Model Hovercraft Technical Suggestion.

Matching a centrifugal fan to a chosen model size.

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Here's my method for lift fan testing. I don't claim any scientific sophistication for it, it's just a starting point...... All you do is "model" the model.

The main idea is to exhaust the fan into a fixed volume which represents the skirt volume and the airspace under the model. The outlet of the fixed volume represents the "hovergap", the area between the edge of the skirt and the ground through which the air escapes. A load placed on top of the bag represents the required cushion pressure. Success is judged by the ability of the system to support the load.

This needs to be quick and easy to do, so there's a compromise in that the "model" is a tube and inevitably won't accurately represent the airflow in the real model. However, it wil1 be possible to establish a working figure for cushion pressure and airflow for a particular fan/model combination. By using an estimated skirt volume it is also possible to obtain an idea of how quickly the skirt could respond to disturbances. <Photo01>

Step (1)
Estimate the skirt volume and the airspace volume under the model.
This doesn't need to be super accurate - a quick method is to calculate:
    hardstructure length x width x sidebody height x 2 (assuming an R/2R bag skirt)
and ignore the volume of the hull under the sidebody line.

Example: for Mark Porter's 2000TDX design this gives 106cm x 50cm x 7cm x 2 = 74.2 litres

A more precise calculation gives:
    Outer skirt volume: 106cm + 50cm x (pi)r^2 where r = 7cm = 24.01 litres
    Airspace under: 84cm x 22cm x 7cm = 12.9 litres
    Inner skirt and air space (sidebodies):
    2 x 14cm x 106cm x 7cm = 20.77 litres x 2 (2sides) = 41.4 litres
    Total = 12.9 + 41.4 + 24.01 = 78.3 litres

Step (2)
Make a tube from suitable polythene bags to represent the volume from (1)
Use a radius for the tube of about double the skirt radius, otherwise the tube will be too long!
Domestic freezer bags 303mm x 430mm will be ok.
Cut the sealed ends off and stick end to end with Duck/Gaffer tape.
Leave a bag to bag overlap of 10mm.

Step(3)
Tape the fan unit to one end of the bag and a fixture of suitable cross sectional area representing the hovergap to the other end. Use a yogurt pot rim or short cardboard tube, plastic pipe etc.
If necessary use two or more tubes of the same diameter to give the cross sectional area required.

Example: for 2000TDX the hovergap area could be:
    (2 x cushion length plus 2 x cushion width) x height of skirt edge above the ground = air escape area
    ((106cm x 2)+(50cm x 2)) x 0.25cm = (212cm + 100cm) x 0.25cm = 78cm^2
A suitable tube is then 78/(pi) = r^2, r = 4.98cm (5cm). Use a tube 10cm diameter. <Photo02>

Step (4)
Choose a suitable piece of wood to simulate the likely loading.
Example: 36" x 2" gives 3 x 0.1667 = 0.5 sq ft
    Weight of wood = 0.67lbs, therefore loading = 0.67/0.5 = 1.34 lbs/sq ft

Step(5)
Place wood on poly bag tube, run motor up, preferably using a speed controller.
With gearboxes this is essential to avoid breaking a belt or stripping gearteeth.

Step (6)
Will the fan support the weight?? If it does, the "hull" should rise from the floor and "hang" in free space with no visible means of support (other than the poly bag).
Which I find quite fascinating, especially if clear poly bags are used!! <Photo03>

Step (7)
Vary the outlet diameter, fan rpm and cushion loading to establish a working point.
Collect the data, ponder the results, build the model!!

Notes:
The pressure in the bag will be very low, for 1.5 lbs/sqft this will only be 72 pascals, (less than 0.3 inches of water) so conventional methods for pressure measurement (eg an inclined slope manometer) will be difficult to use (but not impossible). Consequently, the best way of assessing the air pressure is to vary the bag contact area of the wooden load and/or to add/remove weights to see what happens. A variation is to partially balance the weight of the wood with a spring balance to vary the loading, the difference between the wood and the balance gives the effective weight of the wood. <Photo04>

This part is quite subjective (depends on your point of view).
I have classed the pressure in the bag at a particular loading as follows:

Soft:
the bag is just able to support the load, sides of the bag are curling round the edges of the load.
The bag is soft and saggy, it won't maintain a circular or near circular cross section, bag pressure is too low.

OK:
the bag supports the load, bag cross section is such that the load edges are still in contact (just) with the bag. The only flat part of the bag is directly under the load.

Firm:
Bag supports the load, edges of the load are off the bag, load tends to roll off the bag.
At this point the bag pressure will be obviously too high.

Discussion:
All the (subjective!) bag pressure results will relate to a particular set up with a particular air outlet area. If the results show a satisfactory bag pressure with your fan at a particular RPM then it will be likely to work on the model. It 's also advisable to allow for losses in the model's airducting due to turbulence, so add about 20% more flow to the calculated figure. In most cases this can be obtained by increasing the fan speed. If power consumption is too high it may be better to increase the diameter of the fan, change the motor or gearbox, etc, etc.

