit larger (here 2 kHz) than selected sweeping interval (here 1.5 kHz), to account possible thermal and loading frequency shifts towards lower frequencies. Oscillating amplitude will stay around 50%, or here selected is 60%. Other parameters are related to safe operating performances of generator and transducer (selected by testing and based on operator's experience).



Now we will select “Sweeping” parameters software Tab. Sweeping frequency interval will be roughly 1.5 kHz (here selected 1.475 kHz). Sweeping repetition rate (Sweeping frequency) will be 50 Hz (or we could also select something below 50 Hz, based on testing and trying to get smooth, uniform, regular excitation of the body under treatment). Other parameters are selected based on experience and to get smooth, continuous operating regime.



Now we can start the generator and vibrate the solid body several minutes, what will be enough to remove all residual stress. This kind of vibrational excitation we define as MMM processing.

Infrared stress monitoring during MMM ultrasonic processing

is only an infrared visualization of temperature differences existing in zones of high stress under forced vibrational (ultrasonic) agitation. This method is not very precise, but it is very much logical, intuitive, indicative, and expected to be very useful (since internal molecular friction produced when using forced MMM, sonic and ultrasonic agitation is higher within zones of high residual stress. MMM agitation is generating heat, as long as we apply MMM forced excitation, and as long such stress will exist. We do not measure stress level that way, but we can get visual information showing that stress will produce heat under forced MMM vibrations… Using infrared visualization, we also see when such dynamically induced stress will disappear. We can initially get mostly surface effects of stress related heat dissipation, but since heat is slowly propagating from deeper zones of metallic objects towards surface, we will also see if stress still exist in deeper locations. Here is nothing to quantify, but once when we see that treated object has uniform temperature (everywhere), we can be sure that we eliminated internal, residual stress. Understanding of this will be much better or easier during practical demonstration.

Practical steps with infrared camera to show how residual stress will gradually disappear:

1. Take a very sensitive and fast (high-resolution) infrared camera and adjust it to see the thermal picture of the cold solid object before ultrasonic treatment. The object that will be treated initially has uniform room temperature. No hot spots on infrared camera screen. Camera could be from FLIR.
2. Now we start vibrating the object and monitoring with infrared camera. Suddenly (after first few seconds) we start seeing hot spots in different places of the treated object. Such hot zones are zones of elevated internal, residual stress, produced by sonic and ultrasonic agitation. After several seconds, hot zones will rich certain maximum and stabilize.
3. If we continue applying MMM vibrations and monitoring the object with infrared camera, we will start seeing how hot zones are getting fuzzy and slowly enlarging and disappearing. This is the sign that residual stress is disappearing, and that the object under treatment riches new, stable and uniform temperature distribution.
4. Now we stop ultrasonic treatment during 5 to 20 minutes, and wait that object will again rich stable, uniform, room temperature.
5. Now we repeat monitoring with infrared camera and apply the same MMM ultrasonic agitation, and we will notice that we will no more have red, hot spots on the threated object.