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TECHNICAL DESIGN - PROGRESS REPORT - PAYROLL SHARING PROJECTS COVERING THE PERIOD FROM MARCH 1ST. TO JULY 9TH, 1959

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PROGRESS REPORT ON P.25 JETLINER PROJECT

1.1 PERFORMANCE

This project was started around an internal draft specification for a pure jet aircraft to cruise at 550 - 600 m.p.h. below 25,000' over stage distances of 600 miles, carrying around 45 passengers in first class seating. In addition, a landing and take-off balanced field length of 6000' on airfields at 3000' altitude and 90°F was considered mandatory.

With these contradictory requirements the initial studies were devoted to the selection and matching of wing and engine choices to meet the take-off and landing distances.

To optimize these conditions correctly, two elaborate computer programs have been set up in which all the dependant variables can be altered. Since the time taken to set-up these programs was quite long, an initial design was studied by rule of thumb and 'short-hand' methods in order to produce a brochure for May 15th.

It was found that aspect ratio had a large effect on take-off weight and wing area, therefore a study of three airplanes with aspect ratios of 4, 8 and 6 was carried through various mission profiles and the operating costs analyzed. The results showed an advantage for the aspect ratio 8 airplane, although the wing weight formula which was used may be suspect.

These studies resulted in an airplane with four pod mounted R.R. RB153 engines (with '0' stage) of 4,600 lb. static thrust each on an 845 sq.ft. wing with a sweep back of 30° to achieve a cruise M of .81 at 23,000 ft.

A brochure was issued on May 15th for this airplane.

Further studies have been made on a military version of the aircraft cruising at 40,000' and also a version with 4 Bristol Orpheus 6 engines.

The computer take-off and landing programs when available, showed that the original landing distances were pessimistic although the take-off distances were fairly accurate.

A study of a 300 mile stage length version for American Airlines is currently being worked on. The possibility of 2, 3 and 4 engine versions are being investigated and also the use of leading edge high lift devices, in order to shorten the landing run.

It is doubtful at this time whether the '0' stage RB153 will be available, so further engines are being investigated.

1.2 STABILITY AND CONTROL

Stability and control investigations on early versions of the P.25 showed that the horizontal and vertical tail surfaces proposed were quite adequate for stability and that the tailplane incidences required to trim were reasonable over the whole flight envelope. Latest versions of the P.25 have maintained the same tail volume ratios but no detailed work on longitudinal stability and control has been completed largely because of frequent changes in configuration.

Lateral control by ailerons alone has been shown to be above the required minimum with 30% span surfaces.

A proposed wind tunnel test program has been drawn up to optimize the wing section characteristics, determine all necessary stability and control data, and provide low speed flaps-down information.

2.0 PROGRESS REPORT ON ROTARY WING VEHICLE STUDIES

Introduction

This brief report covers the work of the Rotary wing Group since its inception in mid-May.

2.1 ROTARY WING DESIGN GROUP

Assignment No. P.30 was raised in May 21st. to cover design studies on three specific categories of Rotorcraft, with a view to determining the most suitable specification for the Company's first venture into this field.

Work on one category,(P.30-1, the 4 seat utility autogyro) has reached the stage of preliminary performance evaluation. The design study on the large commercial V.T.O.L. aircraft (.30-2), has progressed to the stage of preliminary specification, including choice of power plants and production of 3-view G.A. drawings.

The specification for the third category (P.30-3 the intermediate 5-7 seat vehicle) is still subject to decision on a suitable power plant and rotor drive system.

All three specifications are based on operation as an autogyro in cruising flight, and the division into categories is based not only on size but on the method of achieving V.T.O.L. or something approaching V.T.O.L., (e.g. clearance of a 50 ft. barrier in 200 ft.)

The smallest vehicle (P-30-1) is thus a conventional jump start autogyro, with, (provisionally), mechanical drive to the rotor for "spin-up". The largest,(subject to a detailed analysis of the airworthiness requirements which may be applied in this somewhat special case) will have at least partial hovering capability, and an engine-out performance which must be matched to the proposed operating methods.

Various engine Companies, including Allison, Boeing, (Industrial Products Division) and General Electric have been contacted in the search for suitable propeller turbine power plants for the P.30 group of projects.

Some preliminary investigation has been undertaken on the problems of ducting hot gases through the rotor system to supply tip jets.

