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An Analytical Study of the Trend Monitoring Parameters on Rolls Royce RB 211-535c Engines

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Abstract

The aim of this paper is to perform an analytical study on the performance parameters (shaft speeds, turbine gas temperature (TGT), Fuel flow, Vibration) of ROLLS ROYCE RB 211-535C enginefitted on aircraft VT-BDJ and VT-BDK operated by Blue Dart Aviation, India. The engine parameters monitored under cruise conditions from the sensors were collected from March 2013 to January 2014. The data presented in this paper gives an apparent method for an "early detection of deterioration" by analysing engine parameters and providing an early maintenance measures to be performed which will enhance the life of the engine. By analysing the trend monitoring data, it has found the RB211-535 engines are highly reliable and low maintenance cost.

Keywords: Trend monitoring, Shaft speeds, Turbine gas temperature (TGT), Fuel flow, Vibration.

Introduction

Rolls Royce RB211-535C engines are three shaft, High by pass ration turbofan engines, basically designed for Boeing 757 commercials aircrafts. Rated at 37,000 Pounds of thrust, Shorter engine, fewer stages, having better structural integrity and better optimum aerodynamics. Worldwide 50 airlines used 35million flight hours.

Ninety percent of the Rolls Royce trent engines sold to customers are under contract agreement called "Total care", also called "Power by the hour" in which airlines makes regular payments based on the hour flown and the engine manufactures retains the responsibility for maintaining the engine.

Engine Health Management Systems (EHM) plays the critical in assisting operators in managing the safety, reliability, availability, and affordability of their gas turbine engine[1]. By EHM the following defects / faults can be detected, i. Early hot section deterioration, ii. Hots starts, iii. Faulty fuel nozzles, iv. Dirty or eroded compressors, v. Foreign Object Damage (FOD), vi. Bleed air leakage, vii. Instrumentation error.

The modern trend is to maintain engines on an on-condition monitoring basis, where in the engines are removed only when an internal component reaches its individual life limit, or when performance monitoring suggests that the engine is operating outside manufactures recommended limits[2].

Primary causes of engine removals depend heavily on the type of the operation. Engines operating on short haul operations experience higher removals due to EGT margin deterioration and life limited parts (LLP)[3]. Engines operating on medium-to-long haul flights tend to have a higher percentage of removals due to hardware deterioration and EGT margin deterioration. The unscheduled removal causes result from FOD, High oil consumption and engine vibration.

Methodology

The critical parameters are monitored automatically and continuously by advanced sensors and instruments and sent to the ground stations by automatic data link system called ACARS[4]. The main parameter under cruise conditions are TGT, Fuel flow, Shaft speed and Vibration.

The above mentioned engine parameters were collected from the RR RB211 engines fitted on aircraft VT-BDJ and VT-BDK operated by Blue Dart Aviation, India. The collected data has been corrected or normalized to a standard operating condition to help to reduce the effects of operating conditions variance from flight to flight. The data is compared with the reference model (run at the same operating conditions and power setting as the measured engine data) and the resulting residuals between the measurement data and the reference model are referred to as delta measurements or Δy. Anomaly detection logic is applied to detect any unanticipated rapid shifts in the observed Δy measurements. This logic gives the capability to distinguish between gradual deterioration and rapid shifts.

The method presented in this paper gives a clear procedure for an early detection of deterioration by analyzing the trent parameter and providing and early maintenance measure to be performed which will enhance the life of the engines.

Table-1
Data Period

Aircraft	Engine Sr. No.	Periods	
VT-BDJ	30103 and 30062	March 2013	Jan 2014
VT-BDK	30066 and 30017	Aug 2012	Jan 2014

Results and Discussion

In this section, different graphs are presented with delta residuals which are obtained by comparing and normalizing with standard engine data in order to predict the engine degradation in advance. The resulting residuals between the measured data or monitored data and reference model are referred to as delta measurement.

The green graph line shown in Figure-2 indicates the Delta TGT of Engine no. 1 (30103) and the Brown line indicates Delta TGT of Engine no. 2 (30062) of aircraft VT-BDJ obtained during cruise. The middle scale line presents the normal Delta TGT of standard engine. The delta TGT is plotted against time.

The Figure-2 clearly shows that during the time period of 18th December 2013 there is sudden shift of Delta TGT which shows engine degradation. High TGT can be an indication of degradation of engine performance.

