DOCUMENT RESUME

ED 119 972 SE 020 317

AUTHOR Fowler, Wallace T.; Watkins, R. D.
TITLE A Solution to the Small Enrollment Problem in Aerospace Engineering--Self-Paced Materials Used in an Independent Studies Mode.
PUB DATE Jun 75
NOTE 27p.; Paper presented at the Annual Meeting of the American Society for Engineering Education (Colorado State University, Ft. Collins, June 16-19, 1975)

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage
DESCRIPTORS *Aerospace Education; College Science; *Course Descriptions; Course Evaluation; Curriculum Development; *Engineering Education; Higher Education; *Instruction; Instructional Materials
IDENTIFIERS Keller Plan; *Personalized System of Instruction; PSI; University of Texas Austin

ABSTRACT

With the decline in enrollment in the early 1970's, many aerospace engineering departments had too few students to offer some required courses. At the University of Texas at Austin, a set of personalized system of instruction (PSI) materials for the aircraft performance, stability, and control course was developed. The paper includes a description of course materials, the circumstances under which they were used, and a discussion of the factors which affect the success or failure of this mode. (Author/CP)

Event Number 1210

American Society for Engineering Education
Annual Conference, June 16-19, 1975
Colorado State University
Ft. Collins, Colorado 80521

A SOLUTION TO THE SMALL ENROLLMENT PROBLEM IN AEROSPACE ENGINEERING -- SELF-PACED MATERIALS USED IN AN INDEPENDENT STUDIES MODE

Wallace T. Fowler
Associate Professor, Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin
R. D. Watkins
Second Lieutenant, USAF

Abstract

With the decline in enrollments in the early 70's, many Aerospace Engineering Departments experienced the problem of having too few students to offer some required junior or senior courses. At The University of Texas at Austin, a set of PSI (Keller Plan) materials for the aircraft performance, stability, and control course were written in spring 1972 by the lead author. The materials were used in the classroom for three semesters by the author and a second faculty member. Then the low enrollment effects hit and we were unable to offer the course (a required course in our curriculum) every semester.

In summer 1972 two students had asked to take the course on an individual study basis and had been allowed to do so because the course was not offered formally during the summer. In summer 1973 a third student made the same request and was allowed to enroll. None of the three students completed the course during the summer in which they started, but all students finally finished.

The instructor's attitude toward this educational mode, which was negative after the first three students, was changed through the experience with a fourth student. Three additional students have subsequently taken the course in this mode. The paper includes (1) a description of the course materials, (2) a description of the circumstances under which the materials were used, (3) and an attempt by the instructor and the fourth student (the second author) to isolate the factors which affect the success or failure of this mode of teaching.

A Solution to the Small Enrollment Problem in Aerospace Engineering -- Self-Paced Materials Used in a Structured Independent Study Mode

W. T. Fowler *
R. D. Watkins **

Introduction

In the spring semester of 1972, a set of PSI[1] materials (Keller Plan) was written and used in a senior level aerospace engineering course (aircraft performance, stability, and control). In the Keller Plan, the instructor first carefully determines the objectives for each part of the course. Then, having established intermediate and terminal objectives, the instructor divides the course materials into units, each containing a reading assignment, study questions, collateral references, study problem, and any necessary introductory or explanatory material. The student studies the units sequentially at the rate, place, and time he or she prefers. When the student feels that the material in a unit has been mastered, he takes a "readiness" test over that material. If he passes the test ("passing" in many Keller plan implementations means a 100% score on the readiness test), then he goes on the the next unit. The test is scored immediately by a student assistant called a proctor. If the student does not successfully complete the readiness test, he is told to study the material again and to return when he feels he is ready to take another test over the materials. No matter how many times a student is tested over a given unit, he is not penalized. The testing is viewed as an integral part of the learning process.

*Associate Professor, Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin.

**Second Lieutenant, USAF.

As noted by Dr. Keller, the characteristics of the basic method are:

1. The go-at-your-own-pace feature, which permits the student to move through the material at a speed commensurate with his ability and other demands on his time.
2. The unit perfection requirement for advancement, which lets the student go on to new material only after demonstrating mastery of the current material.
3. The stress on the written word to convey important factual information in teacher-student communication. The lecture, if any, is motivational, and is not the sole source of any vital information.
4. Use of student proctors to score the tests in the presence of the student. This provides immediate positive reenforcement and enhances the personal-social aspect of the educational process.

