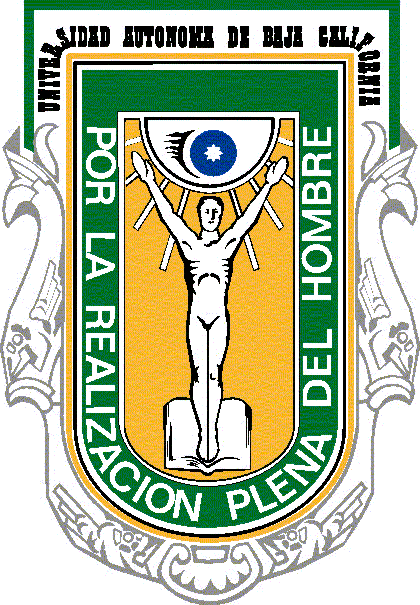
Autonomous University of Baja California.



Faculty of Engineering

Aircraft Stability and Control

**Group:**

397

**Practice 1: “Aircraft performance for turning flight**

**Team Members:**

Leyva Ortiz Luis Angel 01144771

Vasquez Castañeda Carlos Antonio 01155057

Flores Gonzalez Raul Alonso 01142702

Orrantia Montes Jonathan Enrique 1116669

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| **CAREER** | | **STUDY PLAN** | | **CURSE KEY** | | | **COURSE NAME** | | | |
| AEROSPACE ENGINEERING | | 2009 – 2 | | 11365 | | | AIRCRAFT STABILITY AND CONTROL | | | |
| **LABORATORY OF** | | **PRACTICE NAME** | | | | | | **PRACTICE #** | | **TIME** |
| AIRCRAFT STABILITY AND CONTROL | | Aircraft performance for turning flight | | | | | | 4 | | 2 HORAS |
| **1. INTRODUCTION** | | | | | | | | | | |
| There are several maneuvers that an aircraft must perform just on takeoffs and landings. Now, adding recovering maneuvers and emergency protocols and also if the aircraft is a military fighter that number can be pump up by pursuits, out-of-plane, evasive displacements or simply repositioning. If is in an airshow that number just keeps cranking up. But every maneuver is determined by some very important structural or aerodynamics components characteristics on the airframe or the fuselage.  Some of the basic concepts that are perform are maximum sustained rate turn (MSTR), which is the moment when the aircraft can archive the closest turn without losing to much inertia nor generate a lot of G-forces onto the pilot nor the airframe, the sharpest sustained turn (SST), which is actually the closest turn which the airframe or the aerodynamics can allow, and the turn with maximum wing load factor (Nmax), is the sharpest turn in which the airplane is fully loaded before entering in stagnation. All of this will be explained more thoroughly in future section.  Next, an explanation for all those concepts and protocols must be given. | | | | | | | | | | |
| **2. OBJECTIVES** | | | | | | | | | | |
| This practice has several main objectives listed below:   * Create a program capable of compute all the key parameters from a determinate plane using either MSTR, SST o Nmax at any altitude and the plane could be either a propeller or a turbojet aircraft. * Analyze the difference between the 2 cases given below and how do they behave with the variables given. * Evidence how the aerodynamic and structural restrictions affect the values and how do they change within them. | | | | | | | | | | |
| **3. THEORICAL FRAMEWORK** | | | | | | | | | | |
| Turning flight  It is a key tactical maneuver for the combat aircraft, this one can be classified in two categories:   1. Steady turning flight in horizontal plane 2. General turning flight.   In the first one is at a constant altitude, while the general turning flight may involve a gain or loss of altitude.  The flights of commercial transport and general aviation airplanes usually belong to the first category, whereas the fighter aircrafts use the second one to make maneuvers.  Equations of motion for turning flight  The forces acting on an airplane that is steady, with a constant-velocity turn with bank angle and sideslip, the following equations govern the steady turning flight.  Across the flight path:  Along the principal normal:  Turning flight of propeller aircraft  For this case we have to consider the constant-velocity, coordinated turning flight of a propeller aircraft in a horizontal plane. Generally, for propeller airplane whose power developed by the engine and the propulsive efficiency are independent of flight velocity; therefore, numerical and graphical solution must be given due to the resulting equations.  For the propeller aircraft, power available and power required are the basic quantities:  In the case of MSTR, we have to assume that the load factor is the structural limit load factor and . If these conditions are not satisfied, then the aircraft cannot generate the MSTR predicted, and in the case of the SST we cannot get the .  Turning performance of jet aircraft  For this case we keep in mind the thrust is independent of flight velocity where  Then, we can express n as:  Maximum sustained turn rate  This case is given when the aircraft attempts to make a constant-velocity turn in a horizontal plane with maximum rate of turn or angular velocity in turn. The maximum turn rate generated while holding a constant altitude is called “MSTR”.  