If the tests had been done on a model then the bag pressure classifications would be irrelevant, they wouldn't be noticed because the airflow/bag pressure relationship would have been automatically translated into a hovergap change, taking advantage of the inherent automatic adjustment in the system. The question for an electric powered system is: how much hovergap do you need? (it will change depending on the roughness of the operating surface), because an increase in the hovergap will represent an increase in airflow and an unnecessary drain on the batteries and shorten the run time.
I tend to work on 2.5mm or 0.1" for the hovergap, this appears to give reasonable results for airflow and power consumption.

Conclusion:
Why bother?
It can be expensive to build a new model and it's disappointing to find out that more lift power maybe needed. At least with this method, time and materials are not wasted. Assuming that a ducted fan unit is being tested and all the parts are to hand, then about an hour should suffice.

For standard propellor testing a duct of some sort needs to be made, possibly using styrofoam etc.
For a centrifugal fan it could be mounted between two parallel plates.

Aha you say! We might as well build the model! Well yes, why not, it will still take time!
(There's all that stitching to do!)

Worked example:
Performance curves for small centrifugal fans likely to be suitable for model hovercraft use are available from several manufacturer's websites. I hesitate to recommend any particular fan as we are likely to use it outside of its intended design parameters, instantly, by modifying it to fit to a model electric motor and consequently incurr criticism. For fan modifications, you are on your own !!
Let's try to match a typical 5.25" diameter fan to Mark Porter's Griffon 2000TDX model. (It's the most popular model around and several specifications are available).

Model weight will be 2.70Kg (5lbs 15ozs), on a cushion area of 1.06 x 0.5m = 0.53m^2, gives a cushion pressure of 5.09kg/m^2, or 50 pascals.
(1 Pascal = 1N/m^2, 5.09kg/m^2 x 9.81m/s = 50 pascals) Equivalent to 1.044lbs/sqft.
(Choice of model weight is a bit optimistic (!) but is intended to match the fan's performance graph)

From the published data for the "typical" mains powered fan, the air free flow is 260m^3/hour (152 CFM), and at 50 pascals pressure, the air flow = 210m^3/hour (123CFM).

How much airflow is needed for the model??
From information available on the THCC website and the Lift Calculator at Hoverhawks.com, we can perform some simple maths.

(Incidentally, try the Hoverhawks lift calculator with the dimensions for Mark's Griffon and you will find that it works for model dimensions of 1.06m by 0.5m, weight 5kg (11.023lbs) giving a cushion pressure of 92.5 pascals (1.93lbs/sqft). It will allow you to go down to about 87 Pa (1.817lbs/sqft) There is about a 17% addition to the airflow figures, presumably to compensate for losses)

Theoretically,
The escape velocity (Ve) of the air in m/s is:

Ve = sq root(2 x Pc/p)

where Ve is the escape velocity of air in metres/second, Pc is the cushion pressure in pascals, p is the density of air in kg/m^3

ie: Ve = sq root (2 x 50/1.22) = 9.054 m/s

The hovergap area = length of cushion ground contact x hoverheight

ie: (2 x 1.06m) + (2 x 0.5m) x 0.0025m = 3.12m x 0.0025m = 0.0078m^2, (78 sqcm)
gives an outlet diameter of: 78/pi = r^2, r = 4.98cm, (use a 10cm diam pipe.)

The volume of air required is: hovergap area x escape velocity,

ie: 0.0078m^2 x 9.054m/s = 0.07062 m^3/s or 149 CFM.

From the performance graph we find that the airflow at 50 pascals is too low, it's only 210m^3/hour or 123 CFM.
Our theoretical hovergap will become instead: 2.065 mm. It's still set to 2.5mm as we haven't changed the outlet area, so we could instead expect the cushion pressure to be less to compensate.

Using the test rig we can test this arrangement. The fan can only run at one speed (2800rpm) so the load and the outlet area are the variables that we can change.

With a 10cm diameter outlet, the bag supported a load of 15.21kg/m^2 = 3.125 lbs/sqft and was definitely too soft, (ie the load was too much), indicating poor performance.

Using the spring balance to support about 9ozs of the load, this gave an effective weight of
17 - 9 = 8ozs
giving 7.15 kg/m^2 or 1.47lbs/sqft. based on the criteria for the bag shape indicating cushion pressure.

In practice, it was uncertain where the actual load point was, (from estimating the bag shape). It was easy to see if the loading was too much, not so easy to see if it was too little or near the required working point.

The spring balance method can give a first approximation, then use this loading value with no spring balance support to get a closer result. Initial dabbling suggests that an approximate 50% overload can be tolerated and not be noticed in the bag shape. The theoretical change in the hover height due to the lower airflow will be so small that it won't be noticed, unless the skirt, (particularly a bag skirt) tends to stick on wet ground in your local car park! If you are happy with the cushion shape then that's OK!! (However, words of wisdom heard at a Hovercraft Society meeting were: "you can never have too much lift air")

Note that with this example, there is unlikely to be any reserve lift because it has been "used up" by the parameters set for the test. Obviously with a proper dc motor setup with ESC, reserve lift is available by increasing the fan speed.