We can see from Figure-2 during the period of 20th December 2013 there is sudden increase of Delta TGT which is same as the Figure-2.

All the Delta Fuel flow LP shaft speed, IP shaft speed and HP shaft speed as well as vibration are plotted for engine no. 1(30103) of VT-BDJ shows the same abnormalities as earlier

During the time period between 18th December 2013 to 25th December 2013, the engine parameters were found abnormal. It means that there are really some engine faults during that period like surging or stalling of the engine.

Vibration data were taken for all three shaft but as to the data its shows the there no change in vibration so for example only Smoothed IP vibration is shown which is shown in Figure-7.

Below Figure-8 show the delta parameters such as TGT, Fuel Flow, Shaft speeds and shaft vibration of the engine no 1(30066) of VT-BDK during cruise and during the time period of 14th march 2013 to 18th January 2014.

It has been noticed during cruse erratic increase of TGT, Fuel Flow, IP speed and HP speed during time period between 19th December 2013 to 10th January 2014 was found. During this period the engine no 1 (30066) shows that the trends indicate symptoms for bleed air issue. It can be noticed from the given blow graph trends there can be compressor air flow problems

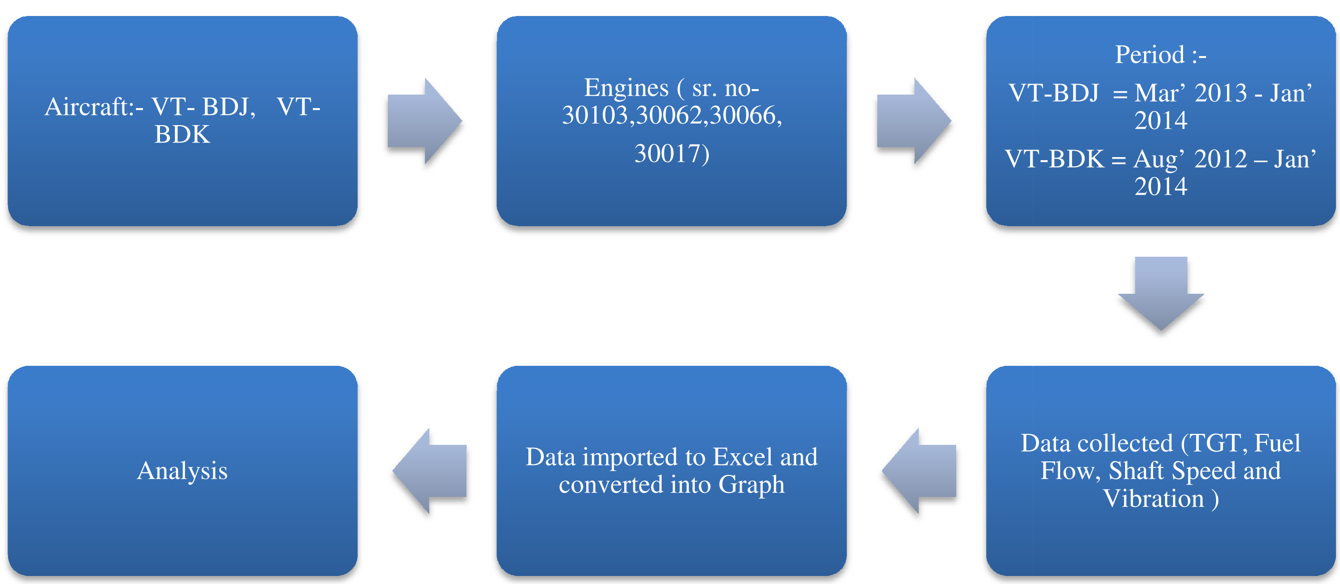

Figure-1
Methodology

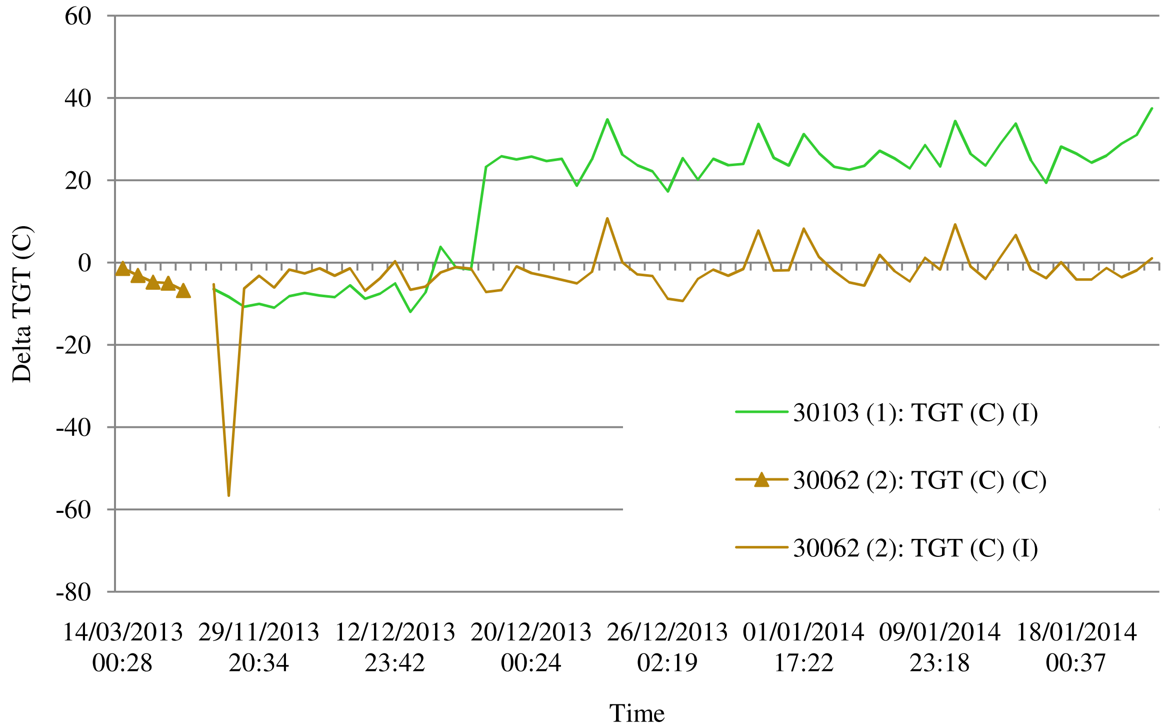

Figure-2
VT-BDJ: Smoothed Delta TGT (C)

