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Fan Blade Balancing Process on CFM56-5B Engine Airbus A320 using the Trim Balance Method

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ABSTRAK

Fan unbalance is a condition of imbalance of *the fan* blades with respect to the axis of play and voltage. This imbalance results in the shaft bearing receiving additional centrifugal force due to unbalanced load. This condition causes excessive vibration that produces noise. *Trim Balance* is a method to reduce vibration by installing *balancing screws* of different weights on the *fan* blades to achieve balanced rotation. *Fan trim balance* can be performed on vibration sources from FAN /LPC or from LPT as they are located in one axle, thus influencing each other. The unit of vibration measurement used is Mils which shows the maximum deviation shift distance (*Displacement*), with a value of 1 mils = 0.001 inch, or in microns with a value of 1 μm = $1x10^{-6}$ m. According to *the Aircraft Maintenance Manual* (AMM) instructions, the recommended maximum vibration limit is 2 mils, for some airlines the vibration limit is tightened to 1.0 mils. Based on ISO 20816-2 standard, the recommended vibration value is 2.5 mils, with an operating threshold of 5.3 mils. The *Fan Trim Balance* process begins with the *engine run-up process* to obtain engine vibration data. During the *run-up* process, the EVMU will record vibrations at N1 levels of 64%, 84%, 88%, 92%, and 96%. Once the data is collected, your EV will adjust the position and size of *the balance screw*, which will then be replaced at the base of the *fan blades*. After adjustment, *the engine re-run-up* to review the magnitude of the vibration. The *trim balance process* will be repeated until the vibration level matches the specified parameters. The ratio of vibration levels before and after the *trim balance* process on *Engine* 1 is 1.5 Mils and 0.4 Mils, with a difference of 1.1 Mils, while on *Engine* 2 is 1.8 Mils and 0.5 Mils, with a difference of 1.3 Mils. In this case, the Airbus A320 aircraft requires two *trim balance processes* to ensure that the vibration level in the engine meets the feasibility parameters.

Keywords: *CFM56-5B, Engine Vibration, Trim Balancing, Turbofan Engine*

1. INTRODUCTION

Gas turbine engine is a set of engines that utilize gas fluid to do work by rotating turbine blades due to the results of internal combustion. The turbine consists of two parts, namely the rotating part / rotor of the turbine, and the fixed part / stator of the turbine. Inside a gas turbine, mechanical energy is generated from the conversion of kinetic energy through compressed air that rotates the turbine to produce power. The simplest gas turbine system consists of three components: the compressor, combustion chamber, and gas turbine. The energy conversion process occurs through three stages, namely compression, combustion, and expansion which take place simultaneously. And the conversion process takes place in different places, namely in compressors*, combustion chambers,* and *turbines* [14].

In turbofan engines, the airflow will be divided into two parts after passing through the fan on the front, namely hot flow and cold flow. Hot flow is the flow of air that will be forwarded to the compressor, then the combustion chamber, turbine and exhaust core with high temperature. Cold flow is a flow that is directly directed to be released into the atmosphere through exhaust. Both flows will increase in speed after passing through the exhaust which results in the emergence of thrust or thrust [10]. The thrust on the turbofan produced by hot flow ranges from 15%-25%, while the thrust generated by cold flow ranges from 75%-85% [5]. Therefore, damage to the fan surface that leads to cold flow plays a major role in the performance degradation of the turbofan engine (decreased thrust and efficiency) [12].

Fan unbalance is one type of damage that often occurs, fan blade unbalance is defined as the imbalance of the fan blades against the rotating axis and stresses that act on each fan blade. This imbalance will cause the *bearings* to receive additional centrifugal force due to the unbalanced load. This condition will cause excessive vibration which will cause noise, and will further reduce the efficiency of the machine and interfere with the work of the machine.

