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AERODYNAMIC CHARACTERISTICS OF AIRCRAFT WITH REFERENCE TO THEIR USE

By M. Panetti

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Present progress in aircraft construction consists in the gradual development of more clearly defined types for special uses. Only in this way can the problem of economical aerial transportation be successfully solved. This is the most difficult problem of all and includes all the other problems. Only thus can the "a priori" discussions on the advantages of one type over the others be converted into a dispassionate evaluation of the factors which justify preferences in individual cases.

The principle affirmed does not, however, prevent economic competition from leading to successful attempts to include in certain types the characteristics of other types.

An example worth noting is that of the principles on which the technicians of the British Air Ministry propose to establish at 140,000 m³ (1,507,000 cu.ft.) the displacement of the airships which are expected to afford rapid transportation between England and her large colonies - Egypt, India and Australia - with successive stages of over 4000 km (2485 mi.) each.

* From "L'Ala d'Italia," April, 1925, pp. 103-105.

The specifications will stipulate the same proportion of useful load as for commercial airplanes, namely, 40% of the full load. Thus the airships will carry 32 metric tons (70,548 lb.) of passengers, crew and freight and 28 tons (61,729 lb.) of gasoline in a full load of 150 tons (330,693 lb.). This division of the load is in almost perfect accord with the rule that the best results are obtained by making the pay load equal to the weight of the fuel required to reach the destination.

In fact the charges are commensurate with the kilometer-tons and depend, therefore, on the product of the two portions of the useful load, the pay load and the weight of the fuel, to which, for a given means of locomotion, the distance to be flown is proportional. The product of two numbers having the same sum is greatest, however, when the two numbers are equal.

In order, therefore, to make the operating expenses of an airship comparable with those of an airplane, it is first necessary to eliminate, or reduce to modest terms, the loss of the supporting gas, which is equal in weight to the fuel consumption during the trip. This is now accomplished by condensing the water vapor in the exhaust gases from the engines, the weight of this vapor being approximately equal to the weight of the fuel consumed. The product of the condensation is added to the liquid ballast of the airship, thus keeping the full load almost constant and therefore avoiding the necessity of gradually reducing, throughout the voyage, the quantity of gas contained in the hull.

This important innovation is a noteworthy example of the improvements which economical exigiencies have imposed upon technical and structural problems. In aeronautics, however, their good influence has thus far been felt only to a slight degree. Much time and money are in fact required for the designing, manufacture and perfecting of any type of aircraft truly adapted to any practical purposes, because its creation by private initiative must be awaited before merchants can make much use of it.

Regularly established air lines have operated only a short time and are still small in number. The principal European lines are the Paris-London, the London-Berlin-Koenigsberg-Moscow, the Paris-Warsaw, and the Paris-Constantinople-Angora and their requirements are small, as regards the production of new aircraft.

The merit of having proposed definite requirements belongs chiefly, however, to the army, whose demands are continually made more rigorous and exacting. The army types, such as pursuit, observation and bombing airplanes, have been respectively converted into racing, touring and commercial airplanes, often by modifying only the structural form of the fuselage and of the compartments for holding the useful load.

The definition of the characteristics of the airplanes, gradually becoming more precise, minutely describes and almost identifies the type, by imposing the choice of an ever more perfect shape for satisfying the requirements, often contradictory, such as high speed in flight and safety in landing, high altitude and a high percentage of useful load, small structural weight and high safety factors.

Positive knowledge of the properties of the wing profiles and of the aerodynamic characteristics of the wings and stabilizing planes is therefore a need which is being felt more every day. In any case, we require the minimum drag, but various carrying capacities: small for swift airplanes; large for slow commercial airplanes.

There are three possible solutions: the thin wing of very fine quality which can support a load up to 20 or more times the force required to propel the airplane in flight, but which requires the biplane structure, in order to assure the strength of the cell, and thus introduces additional drag by the mutual interaction of the superposed wings, by the presence of struts and stays and by the difficulty of covering the control cables.

The second solution is the very thick wing with a safety factor not above 14, which, however, enables the simplest solution with a monoplane without external bracing (the so-called "cantilever") and which can enclose in the wings large fuel tanks and radiators with a high coefficient of heat transmission and a small drag and be able to take advantage of the high relative velocity of the air tangent to the wings. With the thick-wing monoplane, the forms of the airplane can easily become forms of minimum drag with ample and well-designed connections, for which metal construction is particularly adapted. This eliminates the parts projecting beyond the surface of the fuselage and the attachments of the wings and of the landing gear.