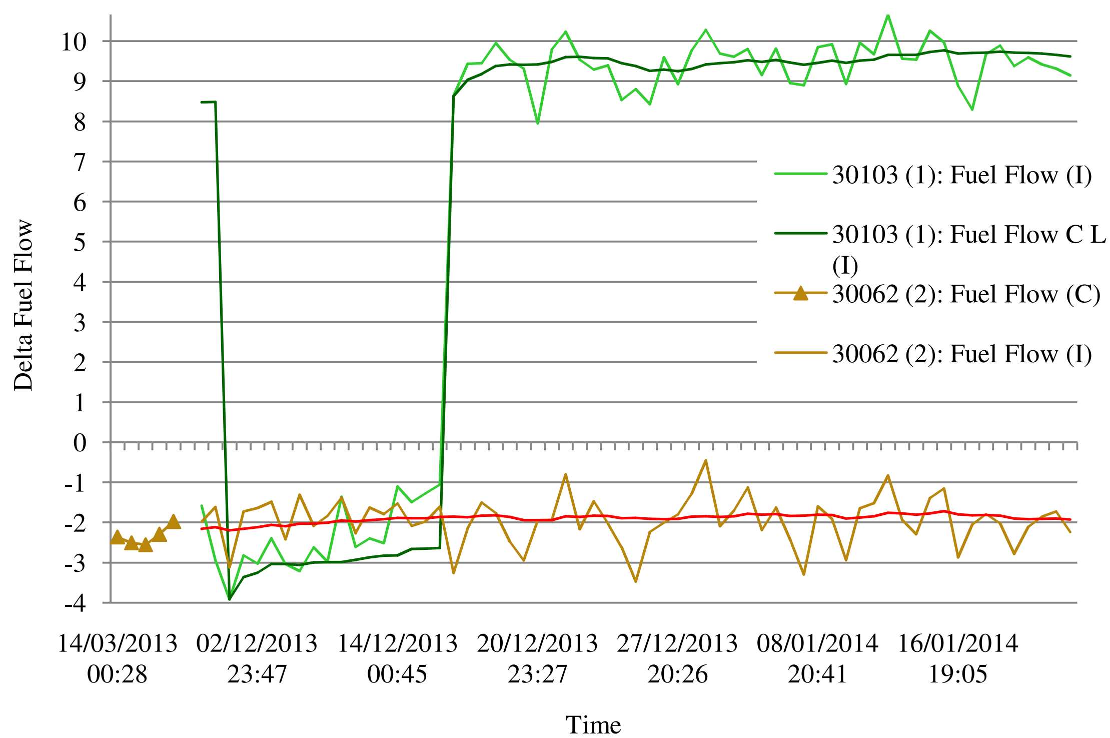

Figure-3
VT-BDJ: Smoothed Delta Fuel Flow

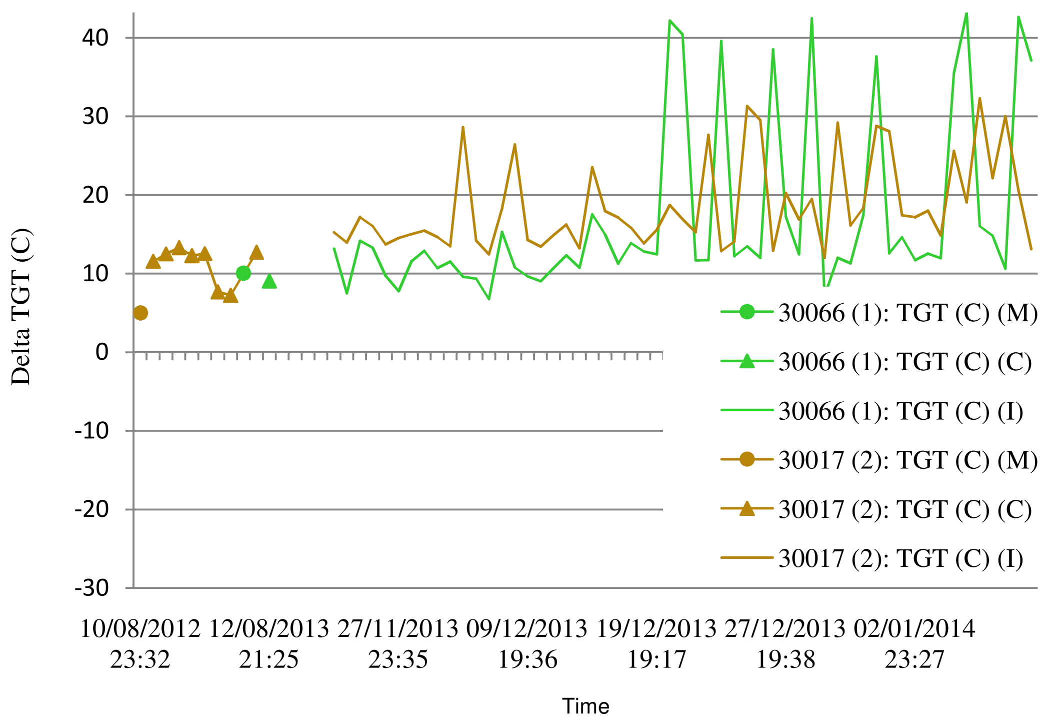

Figure-4
VT-BDJ: Smoothed Delta LP Speed