Course Materials and Usage

The materials which were prepared followed the Keller philosophy. They were keyed to two texts, Flight Mechanics[2] by Angelo Miele (now out of print), and An Introduction to the Longitudinal Static Stability of Low-Speed Aircraft[3] by F. G. Irving. A typical unit plus several example unit readiness tests are given in the Appendix.

The materials were used with a class of sixteen students during the spring semester with the fastest students acting as proctors for the slower students. Due to shifting departmental priorities, the course was taken over in the fall of 1972 by a second departmental faculty member. This faculty member used the materials during the fall 1973 semester and again during the spring 1974 semester. During the spring semester, modified versions of several units were produced by this faculty member in consultation with the author.

Individual Instruction Experiences

In the summer of 1972, two students asked to take the course in the individual study mode as it was not offered formally during the summer session. In the summer of 1973, a third student made the same request. These students were allowed to take the course in a structured individual mode using the PSI units.

The format used for the structured individual study mode was as follows. The student was given a complete set of course units and was told how the course was going to work. All testing was to be carried out by the instructor and was to be either written or oral depending on the material in the unit and the availability of the instructor for oral testing. All readiness tests were to to be scored immediately and 100% concept mastery was required. Arithmetic errors had to be found and corrected before the student could proceed to the next unit.

None of the first three individual study students completed the course during the summer in which they started it. The two summer 1972 students completed the course during the fall 1972 semester. The third student, who began the course in summer 1973, finished the course early in the spring of 1974.

The following list of characteristics concerning the course, students, materials and student-instructor relationships is given to convey a sense of the over-all situation.

1. All three of these students needed to take the course during a summer session in order to get back on schedule in their respective degree plans.
2. The three students seemed to be looking for an easy way through a required course.

3. The grade point averages of the three students were all in the B to C range.

4. During the time which the students were taking the course, the students seldom came in, and the instructor often had to call them to prompt any progress at all. It seemed that "move-at-your-own-pace" feature had been interpreted as "put it off 'til tomarrow, there's no rush."

   Due to the highly interrelated building-block nature of the material, very slow progress meant more readiness tests, more relearning, etc. The go-at-your-own-pace feature seems to penalize the students who are prone to procrastinate.

5. The students felt that the course became a burden and that the readiness tests were hard. The students tended to take the readiness tests before they were ready and repeated an average of more than three tests per unit. This was due in large part to the cumulative nature of the material and to the requirement that on tests the student recall, combine, and use techniques learned in earlier units.

6. The instructor acted as proctor for these three students. No formal meeting times were set. However, the instructor tried to be available at least three or four hours per day during the summers, but the students did not take advantage of this.

In summary, the experience with the three students discussed above was unsuccessful and the instructor had no intentions of ever using the PSI course units in this manner again. The structuring of individual study through the use of PSI classroom materials seemed to be poor educational practice.

Then, in September of 1973, a fourth student (the second author of this paper) approached the instructor and requested to use the PSI materials and take the course in the individual study mode. In contrast to the three previous students (who had gotten behind in their course work, forcing the need to take the course in the summer), this student wanted to take the course as an elective and needed the individual study mode because be was taking another course at the time that the lecture section of the course was being offered. (A lecture section was being offered by another faculty member). The student came highly recommended by his faculty advisor and had an outstanding academic record. In addition, although the student had never taken a PSI course before, he was currently serving as a proctor in a PSI remedial mathematics course for freshman engineering students. After consideration of these factors, the professor decided to grant the student's request.

The individual study was again structured using the course materials prepared for the PSI classroom, and again the professor took on many of the duties which are handled by the proctor in the standard Keller PSI implementation. This time, however, a weekly meeting time was set (which could be postponed or changed at the request of either the student of the professor in order to meet contingencies). The student was given all of the units at the start of the course and set his own goals as the semester progressed. Many of the early readiness tests were given verbally, and the student answered most of the unit study questions in writing. These written answers were used as the starting points for many lengthy discussions of the course material. In summary, the student did exceptional work, and both student and professor found the experience worthwhile.

Since the fourth student, three other students have taken the course via the individual instruction mode. These students were more like the first three students discussed than the fourth, but several changes in operating procedure seemed to have improved performance. A weekly meeting time with the student setting weekly goals seems to help greatly. This procedure seemed to help two of the three students get through the course in one semester. The third student was another procrastinator and took almost two semesters to complete the course.