Balancing is a maintenance procedure to eliminate unbalance in machines with rotary shafts. Balancing methods can include static balancing which is a procedure of increasing or decreasing mass at a certain radial distance to balance the unbalance force, and dynamic balancing in the form of increasing or decreasing mass at a certain radial distance to balance the moment of unbalance. Vibration analysis is an important method that can be used to reduce or eliminate recurring engine problems. From vibration analysis, results will be obtained in the form of vibrational responses that can be a reference to damage to a system, so that preventive action can be taken. To determine the condition of the engine in balance or unbalance, an aircraft engineer will get a report from the pilot through the Aircraft Maintenance Logbook after the flight is carried out. The pilot or crew will report vibrations based on cockpit indicators and/or felt directly during flight. The vibration occurs due to the rotor moving quickly and there is an unbalance on the sides of the rotor. In CFM 56 engines occur at NI, N2 and rotor revolutions. The rotors in question are LPC (low Pressure Compressor), LPT (Low Pressure Turbine), HPC (high Pressure Compressor) and HPT (high Pressure Turbine).

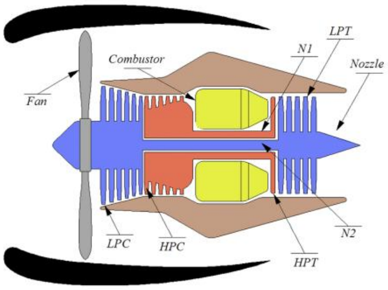

Figure 1. Turbofan Engine Model [15]

Trim Balance is a way to reduce vibration by installing balance screws of different weights to obtain balanced fan blade rotation. This balance screw is installed on the front cone of the engine which totals 38 pieces that surround the cone. Fan Trim balance can be done on vibration sources from FAN/LPC or from LPT because they are in one shaft so that they affect each other. If Fan Trim balance fails at the vibration source from LPT, LPT Trim Balance can be done.

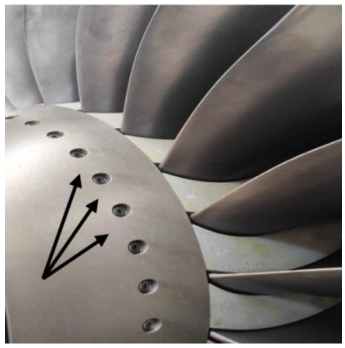

Figure 2. Balancing Screw Position on Fan Module

In the operation of the Gas turbine engine on an aircraft, it has a limit on the permissible vibration value in order to prevent engine damage and support safety aspects so that it can be airworthy. The unit of vibration measurement used is Mils which shows the magnitude of the maximum deviation shift distance (Displacement), with a value of 1 mils = 0.001 inch, or in microns with a value of 1 μm = 1 x 10-6 m. Airbus aircraft manufacturers have operational standards to support aircraft maintenance called the Aircraft Maintenance Manual (AMM). Based on AMM 71-00-00-860-010-1B regarding Engine operation limits specifically for CFM56-5B engines of Airbus A320 aircraft. The maximum permissible Vibrations limits value is 5.0 Mils, and the recommended Vibrations operating guidelines are a maximum of 2.0 Mils for the N1 Shaft. Table 1 below shows the allowable vibration values based on ISO 20816 on Machine Vibrations and Balancing for Gas Turbines, Steam Turbines and Generators, the limit of vibration values (peak to peak) acting on shafts is classified into 4 zones, namely:

1. Zone A: Vibration when the new machine starts.
2. Zone B: Long-term operating vibration.
3. Zone C: Vibration is not safe for long-term use.
4. Zone D: Vibration that causes damage.

Table 1. Shaft Relative Vibration Zone (ISO 20816-2)

Shaft Relative vibration peak-to peak displacement at zone boundaries (µm)				
	Shaft Rotational (r/min)	*Zone Boundary*		
		A/B	B/C	C/D
Steam Turbine Generator	1500	100	200	320
	1800	95	185	290
	3000	90	165	240
	3600	80	150	220
Gas Turbine	3000	90	165	240
	3600	80	150	220
	5000	65	135	190

2. METHODOLOGY

2.1. Tools and Materials

The Trim balancing process requires some preparation, Table 2. indicate the tools, materials and supporting components needed.

