# AERIAL PROPELLER; INSTRUCTION PAPER

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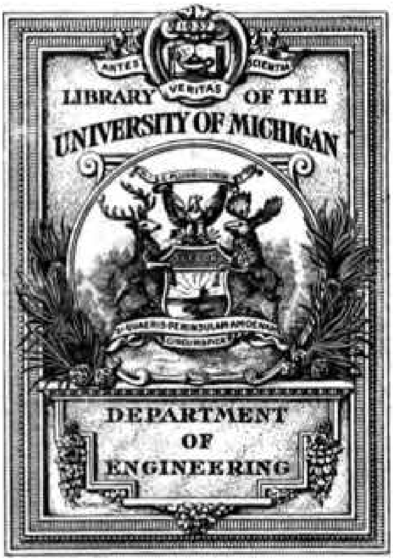
# AERIAL PROPELLER

Volumes have been written on the theory and design of the screw propeller as applied to marine practice, yet after so many years of actual use there are still many things that remain to be definitely settled. A change in the condition of operations renders previous data of little value, as in the case of the adoption of the high-speed turbine for marine propulsion, the "Mauretania" having been equipped with no fewer than three different sets of screws since she was first put in service. It is, accordingly, not to be greatly wondered at that there should be a conflict of opinion where the aerial propeller is concerned. Obviously, the propeller is no less important an essential than the planes themselves, for support in an aeroplane is entirely dependent upon speed. To obtain speed, thrust is necessary, and it is the function of the propeller to produce it. How this may be done most efficiently is the object of an endless amount of research that is being carried on at the present time. The purpose of the present subject is to reflect current practice—to give as far as possible the data upon which the designs of the most successful propellers are based, to show how the propellers themselves are made, and why they are so made, as drawn from actual experience rather than from purely theoretical ideas.

In view of the imperfect engineering knowledge extant on the subject at this late day, it appears rather marvelous that the scientist-philosopher Leonardo da Vinci should have proposed the use of the propeller in one of the aerial navigation schemes which came up in his day—more than four hundred years ago. Of course, the propeller as it exists today was not known then, but the screw principle upon which it is based is centuries old. In fact, General Meusnier's conception of the *turning oars* in his plan for a dirigible balloon antedates the actual use of the propeller for marine service by many years, and was likewise a strikingly approximate anticipation of the aerial propeller of the present day.

**Factors in Propeller Action.** *Pitch.* Before taking up the design or construction, the essential features of a propeller should be



per second times the slip velocity in feet per second. This is *dynamic thrust.* The effort of the same propeller on the column of air in which it acts when standing still, is termed *static thrust.* An illustration of the difference between the two may be drawn from the starting of an aeroplane from the ground. While held prior to running over the ground, the screw is exerting static thrust. The moment the machine is released, it begins to exert dynamic thrust in that it is then forcing the aeroplane ahead. It is generally conceded that the amount of static thrust a certain propeller is to exert affords no definite measurement of what it is capable of doing when driving the machine through the air, or rather that its static thrust will be much greater than its dynamic, although Sir Hiram Maxim states that, as the result of his experiments, both were found to be the same. The thrust of the propeller in question was said not to vary whether it was traveling through the air at a velocity of 40 miles an hour, or standing stationary, the r. p. m. rate of the motor remaining constant. The explanation is that when traveling, the propeller is constantly advancing on to undisturbed air and that while the slip velocity is reduced, the undisturbed air is equivalent to acting upon a greater mass.

The factors affecting the thrust given by a propeller are: *First,* the diameter, blade area, and pitch or blade angle, which may be termed propeller characteristics; *second,* the speed of revolution, which is proportionate to the engine driving power; and *third,* the rate at which the characteristics of the vessel will allow the propeller to move through the fluid. The propeller which is the most efficient is naturally the one which will produce the greatest amount of thrust in proportion to the power transmitted it by the engine, both when revolving in a fixed position on the ground and when traveling through the air. Each of the factors mentioned must be provided for in the design. A propeller which is too large or of too great a pitch for a given motor, will effectually prevent the motor from developing its normal power by retarding the r. p. m. rate. Propeller blades that are not given sufficient area or pitch will permit the engine to race through not imposing sufficient load on it, and if the speed becomes greatly excessive, the blades are likely to burst or fly apart through centrifugal force. Should the engine be too powerful for the propeller, the blades may bend and break under the strain.

