HOMEMADE LAB EQUIPMENT FOR MECHANICAL ENGINEERING COURSES

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Traditionally, engineering programs have been considered expensive because of the abundance of courses containing a laboratory component which usually requires costly equipment. While this will probably always be true, this author has come up with at least a partial remedy for the high cost of laboratory equipment. By developing some lab pieces which can be made by an instructor (or lab technician), expensive items which would normally have to be acquired through the equipment budget process can be had utilizing supply budget monies. The three lab pieces discussed here are presented as examples of the application of this remedy. They were all designed and built by the author using mostly his own money and very little supply budget monies, if any.

I. THE WIND TUNNEL SUBSTITUTE: This device is used to determine the aerodynamic drag coefficient of various models. The unit utilizes a rotating boom driven by a falling weight to propel a model placed at the free end of the boom through a circular path. In the author's design, the boom radius is 30 inches which produces a path length of 7.85 feet per rotation. In practice, the boom is allowed to rotate seven times, starting from an at rest position with the driving weight at its maximum elevation, to allow the model to come close to terminal velocity. The next three rotations are timed and the velocity is determined knowing the path length and elapsed time. It should be noted at this point that system never really reaches terminal velocity. However, if the boom is given an initial push, the model will come closer to terminal velocity after the first seven rotations. Even better, using two runs, one where the push results in a velocity a little less than terminal and the other a bit more, the average of the two measured velocities for the last three rotations will be close enough to be the constant velocity of the system.

In order to determine the drag coefficient, the system must be calibrated. This is done by repeating the process several times using, in place of the model, a series of flat disks of various sizes sufficient to produce velocities larger than and smaller than that of the model. A plot of disk diameter vs. velocity produces the calibration curve. By interpolation, locating on this curve the diameter of a disk at the same velocity as that of the model, the equivalent disk is found. This equivalent disk was driven by the same force as the model at this velocity. Both the model and the equivalent disk, therefore, experienced the same drag force at the same velocity. The only things different are the drag coefficients and the areas. However, since the drag forces are equal, so must be the product of area times drag coefficient for each. Assuming that the disks all have a drag coefficient of one, the drag coefficient of the model becomes the ratio of the area of the disk to the profile area of the model.

This system can easily accommodate a model with a profile area of that of a 6 inch diameter circle. It is interesting to note that with one such model, in the form of a tear drop shape, it is possible to show that the drag coefficient running forward (rounded end first) is half of that when running backward. In order to duplicate this experiment it would require a wind tunnel with perhaps a five foot square test section. This would not only be very expensive, it would take up considerable space. While the cost and space requirement for the wind tunnel might be justified for a course in aerodynamics, it might not be appropriate for a fluid mechanics course. The wind tunnel substitute can be a perfect fit for the fluid mechanics course. If that course has no laboratory component, that poses no problem because, besides being cheap, the system is highly portable.

II. THE PELTON WHEEL TURBINE: This device is also portable and can be used for classroom demonstrations as well as a laboratory exercise in fluid mechanics or fluid power courses.

The unit is essentially an impulse turbine consisting of a wheel containing blades fabricated from split ping pong balls. The wheel is mounted on an axle which also bears a drum upon which string is wound. Weights are hung on the free end of the string and are wound up by the action of the turbine. The turbine is driven by a stream of air when the student or instructor blows into a tube which directs the air into a balloon. Exiting the balloon the air flows into a nozzle which aims it at the turbine blades. If the balloon can be inflated within a fairly wide range of diameters, the pressure can be maintained constant, thus insuring a constant flow rate to the turbine blades even with a variable flow at the input end.

In the experiment, two knots are tied on the string a known distance apart. A stop watch is started when the first knot reaches the drum and stopped when the second knot reaches the same position. The string velocity is determined and the process is repeated several times using a series of weights. Since the weights produce a torque on the shaft and the string velocity is proportional to the RPM of the shaft, a plot of number of weights vs. string speed produces a curve which has the same shape as a torque vs. RPM curve. Invariably, this experiment yields a curve which, in a range of speeds from one half runaway to runaway speed, is a straight line with a negative slope. This proves the turbine law.

III. THE TWO DIMENSIONAL TRUSS DEMONSTRATOR: This apparatus is intended for use in a statics course. While the unit discussed here can identify truss members as to those in tension or compression or those which are redundant, it is possible to modify the device such that quantitative results can be obtained.

At the heart of this apparatus is a number of special members which the author calls "smart sticks". Each smart stick consists of a pair of sticks which are connected together by a grouping of initially stretched rubber bands in such a way that the sticks can slide on each other axially without buckling. When compressive forces are applied to the ends of the smart stick, half of the rubber bands are further stretched while the other half are relieved somewhat of their pretension. The result is that the smart stick becomes a bit shorter. Each smart stick is fitted with a change of length indicating device which, in this case, will show a red flag indicating compression. When tension forces are applied, the smart stick becomes a bit longer, and a green flag for tension will show on the indicator. Of course, when no flag shows, it can be assumed that there is no force carried by the smart stick.

The system demonstrated by the author is a simple five member truss. The members are either 16 inches long or 22 5/8 inches, representing the legs and hypotenuses of 45 degree right triangles. Three of the members of the truss are the short variety and two are the long ones. When assembled, the truss has the appearance of a pair of right triangles sharing a common vertical leg. The vertical leg and the two horizontal legs are short members, and the hypotenuses are two long members. To simplify the system, indicator members, the smart sticks, should be used only when necessary and, at other times, plain sticks can be used. In this case, by symmetry, it can be assumed that, with a concentrated load at the center of the truss, the internal force in the longer members should be identical, and one of these can be replaced by a plain stick. Also, for the same reason, only one of the horizontal members needs to be a smart stick. The example truss cited here is of particular interest because it demonstrates that the vertical member is in tension with the load applied at the lower central joint, while it is redundant if the load is applied at the top center joint.

It should be noted that the smart sticks are flexible and if every member was a smart stick, a load would cause a considerable change in the geometry of the truss. To minimize this effect, the number of smart sticks should be limited to three, and for a more geometrically stable system, only one flexible smart stick should be used at a time. To accomplish this, two of the three smart sticks can be rendered rigid using the provided locking pins. In this manner, each smart stick member can be examined separately by locking the other two smart sticks.