Basically, to achieve the maximum rate of turn, the greatest possible force toward the center of the turn is required. This is achieved by inclining the lift vector as far as possible.  The maximum turn rate generated while holding a constant altitude is called the MSTR.  The equation can be written as:  Where is the reference velocity given by :  For :  And since :  Therefore, the maximum turn rate proceed when , whit this variables we obtain:  The lift coefficient Cl can be obtained using the following equation, to express the ratio of induced drag to zero lift drag:  Applying the equation and reducing:  With u=1, the dimensional flight velocity and radius of turn are given by:  Sharpest sustained turn  In this case we are looking to make a sharpest turn or where the turn has de minimum radius of curvature, this one holding a constant altitude, its name is “SST”. Here we have:  Substituting for load factor and using  For :  Solving the equation, we get:  Rate of turn:  Load factor and lift coefficient are given by:  Turn with maximum load factor  Due to the bank angle and load factor are uniquely related by:  Then, the turn for maximum load factor is same as the turn for maximum bank angle.  We have:  For the maximum load factor :  This means:  Using the restriction this mean that:  Essentially the thrust should be limited as the equation above, otherwise the load factor will exceed the structural limit factor, causing structural failure during such a turn.  Flight velocity is given by:    Knowing that :  Lift coefficient is given by:  If we substitute and , The last equation is reduced to:  For a coordinated turn in a horizontal plane with the maximum load factor, the aircraft is operating at maximum aerodynamic efficiency or minimum drag conditions.  Radius of turn:  Rate of turn: | | | | | | | | | | |
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| DR. ALEJANDRO SEBASTIÁN ORTIZ PÉREZ | | | M. C. VIRGINIA GARCÍA ÁNGEL. | | M.C. OMAR ALEJANDRO MATA LUCERO | | | | DR. DANIEL HERNÁNDEZ BALBUENA | |
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| **4. PROCEDURE (DESCRIPTION)** | | | | | | | | | | |
| **EQUIPMENT** | | | | | | **SUPPORT MATERIAL** | | | | |
| - Computer  - Matlab Software | | | | | | * Class and blackboard didactic material | | | | |
| **5. PRACTICE DEVELOPMENT** | | | | | | | | | | |
| The practice was created using de Matlab guide interface, where we can get an optimum graphic interpretation of all the values given. First of all, we have to put all the static and edit texts, push buttons, etc. in order to ask for all the values of the assessment.    Preliminary interface  This interface bellow just preliminary (prior to the restrictions interface). We are able to see that the program would take all the data available and it will give us the results of either the propeller analysis or the turbojet one. The basic methodology of this graphic interpretation is to put all the data available and the results will be depicted in the table. All the variables had their own units to avoid any kind of wrong value.    Matlab code  *Turbojet analysis*  The first step for the creation of it is select either propeller or turbojet analysis. Inside of them, we are going to enroll the values given by the edit text in 3 categories: MSTR, SST and Nmax.  Firstly, the data must to be taken:  W = str2double(get(handles.edit1,'String'));  S = str2double(get(handles.edit2,'String'));  CD0 = str2double(get(handles.edit3,'String'));  p = str2double(get(handles.edit4,'String'));  k = str2double(get(handles.edit5,'String'));  Clmax = str2double(get(handles.edit6,'String'));  Nlim = str2double(get(handles.edit7,'String'));  power = str2double(get(handles.edit8,'String'));  E = str2double(get(handles.edit9,'String'));  T = str2double(get(handles.edit10,'String'));  g=9.81;  In the code upon we are just taking all the values provided by the user. Then, having all the correct inlets we proceed to get 3 important variables in the analysis, the maximum velocity, Em and z.  vr=sqrt((2\*W)/(p\*S))\*(k/CD0)^(1/4);  Em=(1/(2\*sqrt(CD0\*k)));  z= (T\*Em)/W;  Finally, we get the program will compute all the data arrange perfectly for MSTR, SST and Nmax, then, an example of the MSTR Code will be given (visit annexes for further information related to the code):  %%%% For MSTR%%%%  uMSTR=1;  %vMSTR=uMSTR\*vr;  wMSTR=(g/vr)\*sqrt(2\*(z-1));  RMSTR=(vr^2\*uMSTR^2)/(g\*sqrt(2\*(z-1)));  NMSTR=sqrt(2\*z-1);  clMSTR=sqrt(CD0/k)\*sqrt(2\*z-1);  EMSTR=Em\*(sqrt(2\*z-1)/z);  We have to follow the same procedure with the 2 remaining. And finally we depicted all values in one balanced table:  data=[uMSTR uSTT uNM; wMSTR wSTT wNM; RMSTR RSTT RNM; NMSTR NSTT NNM; clMSTR clSTT clNM; EMSTR ESTT ENM];  set(handles.uitable1,'data',data);  *Propeller analysis*  Actually, this analysis has the same methodology as the last one, but this case needs to consider the velocity constant, and also the power created by the motor and the propulsive efficiency are independent of the velocity of flight.  