Advanced Technology and Manufacturing Institute

Vacuum Hot Press System Operation

Revision	Date	Description	Curator
0	6/03/08	New document	Todd Miller
1	11/19/08	Title change, updated process sequence	Todd Miller
2	9/15/09	Updated Vacuum System Operation Check Sheet to accommodate install of new gauges and controller	Jack Rundel
3	6/3/10	Clarification in Vacuum System Operation Check Sheet on loading and unloading.	Jack Rundel
4	9/04/14	Update to reflect turbo pump operation and include metal bonding parameters.	Todd Miller
5	10/06/14	Clarification of idle state temperature settings.	Todd Miller
6	7/17/18	Edited to reflect institute name change	Todd Miller
7	1/04/19	Minor updates and corrections	Todd Miller

System description

The vacuum hot press (VHP) is comprised of a high temperature electrical furnace (1200C, graphite elements, and graphite chamber lining) and a hydraulic ram capable of exerting many thousands of pounds force. The end rods are graphite. The vacuum system consists of a turbo pump with backing pump and a separate roughing pump.

Safety and equipment care considerations

Consistent with fabrication floor policy, safety glasses MUST be worn when operating the VHP.

The press is capable of delivering force in excess of what he graphite rods can withstand. Additionally, the pressure exerted is dependent upon the open areas within the device being presses. The area bearing the force applied by the rods is unique to each device and must be determined prior to system operation. DO NOT EXCEED 1500 psi WITHOUT PRIOR CONSULTATION WITH ATAMI STAFF.

Graphite or alumina blocks MUST be used between the graphite rods and the part being pressed. A release agent such as Zyp boron nitride MUST be applied between the blocks and the part being pressed to prevent bonding.

The furnace MUST NOT be opened at temperatures above 100C. Oxidation and degradation of the graphite elements will result if opened at temperatures above 100C.

If an anomalous response is experienced when operating the system, stop work and report the circumstances to ATAMI staff immediately.

System Operation for Metal Laminae Bonding

The general sequence for bonding metal parts in the VHP is as follows:

- Ultrasonic cleaning of metal shims, especially if patterned using the ESI laser. Cleaning for 60 minutes at 35C in a detergent bath (e.g. Citrinox) is recommended.
- Rinse and dry completely after ultrasonic clean. If you are particularly concerned about the condition of the shim surfaces, a solvent clean can also be done (acetone, methanol, DI water). Dry using N2. Successful stainless steel bonding is routinely done without solvent cleaning.
- Stack and align shims. Use of alignment pins is best for maintaining alignment during the bonding process.
- Ensure the graphite blocks have appropriate relief holes for your alignment pins in them. This should be checked well before you plan on bonding to allow time for modifying the blocks, if necessary.

- Prepare graphite blocks by spraying boron nitride (Zyp) coating on them. Spray a very thin layer on the surfaces contacting the shims, allow 2-3 minutes to dry, and apply a second coat, as necessary. Allow 30 minutes for the coating to dry and outgas before placing your shim stack between them. It is best to spray the graphite blocks the day before your bonding.
- It is highly advised that you plan for two days to make your bonding run. The first day you should run a "burnout" cycle to allow the system to outgas at your bonding temperature. This ensures a clean system and increases the likelihood of a successful bond. On the second day, loading your parts in the morning will allow you to attend the tool and apply your bonding pressure during the day. After the system ramps down overnight, you can unload your parts the next morning. If the system has been recently run (within a day or two) up to your bonding temperature, the burnout cycle can be skipped.
- When you approach the VHP, it will likely be in an idle mode where it is in high vacuum and at a temperature of 100°C. The Eurotherm temperature controller will be in "Auto" with the temperature manually set at 100°C. The "Run/Hold" indicator light will be off. Prior to venting the system turn the furnace power off to prevent the furnace from trying to heat up while loading.
- Prior to venting note the base pressure (ion gauge reading, Channel 1) on your logsheet. The pressure should be in the low E-6 range.
- Vent the VHP chamber by pressing the red button marked "vent". Turn off the ion gauge (Channel 1) by pressing the EMIS button on the controller. Monitor the system pressure using the TC gauge (Channel 3). You will hear the system valving automatically close the gate valve isolating the turbo pump. Wait until the pressure reads 760 Torr (7.6 E+2) before opening the chamber.
- Turn on the hydraulic pump to operate the furnace elevator and rams. Switch the elevator position valves to "raise" and "on" (ensuring the force valve position is "off") to open the chamber.
- Place your part stack on the bottom rod (lower the rod as necessary to create an adequate opening). Refer to the center of furnace position indicated on the frame. Ensure that the center of your part is level with this position. If it isn't, add additional graphite blocks to raise the part to the proper level. If your part is too high, as can occur with a tall stack, or way too low, you may need to change the bottom rod to a shorter or longer rod, respectively. This is easily done, but great care should be taken, as the graphite is brittle and weak under tension. Only screw the rod in so that it seats firmly; DO NOT OVERTIGHTEN.
- Apply a slight amount of force (turn position valve to "press" and "on", elevator position will need to be "off"). Reduce the force on the by turning the force control knob before the rod contacts your stack to avoid excessive pressure. Then turn the pressure up until the force readout just begins to response, a reading of about 500. This force will hold you stack in a stable position, but also allows for thermal expansion during the ramp up to the bonding temperature.
- Place the thermocouples in close proximity to your part. You may need to work with them a bit to position them in close proximity to the rod and safely away from the heating elements. One thermocouple controls the furnace, while the other three are read by the data logger. Be sure to monitor the data logger for verification of temperature (a safety precaution in case of a faulty thermocouple.)