Student Benefits of the Individual Instruction Mode

The individual instruction mode has a tremendous effect on the students who are exposed to it. For the student to which the instructional mode is well suited, these effects are all good. The second author (R. D. Watkins) was one such student (Mr. Watkins is now a second lieutenant in the USAF undergoing undergraduate pilot training). The views which follow were those of Mr. Watkins.

In comparing the structured independent study course with the standard lecture format from the student point of view, the following factors are important.

1. In the structured independent studies course, the students must take on a much more active role in the educational process. The procedure of letting material slide until just before a quiz won't work.
2. The informal teacher-student relationship, combined with the lack of pressure on readiness tests make learning a much more satisfying experience.
3. The student feels a much greater sense of accomplishment because the learning is much more a product of his own efforts than those of a lecturer.
4. The depth of understanding of course material attained is much greater.
5. In a properly designed course of this type, the student ends the course with the confidence that he can pick up an unfamilar book and learn from it without the aid of a teacher.

6. The two-way communication encouraged by the system of instruction made the acquisition of information an exciting process.
7. This mode of instruction can build the overall self-confidence of students tremendously.

Criteria for Student Success or Failure

We have described above several instances in which PSI type materials have been used in the individual instruction mode. In the situations described, it might be said that the instructor should receive 2D's, 2C's, 2B's, and one A in the implementations of the individualized course. We will now attempt to draw some conclusions from the overall experience. Unfortunately, it is the nature of individual study situations that no large numbers of "subjects" are available for analyses, statistical or otherwise. Any generalizations made must be drawn from situations involving very small numbers of students, and the reader should keep this in mind at all times.

In the consideration of the use of PSI course materials in the manner described above, one must be aware that certain student characteristics can greatly affect the probability of success. It is important to identify these characteristics, if possible, and to screen prospective individual study students so that those with personalities not suited to this instruction mode are guided into another education channel. It is equally important however, to identify students who would do well in this type of situation, because for certain types of students, at certain points in their academic careers, this type of course may well be among the best types of learning expreiences.

First, the student's background is important. Has he understood the important prerequisite materials? A student who is well grounded in the prerequisites will have a head start, but a motivated background-deficient student may well use the individual study experience to fill in gaps in his background.

Second, the student's response to responsibility is important. A student who does not react well when given a responsible role likely will not do well. Similarly, a student who does well only when in direct competition with others may not do well in this type of course.

The major factors which seem to stand out as the most important predictors of success are the student's interest and degree of self discipline. A student who is self-disciplined but not interested in the material may finish but may hate the material. A student who is interested but has no self-discipline will probably finish slowly or not at all. The interested, self-disciplined student can be expected to do well even though he may have background dificiencies.

An interesting and almost obvious predictor of student seccess in self-paced courses has been noted by Dr. John K. Henneberry,[4,5] Professor of Phychology at Le Moyne College, Syracuse, New York. In his work, Dr. Henneberry describes a situation in which a student is given a self-paced study task and is then told to set a realistic date for finishing the task. If the student meets hiw own goal, under no outside pressure, he is a good candidate for self-paced type instruction. If he does not meet his own goal, he is not a good candidate for this type of instruction.

Summary

There exist many possible situations where one might use materials written for the PSI classroom in the individual instruction mode. An opportunity exists anytime you have the materials available and an insufficient enrollment in a course to offer a formal section. All such opportunities should not be taken advantage of since in many cases you would be stacking the odds against success.

However, in some situations, small enrollments are a chronic problem. As an example, the enrollment in pre-engineering courses in coummunity and junior colleges. In such instances, either the student is given individual instruction or does not get to take the course. In such instances where the materials are available, the instructor should give careful consideration to using the materials in the individual study mode.

In considering the impliementation of such a course format option, several factors should be kept in mind. First, all students will not do well, just as in the lecture. Second, procrastination will be a problem unless special steps are taken to combat it. Third, if the materials aren't available, don't try it unless you are a glutton for punishment. The initial investment of instruction time is very high.

Finally, the structured independent study mode offers an alternative to not offering a course during times of low enrollment. If several instructors at different schools could cooperate in materials development for a given subject area, then the large initial time investment problem could be overcome. If each unit were written to be as self-contained as possible, then a given instructor could choose his own sequence and topics within limits, for the individual study course. This would maximize the usefulness of the materials.