One important difference is in the mathematic model needed to get the velocity that maximize the angular turn rate, where is given by:  On Matlab we used the “root” command to get the solution to these equation:  rts = roots([1 0 0 P -1]);  urts = rts(imag(rts)==0);  uMSTR=urts(urts>=0);  Essentially, the code remaining will be the application of the formulas to get the SST, MSTR and Nmax values, in order to put them in the table.  Restrictions  We know that to satisfied the correct horizontal flight:  When the exceeds from the maximum given value, we have to obtained a new dimensionless velocity given the correct value (see formulas for further information). An example of how we get the uSST value must be given:  if clSTT>clmax  uSTT=((2\*P)/(((k\*clmax^2)/CD0)+1))^(1/3);  obtaining the correct dimensionless velocity, we also have to be sure that our structural limitation is correct:  NSTT=sqrt(2\*P\*uSTT-uSTT^4);  if NSTT> Nlim  NSTT=Nlim;  end  Finally, the procedure still being the same as the other two programs created.  The same type of code will be used in the turbojet part, with the difference that the value z will not change.    *Final Display* | | | | | | | | | | |
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| **6. FORMULAS** | | | | | | | | | | |
| Propeller formulas:   |  |  |  |  | | --- | --- | --- | --- | | Special case | MSTR | SST | Nmax | |  |  |  |  | |  | g |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  | ) |  | | M |  |  |  |   Turbo Jet formulas:   |  |  |  |  | | --- | --- | --- | --- | | Case | MSTR | SST | Nmax | |  | 1 |  |  | |  |  |  |  | |  |  |  |  | |  |  |  | z | |  |  |  |  | |  |  |  |  | | M |  |  |  | | | | | | | | | | | |
| **7. RESULTS AND CONCLUSIONS** | | | | | | | | | | |
| For the results and conclusions, we need to make proves to the system to check if everything is ok. First of all, we checked one by one all the programs, giving certain values to check their authenticity. Propeller data:    Results for propeller vs propeller with restrictions  Without restrictions  With restrictions  We can conclude that the structural and aerodynamic restriction for the flight will give us a bigger dimensionless velocity and also a biggest radius of turn at the time of flight. However, the limitations provide us a limited rate of turn, but the efficiency actually will be 4 more times better than the other one.  Turbojet data:  Turbo jet vs Turbojet with restrictions  Actually with the data given is not possible to check if the restrictions are useful, due to the fact that since the values do not surpass the limit, it would be the same numbers. But if we change the value of the weight from 50,000 N to 20,000 N the change is more visible:  With restrictions    Without restrictions    Notice how the lift coefficient and the load factor changes. Since the values are independent form the other ones, all the other data remains the same.  Conclusion  In control and stability of aircraft it is important and very helpful to have software for the solution of problems related to aerodynamics, the data obtained is important to know for the design and considerations of aircraft, we cannot simply rely on theories, we must have scientific bases as well as obtaining data through formulas, of course this must also go hand in hand with simulations or real laboratory tests to be certain that our results were ideal. The industry is growing, and the solution methods must be updated, that is why nowadays the use of software for the solution and programming interfaces are commonly used. As we learn in this practice to reach the maximum rate of turn, the greatest possible force towards the center of the turn is required, get this information for example, is very helpful for pilots and engineers, since the pilot performs the maneuvers and this type of values helps you to know the limits of the aircraft, and the engineer to find ways to improve the aircraft or change certain parts of the design to improve its performance. | | | | | | | | | | |
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| **8. BIBLIOGRAPHY** | | | | | | | | | | |
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