*Pitch Ratio.* Another characteristic having an important bearing on the result is the *pitch coefficient*, or *pitch ratio*, as it is frequently termed. There is a certain analogy between the propeller and the main planes in that both are intended to drive through the air easily and at the same time exert a sufficient hold on the air either for the purpose of support, as in the latter instance, or for driving, as in the former. Pitch ratio is consequently analogous to aspect ratio. It is the ratio that the pitch bears to the diameter, or length of the propeller. The pitch coefficients of eighteen well-known monoplanes and biplanes vary from 0.4 to 0.2, the mean value being 0.62, which, as it so happens, is exactly that of the Farman propeller. The pitch ratio of the Wright propeller is said to be 1, and its unusually high efficiency is generally conceded, though very few builders have apparently considered it expedient to adopt the means that make this efficiency possible, *i.e.*, propellers of large pitch and diameter turning at the very slow speed of 450 r. p. m. The propeller of the Bleriot XI has a pitch ratio of 0.4, but it is designed to run at 1,350 r. p. m.

*Diameter.* The diameter is affected by structural considerations, the placing of the motor and other conditions, which restrict the size of propeller that can be employed on a certain machine. Different experimenters have widely-differing standards in this respect, as witness the use of 4-foot extremely high-speed propellers on some machines and 8-foot slow-speed propellers on others. The disadvantage of using a very small propeller is now generally recognized, however, and few, if any, of less than 6-foot diameter are employed. The question of efficiency is so largely dependent upon the diameter, that we may look for an *increase* rather than a *decrease* in the machines of the future. In fact, the whole question of the efficiency of the 2-bladed aerial propeller seems to be one of *diameter* and *speed*. Speaking in general of properly-designed concave propellers, a propeller of large size and slow speed is always more efficient, all other things being equal. Reduce the diameter and increase the speed and the efficiency drops off very rapidly—from as high as 50 pounds thrust per horse-power to as low as 6 pounds per horse-power, these figures being the result of experiments carried out especially to establish the effect of altering the relation of these two essentials of design. The falling off in the efficiency at high speeds is remarkable, for while it seems possible with the best designs to obtain as high as 40 to 50 pounds thrust per horse-power, the average modern aeroplane has a screw of one-sixth this efficiency, or about 7 pounds per horse-power.

*Peripheral Speed.* The limiting factor in the propeller is its peripheral rather than its rotational speed, since it is upon this that the centrifugal stresses, which are by far the most severe of all involved, depend. The propellers of practically all aeroplanes built so far run at peripheral speeds ranging from 12,000 to 40,000 feet per minute, with occasional instances of speeds as high as 50,000 feet per minute, the rotational speeds being so adjusted to the diameters of the propellers as to produce little variation outside of the range given. At the higher of the speeds mentioned, nearly 570 miles per hour, centrifugal force is so great as to test to its utmost the quality of the finest structural material obtainable.

That it is better to gain permissible peripheral speeds by the use of large diameter propellers at low-rotational speeds, rather than with small propellers at high-rotational speeds, becomes very evident with a little study. Take, for example, the case of a portion of a propeller surface, 1 foot long and 1 foot wide, traveling edgewise round a 30-foot circumference, 600 times a minute, it being assumed that a peripheral speed of 18,000 feet per minute is the maximum permissible in the case in question. Under the conditions stated, the surface passes any given point 10 times per second—often enough to produce a material disturbance of the air worked against. Now assume the circumference reduced to 15 feet by a corresponding halving of the propeller diameter, and immediately it becomes apparent that a doubling of the rotational speed is allowed without increasing the peripheral speed.

But, under the new conditions, the assumed propeller surface passes any given point 20 times per second, twice as often as before with a correspondingly reduced assurance of finding undisturbed air to work against. Moreover, since the blade surface travels the same distance in the same time in both cases, there is no opportunity to reduce its area on account of the higher rotational speed in the smaller propeller. The result is that the blade which is of a width only $\frac{1}{30}$ the length of its path in the large propeller, is in the smaller one $\frac{1}{15}$ its length—a condition that operates directly against