Report No.TD/RW/9, on the feasibility and probable cycle efficiency of the cold-jet tip drive system is in course of issue.

A proposal has also been prepared on a program of ground rig testing to cover the period July-December 1959. The initial stages of this program, involving design of a "Hot-gas" rotor blade test specimen, are already in work.

2.2 ROTARY WING PERFORMANCE GROUP

Reports are in course of preparation on the general subject of jump take-off. While the stability and control section has produced a computer program which predicts jump-start capabilities assuming a certain arbitrarily chosen pilot technique, (which is quite adequate for the purposes of preliminary design), the performance group is attempting to produce take-off performance charts of a more general nature which will enable the pilot technique to be optimised for any given configuration.

Work has also started on performance estimation for the P.30-1 project, and a report is being prepared on the design of the proposed ducted fan, the problem being to satisfy the three main requirements of take-off thrust, cruising efficiency, and low speed directional stability.

Prior to starting on the P.30 assgnment, the efforts of the performance group were concentrated on producing basic data in a form in which it could be used for parametric studies. The I.B.M. computer facilities were used to evaluate rotor lift/Drag ratios, and hovering thrust, over a wide range of variables, and results plotted in non-dimensional carpet form.

A standard method of evaluating aircraft profile drag, based on certain recognised aerodynamics data sources such as the R.Ae.S Data Sheets, was devised. (Report No. DE/1 by L. Robinson)

Investigations into the phenomena of retreating blade stall and the effect of various parameters thereon were made by N.Timoshenko (Report No. TD/RW/10)

Preliminary analyses of jump-start take-off techniques and performance have been made.

Report No.Gen./Power/1 by P.Isaac was issued May 11th and is a review of the various methods of obtaing tip-jet drive, including compressed air storage with tip burning, continuous compression with tip burning, ram jets. Cycle efficiences are compared for a range of air supply pressures, and for pressure and velocity type nozzles.

2.3 ROTARY WING - (STABILTITY AND CONTROL GROUP)

A study has been carried out of several control systems for helicopter rotors with a view to establish an optimum and economical configuration for use in a gyroplane with limited or no hovering capabilities. Jump start requirements (inertia or partial power)have also been considered. Investigation has been started with a servo tab controlled rotor as this appeared to offer significant advantages, particularly at flight velocities near hovering. The following reports to be issued shortly describe methods of analysis and sample calculations for rotors equipped with servo tabs:

TD/RW/3 By D.L.Martin

Aerodynamic derivatives of a servo tab controlled, torsionally rigid rotor blade.

This report presents general methods of aerodynamic analysis of a rotor equipped with aerodynamic servo tabs. The method is easily adaptable to any of the rotor configurations presently in use. Final results are presented in the form of a matrix suitable for digital computer processing.

TD/RW/1 By G.W. Haynes

Non-hovering rotor characteristics.

Matrix presented in TD/RW/3 in general form is adapted to a specific rotor and a specific solution obtained in a form suitable for further analysis of the complete aircraft dynamics on an analog computer. Variation with forward speed of 21 rotor stability and control derivatives is shown illustrating the characteristics of the servo tab system.

TD/RW/2 By V.Baddeley.

Investigation of the control characteristics of a tab controlled articulated rotor in forward flight.

This report is a continuation of report TD/RW/1 and contains a parametric study of a specific tab controlled rotor in an effort to produce an optimum configuration from stability and control viewpoint.

TD/RW/4 By F.Potts.

An investigation of the effect of the flapping hinge offset on the longitudinal stability of a gyroplane.

This report contains methods and results of a study of longitudinal stability of a gyroplane equipped with a wing, a tailplane and an autorotating rotor carried out on an analog computer. In particular the effect of flapping hinge offset on longitudinal stability is investigated. The report utilises results of report TD/RW/2 and shows effects of varying of the tab parameters. Complete block diagrams for analog computer simulation are included.

The above reports indicate that a tab controlled rotor is not an optimum configuration for an autogyro application but may have some merits in helicopter application. A study of a more conventional rotor head system believed to be applicable readily to an autogyro has been carried out in report TD/RW/8 by V.Baddeley.

Effect of pitch-coning coupling on control derivatives.