Table 2. Tools and Materials

Reference	*Qty*	*Designation*	*Pic.*
No Specific	*AR*	*Warning Notice(S)*	
No Specific		*Torque Wrench: Range to between 65 and 76 lbf.in*	
CFM56-5B	*1 Set*	*Fan Trim Balance Kit*	
CP5062		*MoS_2 Dry film lubricant*	

Fan trim balance kit contains 7 balance screws with different masses and sizes ranging from P01 to P07 sizes, can be seen in figure 3, P07 size balance screw is the smallest size and P06 is the largest. The difference in size serves to adjust the weight around the front cone of the engine so as to reduce vibration and produce balanced fan blade rotation.

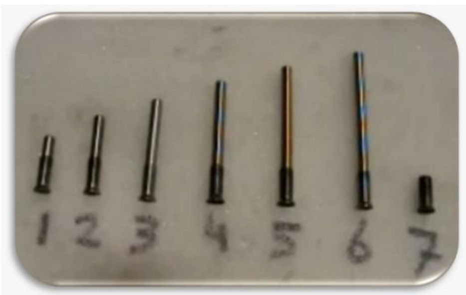

Figure 3. Balancing Screw

2.2. Procedure

The fan blade balancing process on the CFM56-5B engine of Airbus A320 uses the trim balance method, carried out in accordance with the Aircraft Maintenance Manual (AMM) guidelines, with the following procedures:

A. Provides power to the aircraft's electrical circuitry
B. Ensure that the circuit breaker is in closed condition
C. Safety Precuations
   a. Install WARNING NOTICE(S) so that other personnel do not turn on the engine.
   b. Make sure that the engine is in dead condition, at least five minutes before performing the procedure.
   c. Maintains the “ON” mark on the ENG/FADEC GND PWR/1(2) button in dead condition.
   d. Install WARNING NOTICE(S) so that personnel do not power FADEC 1(2).
D. Aircraft system configuration
   a. On the rear cone spinner part, type identification (P0X) as well as the position of all 36 balancing screws.
      NOTE: *Balance screws* are identified by a number (P0X) engraved on the head screws.
      NOTE: Balance screws *numbering* may vary by supplier, from P01-P07 or from P08-P14.
      NOTE: The round mark on the back of the *spinner cone* indicates the No.1 fan blade located to the left of the mark. (calculated counterclockwise)
E. Aircraft maintenance configuration
   a. To carry out the procedure, flight or ground vibration data is required. Ref. AMM TASK 77-32-34- 860-042 or Ref. AMM TASK 77-32-34-860-043.
   b. *SYSTEM REPORT/TEST ENG* data required. Ref. AMM TASK 31-32-00-860- 012.
   c. Press EVMU indication button: Displays the first page of the EVMU.
   d. Press the “*NEXT PAGE*” button
   e. Press the “*ENGINE UNBALANCE*” button
   f. The *EVMU ENGINE UNBALANCE menu* has been displayed on the monitor.
F. Testing

Table 3. Procedure

ACTION	*RESULT*
1. Press the button pointing ENG1(2) TRIM *indication.*	Displayed: Menu *The EVMU ENG1(2) TRIM BALANCE*
2. Press the button pointing ONE *SHOT TRIM BALANCE CFM56-5B indication.*	Displayed: Menu *EVMU ENG1(2) CURRENT VIB INPUT.*

ACTION	***RESULT***
3. Press the button corresponding to the required data: - *FLIGHT DATA* - *GROUND DATA* - *MANUAL INPUT.*	Displayed: Engine vibration data.
4. Collect vibration data on result sheets or with MCDU screen prints. This data is necessary if you have to trim	
5. Press the button pointing *CONT indication.*	Displayed: INFLUENCE *COEFF SELECT Menu*
6. Press the pointing button. *GENERIC COEFF CFM56-5B indication* NOTE: You can use a certain coefficient for *the Trim balance* of the engine. In this case you must enter N1/SENS/DEG data for sensor *bearings* 1 and TRF in the ENG1(2) SPECIFIC COEFF menu.	Tertampil pada layar : Menu *ENG1(2) INSTALLED CURRENT SCREW.* Compare the data shown on the MCDU with the data obtained in step 4 of all 36 holes. If necessary, note the *screw* identification (P0X), and press the *Current screw positions button*
7. Record the hole/screw configuration on the result sheet or with the MCDU screen print. This data is necessary if you have to trim *balance*	
8. Press the button pointing the *CONT indication* to *memorize the* Screw *configuration*	Displayed: Menu *ENG1(2) SCREWS TO CHANGE* Print each page that appears.
9. If you want to save the latest configuration, press the Update button.	NOTE: If the *Update button* is pressed, it will change the menu *ENG1(2) INSTALLED CURRENT SCREWS.*
10. On MCDU, press the button pointing to *RETURN* until the CFDS menu appears.	

