German Advanced Composites
Fast Forward with Innovation

Vacuum Basic Knowledge

Pressure is the amount of force acting vertically per unit area. The symbol of pressure is p.

The atmospheric pressure that we experience on earth is caused by the weight of air above the measurement point and for this reason it varies with the altitude above sea level. The standard atmosphere (atm) however is an established constant. It is approximately equal to typical air pressure at earth mean sea level and is defined as follows:

1 atm = 760 Torr = 29,92 "Hg = 14.7 psi = 101.3 kN/m2 = 1013 mbar = 1013 hPa

In practice, atmospheric pressure at sea level will vary from about 980 mbar to about 1030 mbar. At the summit of Mount Everest atmospheric pressure averages about 300 mbar.

The barometer in our home gives an absolute (atmospheric) pressure. The reading is the pressure above the absolute zero of pressure (or perfect vacuum). The vacuum of an infusion set-up is measured with an analog dial gauge (or manometer), usually mounted on the vacuum pump or resin catch pot, and the reading is relative to the external atmospheric pressure. This relative measurement is called gauge vacuum and is the pressure difference below the atmospheric pressure. Actually the vacuum gauge (manometer) works the opposite way to the barometer.

Thus the absolute pressure in the vacuum bag or resin trap is equal to the current atmospheric pressure minus the gauge vacuum pressure ($P_{abs} = P_{atm} - P_{rel}$). Relative pressure (the gauge vacuum) is the driving force for the resin to get into the part. It is the difference between the atmospheric pressure and the absolute pressure in the bag ($P_{rel} = P_{abs} - P_{atm}$)

That means that in a location such as Florida (sea level with high atmospheric pressure) you get more pressure and can infuse over a longer distance than someone doing infusion in the mountains of Colorado. Weather affects the infusion process in the way that good weather provides higher pressure and bad weather lower pressure.

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This means that the residual pressure inside the lay-up may differ from the gauge reading because of changes in atmospheric pressure due to changing weather conditions and altitude variations. For instance at sea level and standard weather (P_{atm} = 29.9 inHg) a gauge vacuum (P_{rel}) of 25.9 inHg is equivalent to an absolute pressure of 4 inHg. In other words, the vacuum gauge that read, for example, 25.9 inHg at full vacuum is actually reporting 4 inHg, or 136 mbar absolute pressure. That is still in the low vacuum.

For a high-quality infusion process we strive to achieve an absolute pressure in the range of 10mbar (0.145psi or 0.295inHG) to 20mbar (0.29psi or 0.59inHG) above the absolute zero of pressure at the pump. We are able to achieve this with oil lubricated vacuum pumps.

If we want to confirm that a bag has been evacuated to this degree of vacuum, the gauge used to measure this value needs to be accurate in this region.

A conventional analog dial gauge, usually mounted on the vacuum pump or resin catch pot will experience inaccuracies of at least ±25 mbar from weather variations alone, plus variations due to the accuracy of the mechanism within the gauge, typically between 1 and 3% of full scale, perhaps another ±30 mbar.

It is apparent that an analog vacuum gauge with a total accuracy of ±55 mbar (1.62inHG) is not an appropriate instrument for measuring an in-bag vacuum of 10 to 30 mbar.

If the purpose of the vacuum infusion process is to produce high-quality parts, we recommend to use a digital absolute pressure gauge to measure the vacuum level. Such a device measures the pressure relative to the absolute zero of pressure and is unaffected by weather or altitude, so you know exactly what is happening inside the vacuum bag.

We have gained excellent experience with the Greisinger GDH 200-14 in countless projects. It responds to pressure changes with a resolution of 1mbar down to absolute zero in an instant which does not only save time with setting up the vacuum system and finding leaks. It is also a reliable performance indicator for the quality of the infusion process.

Vacuum integrity or the significance of leaks

Where vacuum bagging can be more tolerant regarding leaks, with vacuum resin infusion leaks in the vacuum system are impermissible. This is because a leak in the set-up will create a line of air bubbles from the origin of the leak all the way to the exit of the lay-up. If the bag and associated parts don’t hold vacuum, you will not be able to produce high-quality products no matter how hard you try.

Resin penetration in the region of this line of bubbles will be reduced with a resulting reduction in structural properties and poor appearance. The great thing about the infusion process is that you can pre-test for vacuum integrity before you shoot the resin.

The existence of vacuum leaks can be checked prior to infusion with a pressure rise test. First be sure there are no leaks in the vacuum pump, resin trap and connections to each other. After evacuating the lay-up to maximum vacuum for as long as practicable, close the vacuum line between pump and resin trap and observe the change in vacuum on the digital absolute pressure gauge connected with the resin feed line. A slight pressure variation is normal but the question is how fast this occurs. A visible movement is easy, go back to the vacuum bag and continue searching for big leaks.

A pressure rise of 3 mbar in 15 min is about the maximum (for me) that is acceptable. (Don`t try to measure this with an analog dial gauge. We have learned above that it is by far too imprecise)

This doesn't mean there are no leaks anymore but finding them will take a lot more effort depending on the size of the set-up.

Finding and repairing vacuum leaks, especially in resin infusion applications, can be a complex process, involving issues such as mould quality, bag quality, bag connections, bag sealing techniques and vacuum tubing quality. Consumables of good quality may cost more than those of lower quality but the time saving from reduced leak problems is likely to outweigh the material cost saving.

The use of a precise digital absolute pressure gauge is a must to shorten the time used to find the leaks.