REFERENCES

1. Keller, Fred S., "Good-bye Teacher...", Journal of Applied Behavior Analysis, Vol. 1, 1968, pp. 79-89. The method developed by Dr. Keller is called a personalized, proctorial, or self-paced system of instruction.

2. Miele, Angelo, Flight Mechanics-Theory of Flight Paths, Vol. 1, Addison-Wesley, Reading, Mass., 1962.

3. Irving, F. G., An Introduction to the Longitudinal Static Stability of Low-Speed Aircraft, Pergamon Press, London, 1966.

4. Henneberry, John K. "Latency after a Priming Period and Grade Point Average as Predictors of Student Pace, Performance Gains, Grade, and Fulfllment of Grade Expectations," (Paper Submitted to Second National Conference on Personalized Instruction in Higher Education, 1975)

APPENDIX

ASE 367K - Unit 3

Flight in a Horizontal Plane

OBJECTIVES

Upon completion of this unit, the sutdent should be able to:

1. Derive the equations for flight in a horizontal plane.
2. Determine the number of degrees for aircraft in steady level coordinated turns.
3. Explain the limitations to steady level coordinated turning flight and compute the limiting bank angle when given data for a specific aircraft.
4. Compute turn radii, load factors, turn rates, and bank angles when given the appropriate data.
5. Justify all assumptions made in the analysis presented in the Discussion section of this unit.

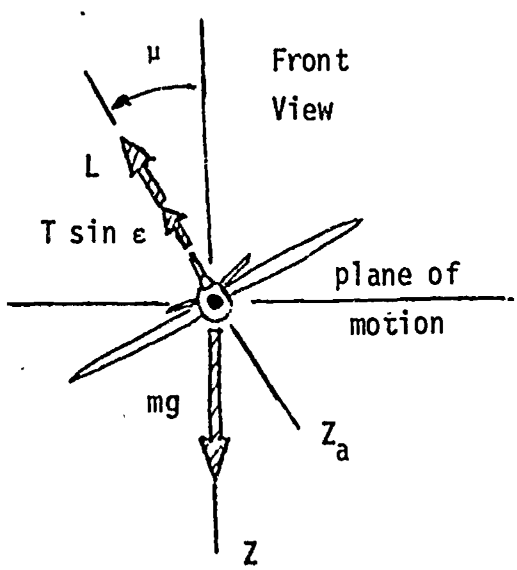
READING ASSIGNMENT

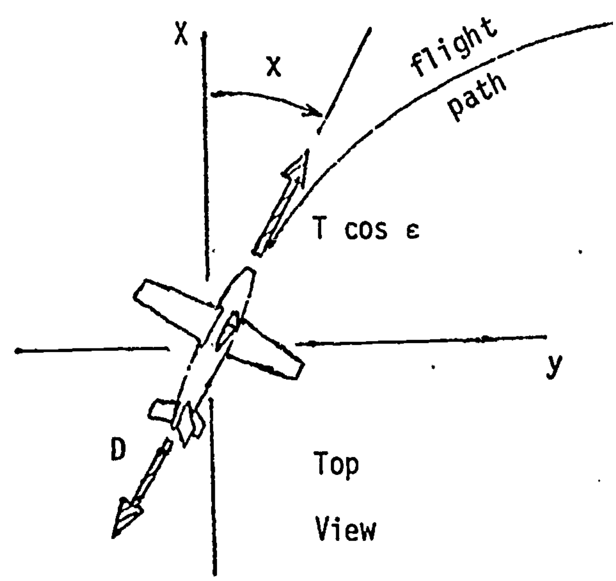
Chapter 4, Sections 1 through 8, Miele.

DISCUSSION

Basic Equations:

For the purposes of this discussion, it will be assumed that all turns made in the horizontal plane are coordinated. This means that there will be no sideslip angle ($\sigma = 0$) and no side force ($Q = 0$). [Note that the use of σ for sideslip angle as Miele does not universal; many authors use the symbol β to denote sideslip]. Let us also assume that there is no thrust sideslip angle ($\nu = 0$). Finally if the flight is to take place in a horizontal plane, the flight path angle, γ, must be identically zero. These assumptions lead to two two-dimensional figures which can be used in place of Figure 5, page 54 in the Miele text. (The single figure in the text is correct, but it is easier to look at the two figures and see what is going on).





