Moving Air - Equipment for Sucking & Holding

Laser micromachining equipment uses suction to hold parts in place during processing, and also to extract fumes from the process area.

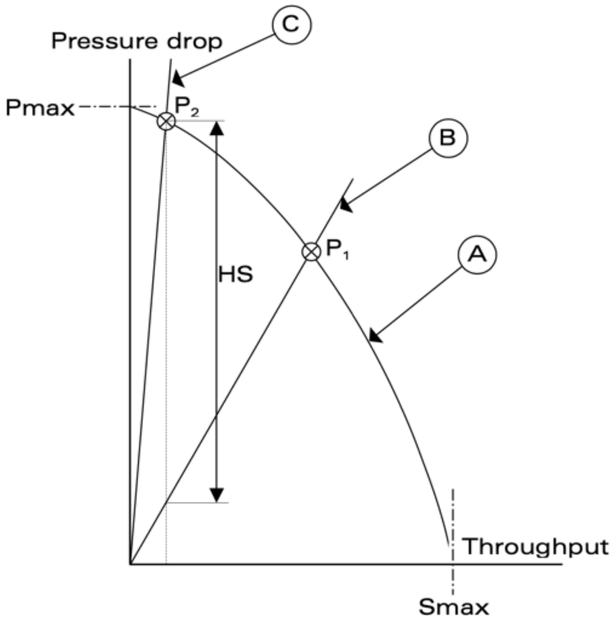
The suction circuit comprises a pressure/suction generating device, which might be called a **pump, blower, fan, extractor** etc. The name reflects habitual use in some specific applications area, the basic physics is the same in all cases. Whatever its name, the generating device creates a pressure differential between inlet & outlet, depending on the flow rate. The **pressure differential** is greatest when the pump inlet/outlet is blocked, generating for zero flow either vacuum or pressure **Pmax**, of similar magnitude in the two cases. Conversely, the **flow rate** through the pump is maximized when all obstructions are removed and the pump operates with output feeding directly into inlet - **Smax**.

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, roots blower, vane or piston pump, etc.

The pump does not act in isolation, 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 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 Pmax at the expense of throughput. A cooling fan designed to move the maximum amount of air through a cabinet aims at high Smax. A pump designed to optimize flow through an external circuit of intermediate conductance must seek to develop a characteristic curve with maximum convex shape of the curve,- pushing P_1 as far as possible to the upper right along the conductance line.

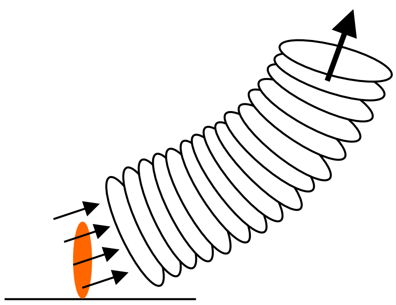


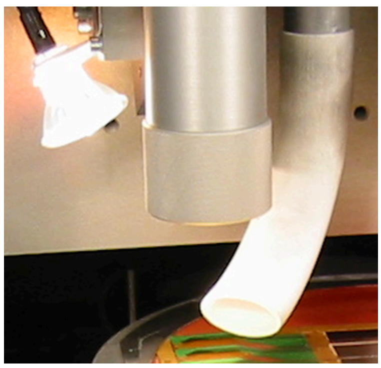
Sucking Fumes

As above, the flow rate will be determined by a point like P_1 ; the selection of pump characteristics and circuit conductance must seek to maximize flow rate.

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., so a large nozzle may have the size to swallow all fumes but lack the airflow velocity 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 used 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 of these rather special nozzles are described in Technote RA/E/04.