(1) On the back of the *Spinner cone*, change the size and position of the balance screw as indicated.
   a. Give a light lubrication to the balance screw using MoS_2 dry film lubricant (material ref. CP5062)
   b. Torsi *balance screw* dengan *range* 65 hingga 75 lbf.in

G. Solution: Release *WARNING NOTICE(S).*

Figures 4 is the display of the Engine vibration monitoring unit (EVMU) menu on the Multifunction control display unit (MCDU) instrument in the aircraft cockpit which serves to calculate the difference in the size of centrifugal force that occurs in the engine shaft (N1). The instrument can automatically recommend balance screw adjustments by running up the engine.

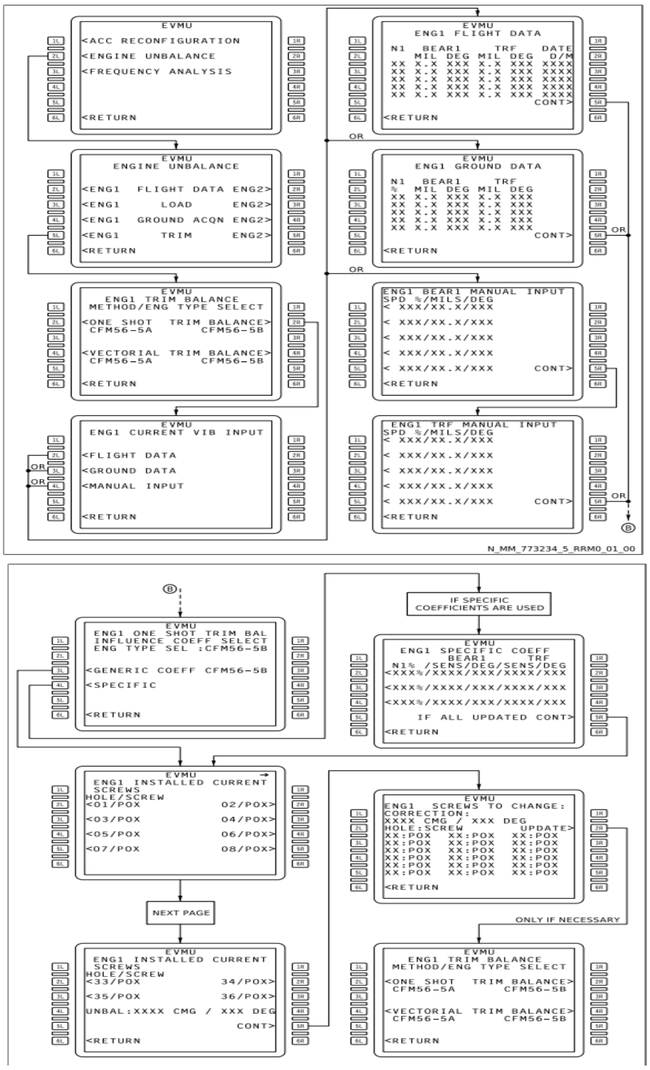

Figure 4. Trim Balancing Flowchart on EVMU

3. RESULTS AND DISCUSSION

3.1. Vibration Before Trim Balance

The amount of vibration that occurs in engine 1 and engine 2 at a certain power level before the Trim Balance process can be seen in Table 4. Based on AMM references, the maximum recommended vibration guidelines is 2 mils, but for certain airlines, the vibration limit that occurs is tightened with a maximum limit of 1.0 mils to be able to realese or return to fly. Based on the ISO 20816-2 standard on Machine Vibrations and Balancing for Gas Turbines, Steam Turbines and Generators for Gas Turbine Engines, the recommended vibration value is 2.5 mils, and with a maximum operating threshold value of 5.3 mils.