- Before closing the system, wipe the top of the chamber o-ring with a Kimwipe to remove and particles that may have fallen onto it during part loading. If the o-ring came out of the groove when vented (as can happen if the chamber is opened before it reaches > 760 Torr), remove the o-ring and lightly grease it with vacuum grease. Lightly grease means uniformly coating the o-ring with a very small dap of grease, then wiping the o-ring with a Kimwipe. Only a small residue of grease should be left on the o-ring. Excess vacuum grease burns off at typical bonding temperatures and impacts the vacuum quality and pump performance. Carefully clean the o-ring groove with a Kimwipe before replacing the o-ring.
- Close chamber and pump down to high vacuum by pushing the green button labeled "pump". When the system is clean and there are no leaks, it will take less than 5 minutes for the system to pump down and crossover to high vacuum, which is signaled by all four indicated light being lit (1-4). Light "3" is the last to light up and does so when the crossover setpoint is reached (5.0 E-2). If the system takes longer than 15 minutes to crossover, vent it and regrease and reseat the chamber o-ring. If it still takes more than 15 minutes to reach crossover, contact ATAMI staff for assistance.
- After the vacuum system has crossed over to high vacuum, light the ion gauge (on Channel 1, press "EMIS"). The vacuum should drop down into the E-6 range within 10-15 minutes.
- Adjust the temperature setpoint to the actual reading. Turn on the furnace power. Slowly raise the setpoint to 2 degrees above the actual and allow time for the controller to respond. SLOWLY ramp the setpoint to 100°C being careful to avoid excessive overshoot. Allow the system to idle at this temperature for 30 minutes or more prior to initiating your ramp to allow for outgassing of volatiles and water vapor.
- Program your desired temperature profile. Programming the Eurotherm is covered during practical VHP training; if you need subsequent assistance, contact ATAMI staff. One note, however, is to be sure the "RUN" number references the appropriate "PROG" number. A standard condition for bonding stacks of thin stainless steel layers is 1000°C at 1000 psi for 60 minutes. The conditions are dependent up the total size of the part as well as the layer thickness. The following restrictions apply to temperature control of the VHP:
    - Do not adjust the power limit knob on the control panel. Doing so will put the VHP at risk of overcurrent condition, tripping the breaker and power to the whole system. This puts the system at great risk of damage and will ruin your process run. The power knob is currently set at 7.19.
    - Maximum temperature is 1150°C. If you need to go to a higher temperature (up to 1200°C), consult ATAMI staff.
    - Ramp rates are limited by the thermal response of the system as well as the vacuum integrity. Too high of ramp rates result in a large lag of actual temperature to control temperature and also create excessive outgassing rates that degrade the vacuum. Maximum ramp rates are as follow:
        - 100 - 700°C; 7°C/min
        - 700 - 900°C; 3°C/min
        - 900 - 1000°C; 1.5°C/min
        - 1000 - 1100°C; 1.0°C/min

    - 1100 - 1150°C; 0.5°C/min
- Start your temperature ramp. During the ramp, monitor the system pressure, particularly above 500°C. Note the system pressure periodically through the ramp on your logsheet. If the pressure rises into the E-4 range, put your temperature ramp on "Hold" and allow the pump to catch up with the outgassing. If the pressure persists in the E-4 range, you likely have a system leak and it is highly recommended that you abort your run and restart. If you find yourself in this situation, seek out ATAMI staff for assistance.
- When the system reaches your bonding temperature, increase the ram force to achieve the bonding pressure you determined previously and based on the effective area on your stack. The force control is a simple needle valve; accurate adjustments are difficult. Additionally, the force tends to drift down. It is highly recommended that you attend the system to monitor and adjust the force.
- Once the bonding cycle is complete, reduce the pressure on the rams and initiate the temperature ramp down. Ramp down rates of 5°C or less are recommended.
- Remove your parts the following morning. Push and hold the "RUN/HOLD" button on the Eurotherm until the indicator light goes to end your thermal cycle. Reduce the temperature setpoint to below 15°C (controller still in "AUTO"). Vent and open the chamber to remove your parts. Be sure to place the thermocouples near the center of the heat zone (as indicated by the label on the frame) prior to closing it and pumping down.
- Close the chamber attending to the o-ring as before, and return to high vacuum (push "pump"). Having just gone through a high temperature cycle, the system should pump down in 7-20 minutes. If it takes longer than this, vent, lightly grease and re-seat the o-ring, and pump again. If it still takes longer than 20 minutes, notify ATAMI staff.
- After the system has crossed over to high vacuum, turn on the ion gauge and raise the temperature setpoint to 100°C (controller in "AUTO").

VHP Operation Log Sheet

Date, time: _____
Operator: _____
Base pressure prior to loading (Channel 1): _____
Target dwell temperature: _____

*** Note time for crossover to occur (time from pushing "pump" to reaching 5E-2) ***

Time	Temperature	Pressure	Comments