A simple autogyro with fixed collective pitch setting requires a high ratio of pitch-coning coupling. The effect of the pitch-coning coupling on control derivatives and stability of a conventional rotor head is the subject of this report. Methods developed in report TD/RW/3 have been utilised in this report. This study will be supplemented by an analog computer simulation in a separate report since this system appears to offer desirable characteristics for autogyro application.

In addition to the dynamic stability of rotary wings the following subjects have been studied and will shortly be issued in report form:

TD/RW/7 By E.Kisielowski

Investigation of the longitudinal trim requirements of a gyroplane.

Methods are presented for calculation of trim requirements in autorotated flight for a gyroplane equipped with conventional wing, tail surfaces and elevators, including power effects and c.g. travels

TD/RW/6 By R.Rangi

Investigation of take-off performance and techniques of a gyroplane and a gyrodyne by digital computer methods.

Methods suitable for numerical solution on an IBM 704 digital computer are shown together with examples of a jump start take-off autogyro. Methods permit evaluation of an optimum take-off path of an autogyro utilising kinetic energy of a spun-up rotor or partial power of combination of both. Control requirements during take-off can be predicted. Take-off includes transition into fully autorotated flight.

2.4 ROTARY WING - STRUCTURES GROUP

Summary

The investigations in this field were directed towards setting the basic structural requirements for this type of aircraft. In particular, a detailed theoretical analysis of the Coriolis forces on the rotor was undertaken.

General Investigation

To avoid ground resonance, it is essential to have a hub frequency as high as possible. But as the upper stiffness limit of the complete aircraft on the ground is set by the undercarriage wheels, it is necessary to ensure that other structural components (pylon, wings, fuselage) do not have this frequency. This can be achieved by providing fuselage and wing bending continuity, and the provision for rigid fuselage roof frames to support the pylon against excessive bending. The design being such that a natural frequency criteria of 3-5 cps. be satisfied. It was found, however, that a design for a safe life of 10,000 hrs. automatically satisfies the frequency criteria.

For a rotary wing aircraft, jump starting presents a new design case for the wings. The condition is such that the rotor carries all the lift and the wing is loaded mainly by the dynamics of the large concentrated masses located outboard

These problems are still under active consideration.

Analysis of the Coriolis forces on a helicopter rotor.

Report No. S/RW/1 being completed.

A general non-dimensional analysis of the root bending moment of a flapping blade is described. The results are expressed in terms of non-dimensional parameters such as:

1. $Z = \left(\dfrac{\text{rotor angular velocity}}{\text{blade natural frequency}}\right)^{\frac{1}{2}}$

2. $P = \dfrac{\text{coning angle}}{\text{flapping angle}}$

3. $= \dfrac{\text{Tip mass}}{\text{total blade mass}}$.

As expected the moments peak to infinity at the resonance points, however, the introduction of structural damping reduces the peaks.

Comments are then made on the different conditions which occur when the rotor is driven at constant angular velocity from the blade tip instead of the rotor shaft.

2.5 ROTORCRAFT DYNAMIC GROUP

2.5.1 Blade Flutter

An analysis of the effect of pitch-cone coupling on the flutter of rotor blades has been made. The analysis leads to a simple approximate formula for the flutter speed of the rotor blade which is dependent on the degree of pitch-cone coupling. Thus a simple mass-balancing criterion is established to avoid flutter.
Report in draft.

2.5.2 Ground Resonance

Coleman's criteria for the edgewise blade stiffness required to avoid ground resonance have been extended to some extent and presented as design charts. The charts are applicable to two or three-bladed rotors without lag hinges.
Report in draft.

Some work has been done on the size of damper required to prevent ground resource on blades with lag hinges. This work is only partially complete.

3.0 SUPERSONIC TRANSPORT-

The design studies summarised in this report have concentrated on an aircraft to carry 120 passengers on the North Atlantic route at about M = 2. The configuration has been assumed to be a slender delta-type wing with integrated fuselage. This configuration seems to have great promise and is also a logical extension of the company's experience on the Arrow.

The inclusion of systems studies at this stage is necessary because:-

a) The air-conditioning problem is a serious one at these cruise Mach numbers, and
b) The high fuel/gross weight ratio combined with the slender configuration makes the fuel system design critical.