The assumptions imply that $\overline{T}$, $\overline{D}$, and $\overline{L}$ lie in the aircraft plane of symmetry. The variable χ is the heading angle measured clockwise (as viewed from the top) from some earth fixed reference direction (usually either true north or magnetic north). The bank angle μ is measured between the local vertical and the negative aircraft z-axis (recall that positive aircraft z-axis points out the bottom of the aircraft). The sign convention for bank is such that a right bank (right wing moving down when the aircraft is in a normal cruise attitude) gives a positive value for μ. The coordinates x and y give the position of the aircraft over the earth and can vary, but according to the assumptions, altitude is constant. In the earth fixed coordinates, the velocity is given by

$$\overline{v} = \dot{x}\overline{i}_e + \dot{y}\overline{j}_e \tag{1}$$

where $\overline{i}_e$ and $\overline{j}_e$ are the appropriate unit vectors in the earth fixed coordinates. However, in terms of the heading angle, χ, the velocity is given by

$$\overline{v} = \overline{v} \cos\chi \, \overline{i}_e + v \sin \chi\overline{j}_e \; . \tag{2}$$

Thus, the kinematic equations are given by

$$\begin{aligned} \dot{x} &= v \cos\chi \\ \dot{y} &= v \cos\chi \end{aligned} \tag{3}$$

In terms of unit vectors tangent and normal to the path in the plane of motion, $\overline{t}$ and $\overline{n}$, respectively, we can write

$$\overline{v} = v\overline{t} \tag{4}$$

and

$$\dot{\overline{v}} = \dot{v}\overline{t} + v \, \dot{\chi} \, \overline{n} \tag{5}$$

(Recall that the second term in equation (5) is $v\dot{\bar{t}}$ where $\dot{\bar{t}} = \dot{\chi}\bar{n}$ due to the rotation of the $\bar{t}$, $\bar{n}$ unit vectors at the angular rate $\dot{\chi}$)

From our two figures, we can write the force equations in the $\bar{t}$, $\bar{n}$, and z_e directions as

$$T \cos \varepsilon - D = m\dot{v} \qquad (\bar{t} \text{ direction})$$
$$(T \sin \varepsilon + L) \sin \mu = mv\dot{\chi} \qquad (\bar{n} \text{ direction}) \tag{6}$$
$$(T \sin \varepsilon + L) \cos \mu = mg = m\dot{h} \equiv 0 \quad (-z_e \text{ direction})$$

As before, if the aircraft is loosing mass as a result of fuel consumption (or for any other reason, for the matter), the mass equation is

$$\dot{m} = -\beta \tag{7}$$

(Note that Miele's use of β as mass flow rate probably forced the use of σ as sideslip angle).

If we also assume that thrust is fixed with respect to the body axes, (eliminating the Harrier, XC-142A, etc., from the analysis), we get

$$\varepsilon - \alpha = \text{constant} \tag{8}$$

(The angle between the aircraft zero angle of attack line and the thrust vector is constant).

Under these assumptions, the equations of motion for flight in a horizontal plane are given by

$$\boxed{\begin{aligned} \dot{x} &= v \cos \chi \\ \dot{h} &= v \sin \chi \\ \dot{v} &= (T \cos \varepsilon - D)/m \\ \dot{\chi} &= (T \sin \varepsilon + L) \sin\mu /(mv) \\ 0 &= (T \sin \varepsilon + L) \cos\mu - mg \\ \dot{m} &= -\beta \\ \varepsilon - \alpha &= \text{constant} \end{aligned}} \tag{9}$$

Compare these equations with those given on pages 54 and 55 of Miele.

Simplified Analysis:

In many analyses, the further assumption is made that thrust lies in the xy plane ($\varepsilon=0$). Under such an assumption, letting W (weight) = mg then the fifth of equations (9) becomes

$$L \cos\mu = W \tag{10}$$

The quantity load factor, n, is defined as the ratio of lift to weight. From equation (10), we see that

$$n \equiv \frac{L}{W} = \frac{1}{\cos\mu} \tag{11}$$

for a level coordinated turn in which thrust lies in the xy plane. Note that under the assumptions made, the load factor in a level coordinated turn depends only on the bank angle. This would not be true in an uncoordinated turn (slip or skid) or in a climbing or descending turn or if $\bar{T}$ did not lie in the xy plane. For level coordinated turn analyses of normal aircraft (no vectored thrust) however, the fact that $\bar{T}$ has a small component perpendicular to the xy plane is often ignored.

