

Equipment for Sucking and Holding

Laser micromachining equipment uses suction to extract fumes from the process area, and to hold parts in place during processing. The suction circuit comprises a pressure/suction generating device, which might be called a pump, blower, fan, extractor etc. The name reflects habitual use in some specific applications area, the basic physics is the same in all cases.

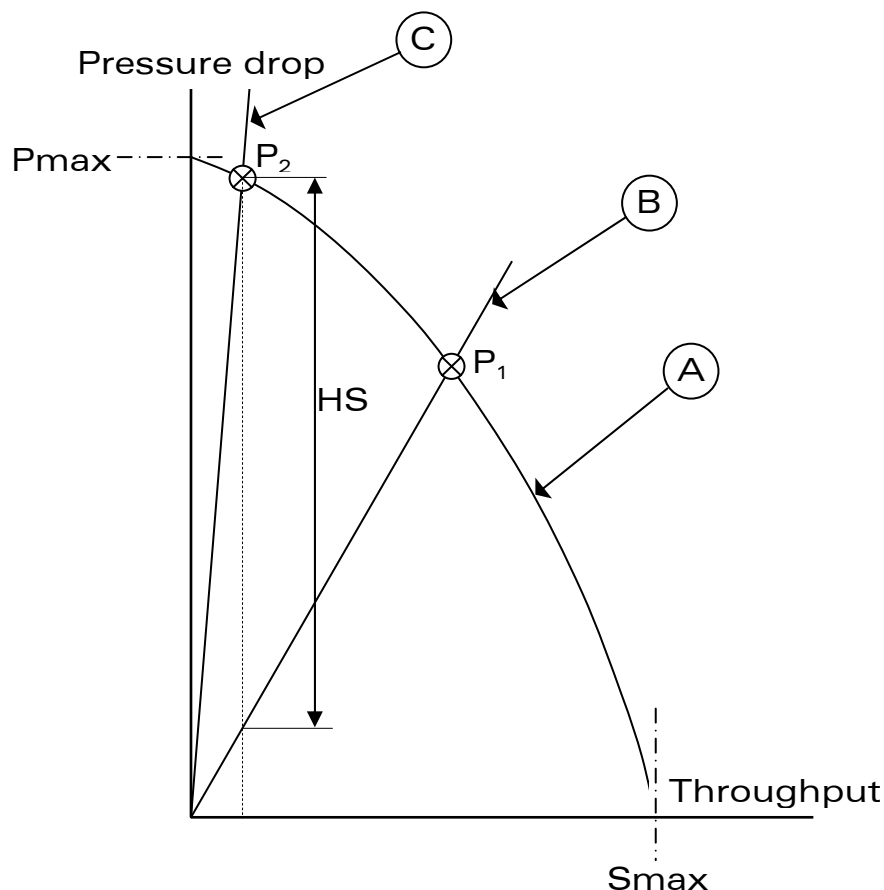
Whatever its name, the generating device creates a pressure differential between inlet & outlet, depending on the flow. The pressure differential is greatest when the pump inlet/outlet is blocked, generating either vacuum or pressure P_{max} , of similar magnitude in the two cases. Conversely, the flow through the pump is maximized when all obstructions are removed and the pump operates with output feeding directly into inlet - S_{max} .

In intermediate cases the relation between flow and pressure differential is shown by a curve such as A. The overall shape of the curve is characteristic of the type of device, - radial fan, tangential fan, centrifugal blower, piston pump etc..

The pump does not act alone, but is connected to a **circuit** of tubing, volumes, constrictions etc., i.e. *everything* that constitutes the complete external circuit between the inlet and output of the pump, which may well also include the large open space of the room in which the equipment is situated, or a factory duct. The complete circuit can be described by its flow characteristics; - a given pressure differential applied to the circuit will result in a certain flow, - over a limited flow range the relation is approximately linear, and the constant of proportionality termed the **conductance**. (we leave aside here the complexities of fluid dynamics and flow regimes)

If a circuit of conductance B is connected to a pump with characteristic A then the flow through both must be identical, and the operating conditions are uniquely set by the intersection at point P_1 , the pressure generated by the pump at this flow rate is that necessary to ensure the same flow rate in the external circuit..