3.1 PERFORMANCE ANALYSIS

Available engine data was combined with drag estimates of a selected supersonic transport aircraft design, to determine range performance in detail. Range performance was determined for various cruising Mach numbers. From this an appreciation was gained of the fuel used for various stages thoughout the flight, including loiter and diversion. Drag estimates were then refined and somewhat optimized which together with estimated greater potential engine cruise performance gave considerably better range performance. A total of 8 range flights were calculated, in which the first four gave a pessimistric result and the last four showed what was achievable under realistically refined conditions. The latter gave more than the desired performance, which should cover any off-design conditions or any over optimistic assumptions.

AERODYNAMIC DESIGN OF SUPERSONIC TRANSPORT

Since the configuration is very slender (aspect ratio less than unity) the design of the aerodynamic shape is based on Adams and Sears "not-so-slender body theory". This is merely a series expension of linearised theory in terms of a slenderness parameter. It is of course not so accurate as linearised theory, but its simplicity enables the shape to be optimised directly for minimum drag. The design of the aerodynamic shape is of course divided into thickness and lift effects which are treated separately.

3.2.1 Thickness Effects.

The area distribution and cross-section shapes have been computed to give minimum wave drag consistent with the restrictions of internal space required for passengers, fuel, undercarriage, etc. It has been found that considerable drag reductions seem to be possible by a spanwise redistribution of area near the trailing edge, so that the area is concentrated further outboard toward the tips. It is proposed that this drag reduction be checked by a supersonic area rule analysis on the IBM 704. This programme will also be used to check the range of Mach numbers in which the "not-so-slender body theory" is valid.

3.2.2 Lift Effects

The chordwise lift distribution which gives the minimum wave drag for a given lift and pitching moment has been computed. This distribution determines the general chordwise camber required for a given planform. An altcrntive possibility which is being investigated is to start with a simple camber shape and modify the planform to give the require lift distribution. This alternative may provide a more logical way of defining the planform.

In addition the design of drooped leading edges (to take maximum advantage of the leading edge section and avoid separated flow at cruise) is being calculated.
Reports on these analyses are to be issued shortly.

3.3 FUEL SYSTEM - SUPERSONIC TRANSPORT

The basic problems of a fuel system for a Mach 2 transport are being studied. The study has centered arond a known basic outline of the aircraft and of known basic performance requirements.

The work completed to date is as follows:-

a) The fuel distribution problem has been solved. That is, the best configuration on fuel tanks and the optimum number of tanks has been determined.

b) Schematics of the following basic systems, listing all the most essential equipment, have been prepared:

a) Fuel transfer system;
b) Refuelling and defuelling system;
c) Fuel pressurization system.

c) The fuel c.g. problem has been studied and a new type of weight control rather flow control system has been recommended. Basic concepts of the system have been marked out.

d) the overall weight of the fuel system including trapped fuel has been determined.

3.4 PROGRESS REPORT ELECTRICS - SUPERSONIC TRANSPORT

An electrics report is almost complete and will be in draft form shortly.

Contents:

1. General
2. Design Objectives and Reliability
3. A.C. Load Summary
4. A.C. System
5. D.C. Load Summary
6. D.C. System
7. Weight Analysis
8. Special Equipment Suppliers

Appendices A,B,C,D,E covering estimates of power requirements for certain systems.
Figures 1,2,3,4,5 - Load Graphs and schematic block diagrams.

3.5 SUPERSONIC FUSELAGE STRUCTURE STUDIES.

Studies have been undertaken to investigate structural problems related to supersonic transport type aircraft construction. A most interesting aspect of this field is that of cabin design. Should a conventional integral type structure be employed or should a floating capsule type cabin be used? It was decided to investigate the latter to determine if it held any potential.

The departure from the conventional idea of a cabin, integral with the fuselage, has resulted from a desire to minimize the effects of kinetic heating of the external skin, on the structure. In addition, this concept permits the design of a self-contained pressure vessel, and also relieves the cabin formers of the necessity of handling wing loads.

The inability to make any provision for windows in this design is not a detriment as long as it can be agreed that an integrated cabin and fuselage design would also be best designed windowless for the speeds and altitudes envisaged.

Present indications are that the capsule, and the centre wing structure will each be carrying bending moments equivalent, in magnitude, to the overall bending moment existing on an intergrated structure.

In addition, with the number of supports required for the capsule, it will not be possible to prevent it from bending in sympathy with the wing centre section.