Summing forces in the xy plane, we will get two scalar equations. It is convenient to sum the forces parallel to the instantaneous direction of flight (along the tangent direction $\bar{t}$) and perpendicular to $\bar{t}$ in the xy plane (along the normal direction $\bar{n}$). [Note that we have a unit vector $\bar{n}$ and a load factor n in our analysis - be careful to keep them straight in your mind]. Summing forces in the $\bar{t}$ and $\bar{n}$ directions, we get

$$\begin{aligned} m\dot{v} &= (T-D) && (\bar{t} \text{ direction}) \\ mv\dot{\chi} &= L \sin\mu \quad . && (\bar{n} \text{ direction}) \end{aligned} \tag{12}$$

Since $R\dot{\chi} = v$, where R is the radius of curvature of the path, and since $m = W/g$, we can rewrite the second of equations (12) as

$$L \sin \mu = \frac{W}{g} \cdot \frac{v^2}{R} \qquad (13)$$

Recalling that

$$L \cos \mu = W \qquad (10)$$

we can square both equations and add to get

$$L^2 (\sin^2 \mu + \cos^2 \mu) = \frac{W^2}{g^2} \frac{v^4}{R^2} + W^2 .$$

However, $L = nW$, so that

$$n^2 = 1 + \frac{v^4}{g^2 R^2} \qquad (14)$$

From equation (14), we can write load factor in terms of v and the radius of curvature of the path, R, or v in terms of n and R, etc. The appropriate relationships for level coordinated turns under our assumptions are

$$n = \left(1 + \frac{v^4}{g^2 R^2}\right)^{1/2}$$

$$R = \frac{v^2}{g(n^2-1)^{1/2}} \qquad (15)$$

$$v = \{Rg(n^2-1)^{1/2}\}^{1/2}$$

The turn rate $\dot{\chi}$ can be found by recalling that $v = R\dot{\chi}$. We get

$$\dot{\chi} = \frac{g(n^2-1)^{1/2}}{v} \qquad (16)$$

If we recall that $n = \frac{1}{\cos\mu}$, it is possible to rewrite equtions (15) and (16) in terms of μ rather than n, if we so desire.

Limitations to Turning Flight:

The ability of an aircraft to execute level coordinated steady turns is limited by three factors. The high speed turns are limited by thrust and drag. The intermediate speed turns are limited by the structural strength of the aricraft, and the low speed turns are limited by $C_{L_{max}}$.

If one considers level, coordinated steady turns, the basic assumptions are: constant altitude (level), no sideslip or side forces (coordinated), constant velocity (steady).

The high speed turn limitation occurs because for a level turn at a given speed, a higher angle of attack is required to maintain level flight than is required for straight and level flight at the same speed. More lift is required ($L = W/\cos\mu$), and thus more drag is produced. This implies that more thrust is required to maintain a given speed in a turn than was required to maintain the same speed in level flight. Thus, considering that there exists a maximum value for thrust, T_{max}, at any altitude, then there exists a high speed limit on steady level coordinated turns which is based on T_{max} which is characterized as follows:

For a steady turn, $\dot{V} = 0$. Thus,

$$T = D. \tag{17}$$

Also, let us assume a parabolic polar, i.e.,

$$C_D = C_{DO} + KC_L^2 \,. \tag{18}$$

If we specify a speed, we can find the corresponding thrust limitation on steady level coordinated turns by finding μ_{max} for that speed. Since $L = \rho SC_L v^2/2$ and $D = \rho SC_D v^2/2$, we can combine the pertinent relations to get

$$\rho SC_L v^2/2 = W/\cos \mu$$

$$C_L = 2W/(\rho Sv^2 \cos \mu)$$

From $T = D$, we get,

$$T = \rho SC_{DO} v^2/2 + \rho Sv^2 KC_L^2/2$$

or

$$T = \rho SC_{DO} v^2/2 + \frac{2W^2 K}{\rho Sv^2 \cos^2\mu}$$

Solving for $\cos \mu$, we get

$$\cos\mu = \left\{\frac{2W^2 K}{(T-\rho SC_{DO} v^2/2)\rho Sv^2}\right\}^{1/2} \qquad (19)$$

If $T = T_{max}$, then for a given v, W, altitude (ρ), and drag polar (C_{DO} and K), $\mu = \mu_{max}$. The load factor in this turn is given by $n = 1/\cos \mu$.