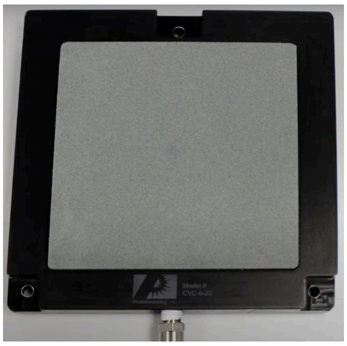
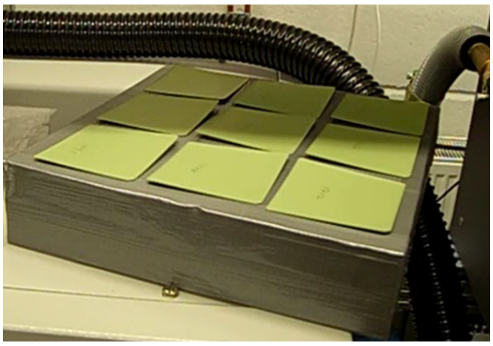
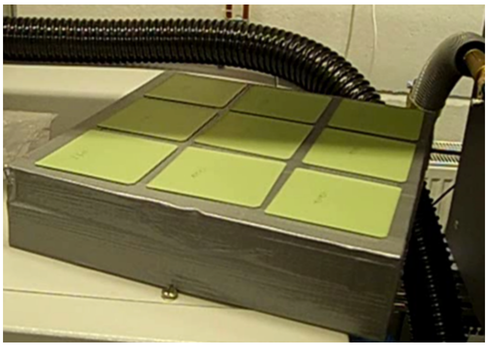
Holding Parts

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,- P1 close to P2, will generate relatively low HS unless TOTALLY leak-tight with the part mounted,- N.B. a circuit C with zero flow will have HS=Pmax, 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 with sticky tape is quick and effective.

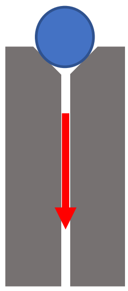
As examples,- thin flexible parts are best handled on a porous alumina chuck (left), which has myriads of miniscule pores where suction into such small holes cannot deform the part but overall conductance is fairly low, with no 'cross leaks' between adjacent areas, so that in general taping off is not required.

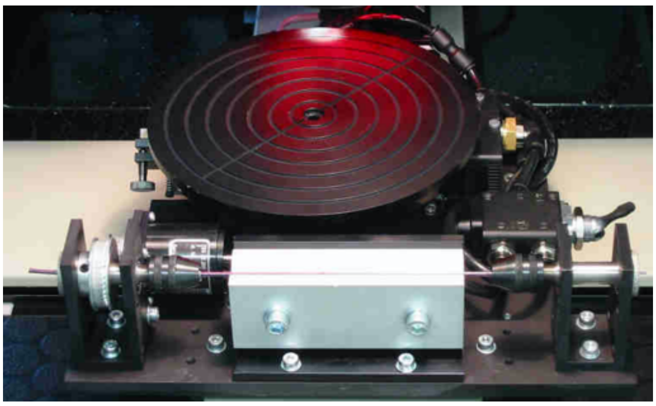




At the other end of the scale these deformed ceramic parts (centre)were handled on a hastily constructed ultra high conductance chuck make from Al honeycomb, where pore size was several mm & 'open' area >98%. With the lands between parts taped off, the 'bottleneck' in the conductance circuit remained the small gaps between bent part & chuck surface, so on starting the high throughput blower any reduction in those gaps less to an immediate increase in HS, further reducing gap & rapidly pulling the parts flat with an audible 'click' (right).

For through-machining, one must also bear in mind that holes laser-drilled through 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 a used to make simple but effective custom chucks, both Al and polymer (Nomex) panels are readily available.

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 leak-tight the part/'V' groove contact is, etc. `





Thus, chucks need to be designed for the parts in question; in a general purpose machine interchangeable chucks can be useful. Left shows a combination part holder on Optec MicroMaster, with simple segmented flat circular chuck & vacuum 'V' groove for long thin cylindrical parts, typically catheters, on a simple motorized lathe; vacuum can be released for stepped rotation, or faced with slippery PTFE for continuous operations.