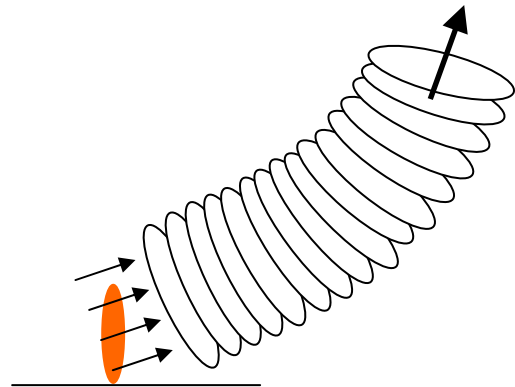
Now the distinction between different types of pressure generating device becomes clearer. A vacuum suction device working without leaks may concentrate on P_{max} at the expense of throughput. A cooling fan designed to move the maximum amount of air through a cabinet aims at high S_{max} . A pump designed to optimize flow through an external circuit of intermediate conductance must seek to develop a characteristic curve with maximum convexity, - pushing P_1 to the right.



Sucking Fumes

The flow rate will be determined by a point like P_1 . The matching of pump characteristics and circuit conductance must maximize flow.

To extract process fumes, a nozzle entrance has to be located close to the process point. To extract all the fumes, the open end of the nozzle must be big enough to swallow the ablation plume in a time before it disperses due to convection or kinetic momentum. Note that with a flow rate determined by P_1 as above, the mean velocity into the nozzle (sucking speed) varies inversely with the square of its dia. A big nozzle may have the size to swallow all fumes but lack the sucking speed to do this before the plume disperses, a small nozzle may have high sucking speed over too small an area, and also become a limiting factor on the conductance of the circuit, further reducing flow.



Nozzles of particular shapes may be applied to best adapt the flow characteristics of the nozzle to the shape of the ablation plume.

Coaxial Nozzles

In some cases, shield gas is desirable at the same time as fume extraction. Examples are described in Technote RA01..

Holding Parts

A vacuum chuck may be an element in a circuit such as **B**, with P_1 operating point. Placing a part on the chuck further reduces conductance of the circuit to **C**, with a shift to operating point P_2 , so that the effective suck on the part is then given by HS .

Clearly, a chuck with too low conductance, - small holes, - little difference between **B** & **C**, - P_1 close to P_2 , will generate relatively low HS unless TOTALLY leaktight with the part mounted, - N.B. a circuit **C** with zero flow will have $HS = P_{max}$, whatever P_1 .

However, a chuck with high conductance, - i.e. large holes, - can also only work effectively if ALL the holes are blocked, - the presence of unblocked holes brings P_2 closer to P_1 , reducing HS . Ideally, the form of the chuck should be adapted to the part, though the simple technique of masking off unused areas on the chuck is quick and effective.

For through-machining, one must also bear in mind that holes laser-drilled in the part will increase the conductance **C** and hence shift P_2 closer to P_1 , reducing HS . Chucks with separate sections may be required, so that sections can be valved off as processing proceeds.

Finally, for through-machining one has to consider back reflections of the laser beam from the chuck. Honeycomb material can be used to make simple but effective custom chucks, both Al and polymer (Nomex) are readily available.

Thus, chucks need to be designed for the parts in question; in a general purpose machine interchangeable chuck faces can be useful.

Circular section tubes etc, can be positively located in a suction 'V' groove, a convenient model is made from two chamfered plates with adjustable gap. The optimum width of the gap depends on how good the 'fit' is before the suction is applied, how well the part is matched to the chuck length, how leaktight the part/'V' groove contact is, etc.