At intermediate speeds, the value of μ_{max} obtained above may be such that the corresponding load factor, n, is greater than the structural load factor limit, n_{max}, specified for the aircraft. In the region where this is true, the bank limit is specified by $\mu_{max} = \cos^{-1}(1/n_{max})$. Once a speed is specified, and μ_{max} is calculated from equation (19), the corresponding load factor must be checked against n_{max}.

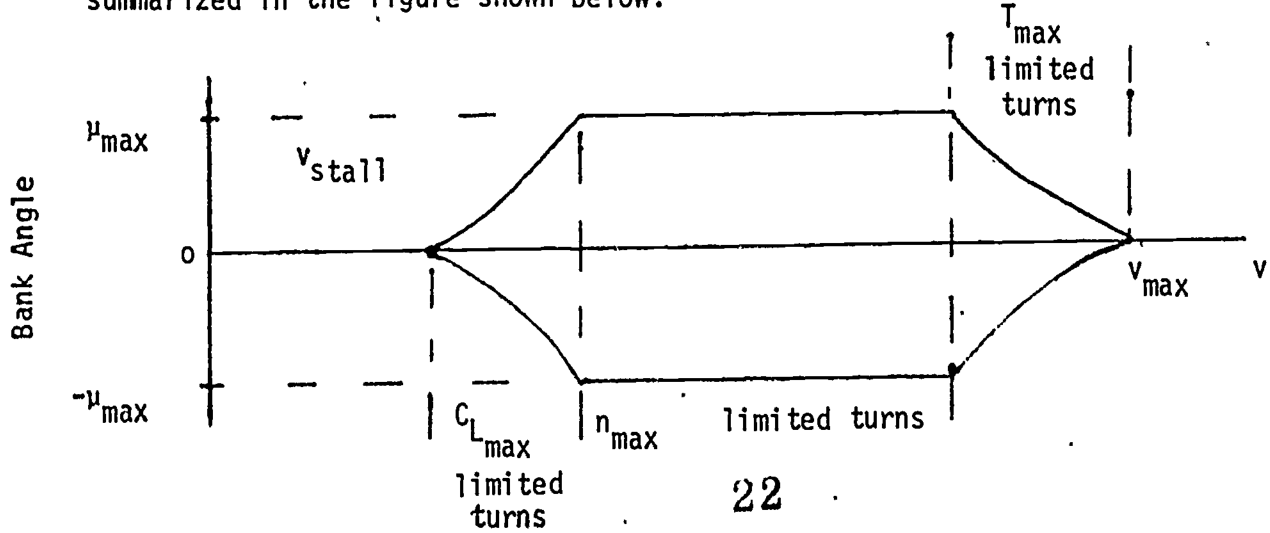
At the low speed end of the flight envelope, the limitation on turning flight is a lift coefficient limitation. The maximum lift coefficient for the aircraft, $C_{L_{max}}$, is assumed known. The lowest possible steady flight speed (straight and level) is given (from L=W) by

$$v = \sqrt{\frac{2W}{\rho S C_{L_{max}}}} \qquad (20)$$

and is called the stall speed. Clearly, since for a level coordinated turn at a given speed the aircraft must have more lift than in straight and level flight at the same speed, turns are impossible at stall speed. If the aircraft is flown at a speed slightly above stall speed, the C_L required for straight and level steady flight is reduced and turning becomes possible. The maximum lift available is always given by $L_{max} = \rho S C_{L_{max}} v^2/2$. For a given v, the corresponding bank angle is given by

$$\cos \mu = \frac{W}{L} = \frac{2W}{\rho S C_{L_{max}} v^2} \qquad (21)$$

for C_L limited turns. As speed increases, μ increases and again the load factor limit is reached. In graphical form, the limits on bank angle due to thrust, load factor, and lift coefficient can be summarized in the figure shown below.



Note the following characteristics of the regions shown on the figure.

$C_{L_{max}}$ limited turns

T increases as v increases

μ increases as v increases

n increases as v increases

n_{max} limited turns

T increases as v increases

μ and n are constant as v increases

T_{max} limited turns

$T = T_{max}(v)$ as v increases

μ decreases as v increases

n decreases as v increases

STUDY QUESTIONS

1. Consider the case of level turning flight at a fixed bank angle. Assume that $T=T(h,v,\pi)$, $L=L(h,v,\alpha)$, $D=D(h,v,\alpha)$, and $\beta = \beta(h,v,\pi)$. Working from equations (9) in the DISCUSSION, determine the number of degrees of freedom under the stated assumptions. [$\pi \equiv$ power setting].