Table 4. Data 1 Ground Vibration

VIBRATION GROUND DATA 1				
Power	*ENG 1*		*ENG 2*	
	N1	N2	N1	N2
30%	1,3	1,6	1,5	1,7
40%	1,3	1,4	1,5	1,7
50%	1,2	1,4	1,3	1,5
64%	1,1	1,7	1,6	1,5
84%	1,2	1,5	1,6	1,8
88%	1,5	1,4	1,8	1,4
92%	1,3	1,4	1,6	1,5
PEAK VIB		*Power*	*VIB MILS*	
#1 ENG	N1	88%	1,5	
	N2	64%	1,7	
#2 ENG	N1	88%	1,8	
	N2	84%	1,8	

3.2. Vibration After Trim Balance

After the Trim balance process, the engine is tested again (run-up) to determine the amount of vibration that occurs. Table 5 is the Vibration Ground Data-2 after the first Trim balance process:

Table 5. Data 2 Ground Vibration

VIBRATION GROUND DATA 2				
Power	*ENG 1*		*ENG 2*	
	N1	N2	N1	N2
30%	0,6	1,0	1,0	1,3
40%	0,5	1,0	1,1	1,2
50%	0,5	1,2	0,8	1,2
64%	0,8	1,3	1,3	1,3
84%	0,7	1,1	1,1	1,4
88%	0,5	0,9	1,0	1,0
92%	0,6	1,0	1,1	1,2
PEAK VIB		*Power*	*VIB MILS*	
#1 ENG	N1	84%	0,7	
	N2	64%	1,3	
#2 ENG	N1	64%	1,3	
	N2	84%	1,4	

Based on these data, the Trim balance process will reduce the amount of vibration that occurs in the aircraft engine, but the reduction is not too significant, there is still over vibrate in certain engine power that exceeds the predetermined limit (1.0 mils) so that the aircraft cannot be realese. The re-trim balance process is required (starting from the 2nd procedure). The engineer adjusts and costumized the size and position of the balance screw on the root fan blade according to the computational results of the Engine Vibrate Monitoring Unit (EVMU). After that, the engine is tested again (run-up) to find out the data on the magnitude of vibration that occurs in the engine. Table 6. is Vibration Ground Data-3 after the 2nd Trim balance process:

Table 6. Data 3 Ground Vibration

VIBRATION GROUND DATA 3				
Power	*ENG 1*		*ENG 2*	
	N1	N2	N1	N2
30%	0,3	0,4	0,2	0,8
40%	0,2	0,5	0,1	0,8
50%	0,2	0,5	0,1	0,8
64%	0,2	0,7	0,2	0,6
84%	0,3	0,4	0,5	1,0
88%	0,4	0,6	0,2	0,8
92%	0,3	0,5	0,4	0,6
PEAK VIB		*Power*	*VIB MILS*	
#1 ENG	N1	88%	0,4	
	N2	64%	0,7	
#2 ENG	N1	84%	0,5	
	N2	84%	1,0	

After the second trim balance process, the engine vibration value decreases to all *power levels*. The vibration reduction is already within the feasibility parameters so that the aircraft can be *realese* and able to fly. The balance screw adjustment results are recorded on the *engine installed current screw menu.*

3.3. Discussion

The *trim balance process* is needed when *the fan module* on the *engine* experiences *over vibration*. which usually occurs due to *unbalance conditions*. Excessive vibration will be felt or known by the pilot directly or based on data on the *Engine Vibrate Monitoring Unit* (EVMU). The pilot will report the condition to the *Aircraft Maintenance Logbook* (AML). The impact of *unbalance* and *over vibrate* fan will caused an excessive noise and can shorten the service life of components. To avoid this, the fan *trim balance process* is undertaken on the *aircraft fan blade*. This process involves mounting weights in the form of *balance screws* to find the right point of weight, so that the *fan blade* can rotate stably and efficiently. This process is done by installing a *balance screw* at the base of the *blade*.

