A SUGGESTION FOR THE POWER PLANT OF AN AEROPLANE*

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This paper has to deal indirectly with the question of power plant in an aeroplane, and has in reality two objects in view: First, to bring to your attention certain principles and their effect upon the performance of the gasoline engine, and, secondly, to do this in as brief and concise a manner as is possible.

Some of you are aware of the apparatus installed at the Worcester Polytechnic Institute some years ago for the purpose of testing aeroplane propellers, and possibly are acquainted with the results, a few of which were presented in a paper at one of the branch society meetings last fall; but in order that those who are not familiar with them may appreciate the value and significance of the experiments conducted, a brief resume will be given here. (Report and description of plant and tests was given in AERONAUTICS, July, 1911.)

The main testing plant is located at a lake about five miles from the institute, and consists principally of a steel boom 85 feet in length, and which is free to rotate about a vertical axis at the center of the boom. At the end of this boom is placed the propeller, which is driven, through a system of gears, by an electric motor located at the center of the boom. The axis of the propeller shaft is at right angles to that of the boom, and is therefore tangent to the circle described by the same.

Rotation of the propeller about its own axis produces a thrust which is available for rotating the boom at any desired speed, and which may be controlled in various ways.

Arrangements have been made whereby the speed of the propeller in r.p.m., the speed of the boom tip in m.p.h., the thrust of the propeller in lbs., and the h.p. delivered *to* the propeller may be readily determined by instruments suitably placed.

An additional scheme for testing was embodied in the use of an ice-boat driven by an aeroplane propeller, and which made possible the obtaining of very high speed in a straight line.

Many tests have been made with these two forms of apparatus, and on many styles of propellers, with the result that there is on hand some very interesting data concerning the performance of propellers under conditions similar to those in actual service.

Perhaps the most notable feature which was developed from tests of the average propeller was the drop in thrust as speed through the air increases, and the approach to zero thrust as this continues to increase.

In the type of propeller put out a few years ago, with a pitch of 5 to 7 feet, this drop is very noticeable. In such cases the "standing" thrust is the maximum obtained, and this falls off as flight begins, and in almost direct proportion, until at ordinary speeds through the air the thrust exerted by the propeller is approximately not over half of the maximum obtained when stationary.

Later types of propellers having large pitches, such as 9 to 12 ft., give a characteristic somewhat different from that just mentioned, in that the maximum thrust is obtained *after* the aeroplane has begun to move through the air. The speed at which this is obtained is approximately 10 to 25 m.p.h., after which the thrust falls off as before.

Still other forms of propellers, notably the "variable pitch" type, may be so constructed as to give a fairly uniform thrust throughout what might be termed the working range of speeds, and which is, of course, the ideal condition.

Simultaneously with the experiments for obtaining the thrust characteristics of propellers, was obtained data showing the "effectiveness" of the latter at various r.p.m. "Effectiveness" in this case has reference to the thrust in pounds per h.p. necessary to drive the propeller, and is, as can be readily seen, the only proper measure of the value of a propeller.

Time will not permit of going into a tabulation of this data, but a study of the same seems to indicate that a relatively low r.p.m. is more desirable than what is now common practice, and which runs from 1,000 to 1,800 r.p.m. These high speeds result in a great deal of energy loss due to the needless churning of the air, and also on account of the fact that the time involved in a half revolution of the propeller is so small each blade of the latter is brought to do its work in a disturbed atmosphere, all of which naturally tends to reduce the "effectiveness" of a propeller.

The Wright propeller, of large diameter, large pitch and low r.p.m., is an excellent example of a highly effective propeller doing with a small engine practically what some of the larger engines, driving propellers of small diameter, low pitch, at high r.p.m., accomplish.

In the majority of cases, propellers are direct-connected to the crank shaft of the engine, and for the two reasons that transmission through gearing or chains introduces a greater possibility of breakdown, and also since it has always been supposed that high r.p.m. of the propeller was preferable. High r.p.m. naturally goes with the customary type of gasoline engine, and this in turn follows, since it is established that for a given h.p. output a high speed engine weighs less, and hence is an argument for its adoption in aeroplane practice.

The real object of this paper is to endeavor to show that there are many reasons why these ideas should be abandoned in favor of an engine of the slow-speed type, driving a propeller of large diameter and large pitch.

Taking up the propeller, as before stated, the average high-speed type is working at ordinary flight speeds at greatly reduced "effectiveness," and this can be materially bettered by reducing the r.p.m., or rather by increasing the pitch to correspond to the reduced r.p.m., in order that the thrust may not be lessened. This will give a greater per cent. of efficiency for the whole system, and for the reasons stated in the beginning.

Turning now to the engine, an analysis of its performance indicates that, generally speaking, with a given bore the power is proportional to the piston speed. This may be effected by increasing the r.p.m. for a given stroke, or increasing the stroke for a given r.p.m.

A concrete illustration of the point it is desired to bring out may be found in the following. Two engines of identical bore, but having in one case a stroke equal to the bore and in the other a stroke equal to twice the bore, with, other things being equal, deliver exactly the same h.p. at a certain r.p.m. for the first, and at half that r.p.m. for the second. Piston speeds and gas speeds are identical in both engines. There are, however, certain differences, and it is on these that the argument depends.

In the short-stroke motor, although the total jacket loss per minute is the same as in the long-stroke motor, the surface exposed to the heat is half as great and the number of times per minute is twice as great, necessitating a much heavier duty per sq. in. of wall surface in the short than in the long-stroke motor. The significance of this is apparent when it is considered that the popular motor for aeroplane purposes is air cooled.

Following this, the number of r.p.m. is in the long-stroke motor being reduced for a given power output, the shocks due to reciprocation are correspondingly less, and this point may be extended to cover many of the parts of the engine. The value incident to this is self-evident. Valve breakages, crystallization, valve-spring trouble, loose bearings, etc., are to a large extent reduced, and in some cases entirely eliminated.

The only real disadvantage which can be traced to the adoption of the long-stroke motor, of the slow-speed type, is represented by the increased total weight making the weight per h.p. output greater. To just what extent this would be is not absolutely known, since automobile engineering has not progressed sufficiently for conclusions to be drawn regarding relative weights per h.p. for *equivalent* designs, since few, if any, exist: but the general opinion seems to prevail that the per cent. increase would be relatively small—say 10. This, of course, is negligible when all factors are taken into consideration, since all of the preceding statements have attempted to show that much more "effectiveness" per lb. of engine and aeroplane would result if these ideas were adopted.

Briefly, then, the arguments are:

1. Increased effectiveness of propeller;
2. Increased life of engine.

As both of these have a direct bearing upon the safety of the aviator or his passenger, there should be no further need for argument, if the data upon which the statements are based is correct.

In conclusion, then, it is stated that the ideal arrangement consists of the long-stroke motor of such dimensions that 700 to 1,000 r.p.m is the speed at which maximum h.p. is developed, and direct connected to this a propeller of such dimensions as to absorb the maximum h.p. at the speed mentioned, and also to give its maximum thrust after flight has begun if of the constant-pitch type.

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