2. Starting again from equations (9) and assuming the relations for T, D, L, and β given above, determine whether it is possible to fly at constant speed in level turning flight. If such a situation is possible, sketch the no-wind flight path (looking down from above) over the ground. Be sure to remember that the aircraft gets lighter as fuel is consumed.

3. Devise a scheme for computation of turn limitations on the digital computer. Assume that you are given $C_{L_{max}}$, n_{max}, $T_{max}(v)$, C_{DO}, K, and the aircraft weight W. You are to run through a range of speeds at any given altitude and produce a μ vs. v plot like that given at the end of the DISCUSSION. Set down the computation sequence and flow chart the process. Do not write the program at this time.

4. Rewrite equations (15) and (16) in the DISCUSSION in terms of μ.

5. Explain in your own words (in writing), the limitations to steady level coordinated turning flight.

6. If we drop the assumption of coordinated turns, what does this do to equaions (9)?

7. If we drop the assumption of level turns, what does this do to equations (9)?

8. A conventional aircraft flies coordinated turns at constant altitude and constant speed. The pilot flies a constant power setting and holds bank angle constant. Assume relations for T, D, L, and β

as in study question 1 and work from equations (9). Can the aircraft maintain the specified flight conditions? If not, why not?

Unit 3 - Readiness Test B

The equations of motion for flight in a horizontal plane are:

$$\dot{x} = v \cos \chi$$
$$\dot{y} = v \sin \chi$$
$$\dot{v} = (T \cos \varepsilon - D)/m$$
$$\dot{\chi} = (T \sin \varepsilon + L) \sin\mu /(mv)$$
$$0 = (T \sin \varepsilon + L) \cos\mu - mg$$
$$\dot{m} = -\beta$$
$$\varepsilon - \alpha = \text{constant}$$

where $L = L(h,v,\alpha)$, $D = D(h,v,\alpha)$, $T = T(h,v,\pi)$, and $\beta = \beta(h,v,\pi)$

———oo———

1. Identify all variables in the equations given above.
2. How many degrees of freedom are there in the system described above? List all equations and unknowns.
3. Is it possible to fly in a horizontal phane at constant velocity and constant angle of attack? Argue from the equations given. Remember that the mass decreases as fuel burns.
4. An aircraft is flying in a horizontal plane with its wings level (i.e., no bank). The pilot wants to keep his wings level and hold altitude constant. The aircraft is picking up ice (its mass is increasing). Neglecting the distortions in aerodynamics due to the ice, what variables must the pilot use to maintain the desired flight condition? Argue from the equations of motion given.
5. For steady level coordinate turning flight, how does thrust limit high speed turns, Explain mathematically and with words.

Unit 3 - Readiness Test D

The equations of motion for flight in a horizontal plane are:

$$\dot{x} = v \cos \chi$$
$$\dot{y} = v \sin \chi$$
$$\dot{v} = (T \cos \varepsilon - D)/m$$
$$\dot{\chi} = (T \sin \varepsilon + L) \sin \mu/(mv)$$
$$0 = (T \sin \varepsilon + L) \cos \mu - mg$$
$$\dot{m} = -\beta$$
$$\varepsilon - \alpha = \text{constant}$$

where $L = L(h,v,\alpha)$, $D = D(h, v, \alpha)$, $T = T(h, v,\pi)$, and $\beta = \beta(h,v,\pi)$

oo

1. Consider constant speed turning flight in circle in a horizontal plane for an aircraft in which π, α, and μ, can both be varied by the pilot as necessary. As fuel burns, what conditions must be imposed on π, α, and μ in order to maintain the desired flight conditions? Argue from the equations of motion given.
2. For flight in a horizontal plane at a given speed, show how $C_{L_{max}}$ places a limit on the maximum bank angle. What is the load factor at this bank angle?
3. Consider the addition of flaps to the aircraft described in the equations given. The glap deflection δ_f, affects lift and drag as follows: $L=L(h,v,\alpha,\delta_f)$, and $D=D(h,v,\alpha,\delta_f)$. How many degrees of freedom are there in the system of equations given when the modifications are made to allow flap deflection? List the equations and unknowns.
4. Considering the limitations to steady level coordinated turning flight due to thrust, load factor, and lift coefficient, find the speed at which a minimum radius turn should be made. If you can't solve for the speed explicitly, bracket it within the speed range of the aircraft.