All this takes no account of the fact that, in an airplane with only one wing, the structural devices intended to enable its convenient and economical storage in the hangar can be more successfully applied. It is, however, difficult to equal the great fineness of well-designed biplanes with very thin wings.

The third solution, with a wing of medium thickness, evidently shares the advantages and disadvantages of both the above solutions, whether accomplished with a biplane cell having few and very simple bracings, due to the strength of the spars, or with a monoplane structure reinforced with stays and struts.

It cannot be claimed that the rational differentiation of these types with reference to their various uses has yet been attained. The aerodynamic properties of very thick wings are very imperfectly known. Their lift and drag diagrams show perilous discontinuities for relatively small angles of attack, often below 10° and sometimes as low as 6°.

These discontinuities indicate unexpected diminutions in the lift above the cited angles of attack and substitute the phenomenon of the burble point in the well-known diagrams of medium and thin wings. Neither is the technician reassured by the recent researches of the Physical Institute of London, according to which said discontinuities tend to disappear at high speeds, since there is danger of tail slipping in slow climbing flight and, under such conditions, very thick wings present an evident risk.

It may, however, be said that in the choice of a type, one is too often influenced by school tradition, rather than by a sure knowledge of the attainable advantages in the individual cases.

It is sufficient to cite the German constructors, who, due to the limitations imposed by the Treaty of Versailles, have specialized in light types and have shown a decided preference for the monoplane, even for commercial and military airplanes, which they are actively constructing both in their own and in other countries.

The Albatros, Caspar, Dietrich, Dornier and Junkers are all, with a striking uniformity, high-wing monoplanes, modified at most by a small lower auxiliary wing, performing the function of fulcrum of the structure or of a safety float for preserving the transverse equilibrium or trim.

When recourse is had to the superposing of two wings, for avoiding an excessive span imposed by the requisite large supporting surface, the structural type is that of a double monoplane (i.e., without braces between the wings), as on the seaplane Caspar, and on the Dietrich.

The British and Americans, on the contrary, have not built a single monoplane, with the exception of light airplanes with motorcycle engines. The same may be said of the French, if we except a few pursuit monoplanes, like the Dewoitine, De Marcay and the Gourdou-Leseurre, which is mentioned for the peculiarity of being an exceptional type that, on account of the boldness of its acrobatic performances, requires very strong wings and was calculated with a very high safety factor.

The Fokker firm of Holland adopted, for its German and Russian lines, the monoplane with a capacity of 2000 kg (4409 lb.) of useful load at a speed of 180 km/h (111.85 M.P.H.). For combat airplanes, however, with a speed of 260 km/h (161.56 M.P.H.), this firm has remained faithful to the biplane cell with rigid spars, similar to our SVA.

In Italy, the airplane types, which remained almost stationary in their fundamental lines for several years after the war, are now undergoing profound changes, due to the influence of the contests instituted by the engineering section of aeronautics with well-defined programs especially planned for the development of the distinctive characteristics which have attained so great importance.

When we compare the conditions fixed by such programs with the records made, it is manifest that, even for very swift combat airplanes, the requisite speeds are much lower than the ones attained in races, so that 400 km/h (248.55 M.P.H.) (actually made and exceeded in these races) is not utilizable in practice, for which a speed of 300 km/h (186.41 M.P.H.) may be regarded as the limit.

The reason for such a speed limit is not due simply to the necessity of large useful loads for the armament of very swift airplanes, but chiefly to the importance of assuring, in every case, a minimum speed sufficiently low to afford safety in landing.

The reconciling of high flight speeds with low landing speeds is, in fact, one of the most difficult of aeronautical problems, difficult just because of the simplicity of its import, in which there are secondary elementary defects, to which we may recur.

Even with very strong wings, a speed of at least 60 km/h (37.28 M.P.H.) is required to support 25 kg/m² (5.12 lb./sq.ft.) and the problem of combat airplanes capable of flying 260 km/h (161.56 M.P.H.) is solved today by loads of 50 kg/m² (10.24 lb./sq.ft.), for the Spad 61, up to 70 kg/m² (14.34 lb./sq.ft.) for the Fokker DXIII. On pursuit airplanes, it is, in fact, necessary to reduce the wing area, in order to reduce the drag and to give the cell the strength required for performing stunts and to lessen the retarding effect of large wings on the rapidity of the evolutions.