The determination of the size and weight of the *balance screw* is carried out by computating result of the Engine *Vibration Monitoring Unit* (EVMU) contained in the cockpit of the aircraft. Before obtaining the results of determining the appropriate size and weight of *the balance screw*, vibration data from the *engine* obtained from the engine operation process (*run-up*) is obtained. The *aircraft run-up* process was carried out by starting the *engine* and increasing the speed of N1 levels to 64%, 84%, 88%, 92%, and 96%. When the engine is operating, the

EVMU will record the vibration data that occurs and determine the *adjustment of Screws to change correction.*

After *the balance screws* are adjusted, *the engine* is tested by *run-up* again. If excessive vibration or sound is still found, the *trim balance process* will be repeated, *the balance screws* will be moved or readjusted to achieve optimal balance. This process is repeated until the *fan* rotates stably and efficiently at all speeds.

Figures 5. and 6. show *that the Trim balance process* will reduce the amount of vibration that occurs in the engine, but not significantly. For engines that initially have a large vibration value, the trim balance process is needed more than once. In this case, the Airbus A320 aircraft needed 2 processes to comply with the feasibility parameter of the magnitude of vibration in the engine, which is 1.0 mils.

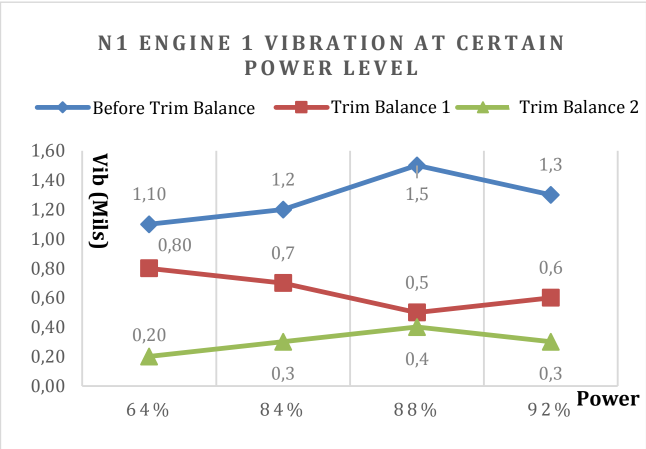

Figure 5. N1 Engine 1 Vibration Graphic

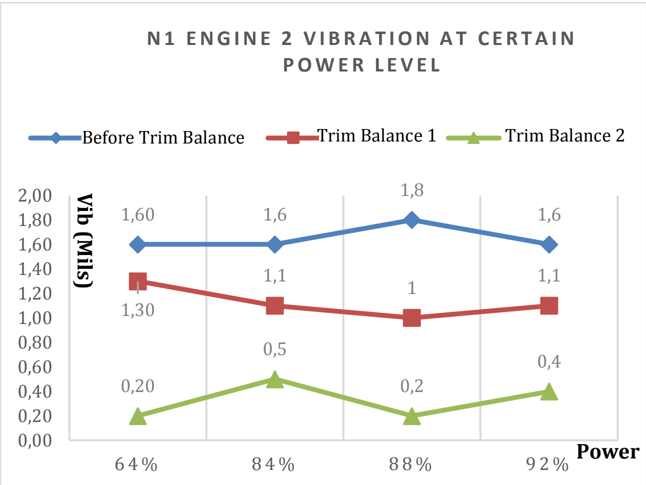

Figure 6. N1 Engine 2 Vibration Graphic

4. CONCLUSION

Based on the tests result that have been carried out, several conclusions can be drawn as follows:

1. The *Fan Trim Balance* process begins with testing the *engine*, which is the *run-up process* to find out the data on the amount of vibration that occurs in *the engine*. During the *run-up process,* EVMU will *record* vibrations that occur at *a certain* power level. After the data is obtained, the EVMU will compute and adjust the position and also the size of the *balance screw*, then the technician will replace *the balance screw* on the root fan *blade*. After that the *engine* will be *run-up* again to find out the amount of the vibration value. If the vibration happened is over *vibrate* from the predetermined limit (1.0 mils) or noise, the *trim balance process* will be repeated until the vibration value has met the feasibility parameters.
2. Comparison of vibration values before and after the *trim balance* process on *engine* 1 is 1.5 Mils and 0.4 Mils, with a difference of 1.1 Mils and on *engine* 2 is 1.8 Mils and 0.5 Mils with a difference of 1.3 Mils.

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