It is therefore reasonable to state that structural weight over the overlapping length will be appreciable higher for the capsule configuration. This is so in spite of the fact that structural reinforcing will be required to cater for the stresses induced by the dynamic heating for the integrated cabin design.

Another problem associated with the capsule concept, is the difficulty in providing supports within the wing, as provision must be made for the relative fore and aft movement of the capsule to the wing, which is in the order of 3 inches for representative size.

To sum up, the investigation to date seems to favor the integrated configuration.

4.0 HYDROFOIL BOAT STUDIES

The following is a preliminary programme for the hydrofoil boat studies with particular emphasis on stability and control. The programme outlined below will be a useful one; however, other aspects of the problem will have to be studied simultaneously (engine requirements, lay-outs, weight distributions etc.) in order to produce results applicable to a specific design. Very little information is at present available on these subjects and a stability study may well turn out to be one of academic interest only unless this information is provided.

The major steps in the study will be as follows:-

1. Formulate equations of motion

2. Determine the applicable hydrodynamic coefficients, ship geometry, and weight distribution.

3. Set-up an analogue simulator of the equations of motion and study the following:-

   3.1 Ship motions at various speeds with linear hydrodynamic derivatives and no wave effects.

   3.2 Effect of non linearities with hydrofoils close to the surface

   3.3 Motion through the waves covering full spectrum of wave frequencies and amplitudes.

4. Perform parametric study of hydrofoil configurations

   4.1 Ladder

   4.2 V - type

   4.3 Canard

   4.4 Other

5. Study the effects of inertial and hydrodynamic coupling which at first glance appear to be of considerable importance.

6. Study methods of improvement of the stability.

The above programme is to be implemented immediately.

5.0 REPORT ON ARROW PROGRAMME TECHNICAL TERMINATION REPORTS

5.1 Vibration modes of a Delta Wing Aircraft

The material for this subject is to be extracted from various Arrow reports and presented in a single comprehensive document. Because of other assignments a start has not yet been made, but there appears to be no reason why this work should not be completed before the end of August.

5.2 Digital Data Reduction Programs: From Flight Recorded Data to Stability Derivatives - Fully Automatic Computation

Reports 71/STAB/5, Digital Computer Determination of Lateral Derivatives from Oscillatory Flight Test, and 71/STAB/5 Digital Computer Determination of longitudinal Derivatives from Oscillatory Glight Tests have been prepared and 10 copies of each are to be dispatched to D.D.P immediately. As for the related IBM-704 digital programs one exist for generating responses, but the one for generating derivatives from responses was incompletely developed prior to the ending of the Arrow contract. The former will be submitted in 10 copies to D.D.P. within the next month and the latter is being reviewed to establish the amount of work to bring it to completion.

5.3 Damping System Design for a Stability Deficient Aircraft

This report is being written and it is expected to be in print before the end of August.

5.4 Matrix Method for Deflection Analysis with Temperature Effects

The matrix method for deflection analysis can be adapted to include the effects of temperature gradients in the structure. The approximation assumes different temperatures for the upper and lower skins and the web of each individial beam. Test data are available and the basic method will be checked against them.

There are two major reports which are presently being edited and the accompanying discussion is being drafted. This should be completed and in print by the end of August.

5.5 Temperatures and Thermal Stress Problems of Supersonic Aircraft Design.

The AGARD report on "Some effects of Internal Heat Sources on the Design of Flight Structures" presented the problem of a jet engine bay, in detail. In this report the discussion is extended to the Kinetic heating of external surfaces. The finite differences and the Biot approximation methods used for computing temperature distribution and thermal stresses if a build up structure are described in detail.

The AGARD report forms the main basis of this subject. The additional iscussion and supporting reports forms a summary of the findings and experience on the Kinetic heating problem. Reports are being edited and the discussion should be prepared by the end of July.

0 INVESTIGATION OF AERODYNAMIC "HOLD-DOWN" DEVICE

The initial investigation of the possibilities of the device are contained in Report TD/Misc/No.1 issued on June 4,1959. Progress made since that date is as follows:-

1) Test have beem completed on a 1 ft. diameter flat plate. Both flow rate and gap were varied in the tests. Pressure plots and total force measurements were made.

2) Progress is being made on the construction of a contoured plate in order to conduct tests similar to those above.

3) Calculations are being carried out on the IBM-704 computer to include the effect of friction losses on various contoured plates.