Under such conditions, requiring wings of very small resistance, the minimum speed cannot fall below 110 km/h (68.35 M.P.H.) and, consequently, any further increase in speed is prohibited by the danger in landing, since large airdromes with perfectly smooth grounds, suitable for racing airplanes, cannot constitute an absolute requirement for aeronautic exercise, of whatever kind and scope.

Technicians must therefore resort to more radical reforms, which can only be rendered possible by the deformability of the airplane. Airplanes fall far short of the magnificent adaptability of birds, just because the former lack the ability of deformation which the latter possess in so high a degree. It may therefore be said that this precious ability, attempted in a few types, now obsolete, like the flexible-winged Caudron, has been too much neglected.

Just as the variable-pitch propeller represents the only solution capable of reaping the full benefit of a supercharged engine at high altitudes, flexible or deformable wings will constitute the only practical means for reconciling high flight speed with low landing speed, as well as for conserving more economical conditions of use on long non-stop flights, when the load of the airplane is greatly reduced by the consumption of fuel.

Its practical application, however, requires a long constructive research, which has yet hardly begun, but which should be accelerated, together with that of covering or conccaling the landing gear during flight, in order to diminish the structural drag and also to lower the center of drift, due to the area of the wheels, which impairs the maneuverability of the airplane.

There is no need of exaggerating the importance of the available motive power, as is often done from a too superficial understanding of the problem.

For demonstrating the fallacy of this criterion, it is only necessary to take a commonplace example in the conversion (I do not say improvement) of some types. Let us assume that a given airplane, without having its characteristics modified, be equipped with a more powerful engine than the one for which it was designed, for example, with a 450 HP. engine instead of a 300 HP.

If the substitution is made without otherwise increasing the weight of the airplane beyond what is required for the greater power of the engine, we must provide a 50% increase on the third of the full load represented by the engine and consequently an increase of 15% in the full load.

Now, in horizontal flight, the ratio of the power required for propulsion, to the full load, is equal to the fineness ratio of the airplane multiplied by the flight speed. If the substitution of the more powerful engine has not impaired the fineness of the airplane, the speed increase, in order to utilize the whole power increase, must be equal to the increase in the rate at which the first member of the equation decreases, which, in the given example, would reach the value $\frac{1.5}{1.15} = 1.3$.

It is, however, well known that the power necessary for flight, on the assumption that the specific drag remains constant, increases according to the cube of the speed. Hence an increase of 50% in the power does not enable an increase of 30% but only of 15% in the speed, which, for the same aerodynamic characteristics, corresponds to an increase of 32% in the lift. If we deduct the 15% increase due to the greater weight of the engine, we have 17% left for making the necessary increase in the strength of the structure and for increasing the useful load. The latter can, therefore, be increased by only a very small amount, while if all the increase in useful load is utilized for additional fuel, it would hardly be possible to run the new engine the same length of time as the less powerful engine, so that the gain in radius of action would be only proportional to the increase in speed, or about 15% of the original radius of action.

We need not be surprised if the course pursued thus far, of continually increasing the engine power, is arrested and if the prediction of the early general adoption of engines of 450 HP does not come true.

There is more need of important improvements in the fineness of airplanes, in the efficiency of the propeller and in the specific engine power, than in the absolute value of the available power.

For this purpose, however, it is necessary to promote indefatigably the study of aerodynamics, both in the direction of theoretical mathematical researches and in experimental investigations. It is only with the aid of these theories and of the experimental results, which now constitute one of the most brilliant chapters of modern mechanics, that the problems pertaining to aviation can be solved in a truly rational manner. Only with the aid of the light emanating from such sources can the mind of the technician envisage the ideal airplane.

The school of Turin, where such studies have been pursued for the last few years, is grateful to all public and private agencies which have assisted it in obtaining its present equipment: In the first place, the Department of Aeronautics which has constantly made generous contributions of money, materials and trained technicians; to the Turin firms, the Fiat, the Savigliano and the Ansaldo, for their financial assistance in the beginning and for laboratory aid accorded at all times.

Studious young men have thus been enabled to derive much profit from these facilities, to carry on, in spite of the complexity and abstraction of the first researches, and, by their zealous and constant application, to prepare the way for the merited success of the science of aircraft construction in Italy.

Translation by Dwight M. Miner,
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