The same approach can be used to test ducted fans and propellor drives. For these, it can be expected that the system will be more sensitive to changes in loading because the performance curve for an axial fan/propellor system will be much flatter than for a centrifugal fan system. Larger changes in fan rpm will be needed to compensate for small loading changes.

Enhancements:
For a "proper" model setup (compared to a mains powered fan) it would be useful to also measure fan rpm, motor current and run time to allow motor/fan combinations to be compared. Use an inclined slope manometer for more accurate cushion pressure readings.

Footnote:
I deliberately left out any reference to measuring the air velocity from the bag outlet for two reasons, first the cost of an air speed measuring device of any sort is quite high relative to the cost of the polybags and sticky tape and probably would only confuse things because, secondly, I have already tried it with a Kestrel wind speed meter! The bag outlet air velocity is not uniform across the outlet area, it's at a maximum in the centre and drops off at the edges. Also the size of the measuring device can influence the readings by blocking part of the exit area. Suffice to say that despite the practical problems of obtaining a reading, the air velocities usually agreed with the calculated velocities. Consequently I left out air velocity measurement, instead to rely on the bag pressure shape to indicate success or failure. If the bag pressure is about right then the airflow must at least equal the calculated figure, if not, just turn up the speed control for more air flow!!

It may seem that everything has been grossly oversimplified and things left out, for example no mention of discharge coefficients, no formulae to relate power consumption to airflow or pressure. For practical modelling we are limited by what is available commercially, most of us lack the facilities to start from scratch, so most parameters have already been chosen for us, it just remains to match the fan and power system to a chosen model size, or conversely, work backwards and find a model size for a particular fan system.

PS. Disclaimer!
Any modifications to commercially available fans should be approached with caution. Particular attention should be directed to: (1) proper, secure mounting of the fan, (2) balancing in 2 planes to minimize vibration, (3) for safety, avoid using metal impellers, plastic ones are preferred.
All comments apply to models only!! Full size design is approached in a far more sophisticated way!!
Apologies to all knowledgeable parties, who by now, after reading this, are either laughing up their sleeves or have been violently sick!!

References:
THCC website, hovercraft principles
Hoverhawks.com, lift calculator.
Griffon 2000TDX model design at www.model-hovercraft.com

Regards,
Brian Wise.

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Photo 1.
General view, fan unit at front, air outlet at far end, wooden load on top of tube.

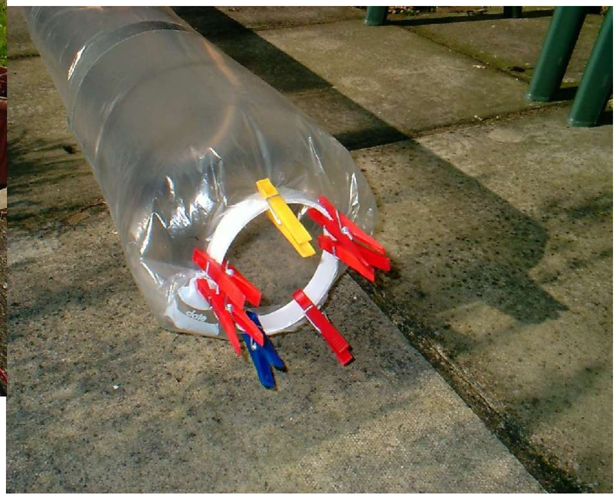

Photo 2.
Air outlet using 10cm diameter plastic pipe, simulates air gap.

Photo 3.
Wooden load, simulates cushion pressure loading.

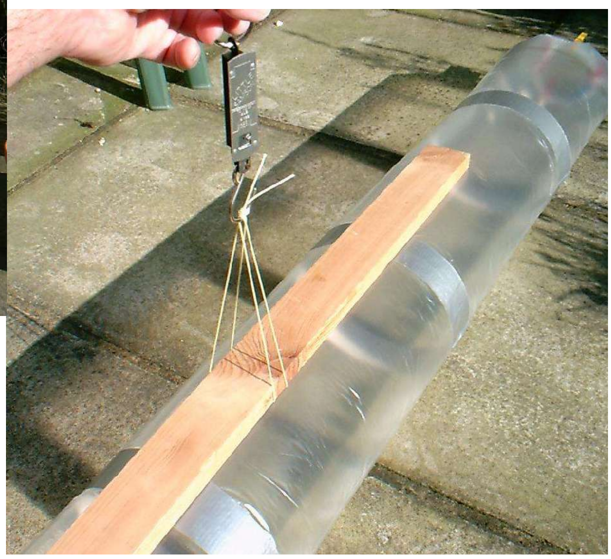

Photo 4.
Spring balance used to reduce and measure loading changes.