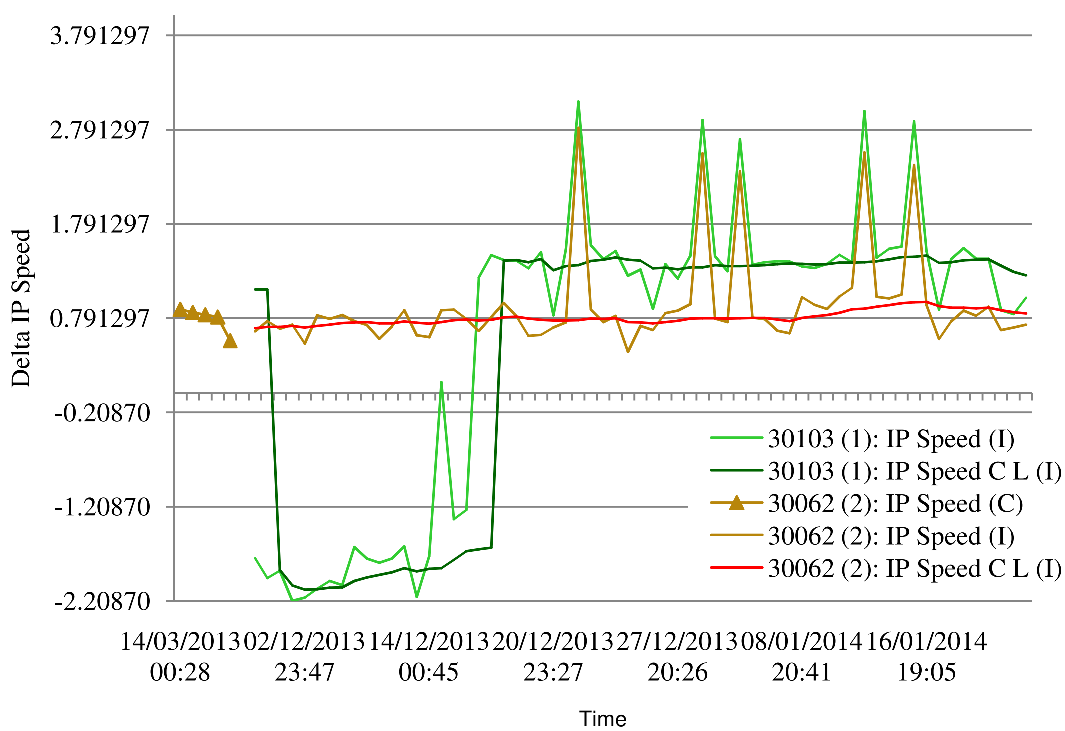

Figure -5
VT-BDJ Smoothed IP Speed

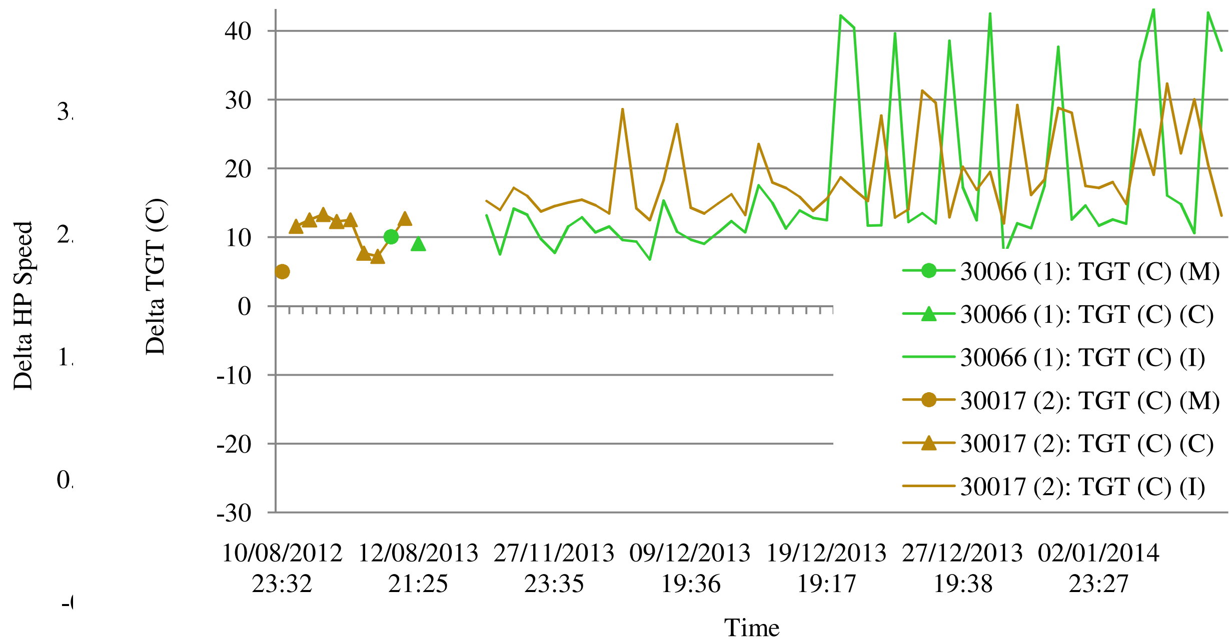

Figure-6
VT-BDJ Smoothed HP Speed

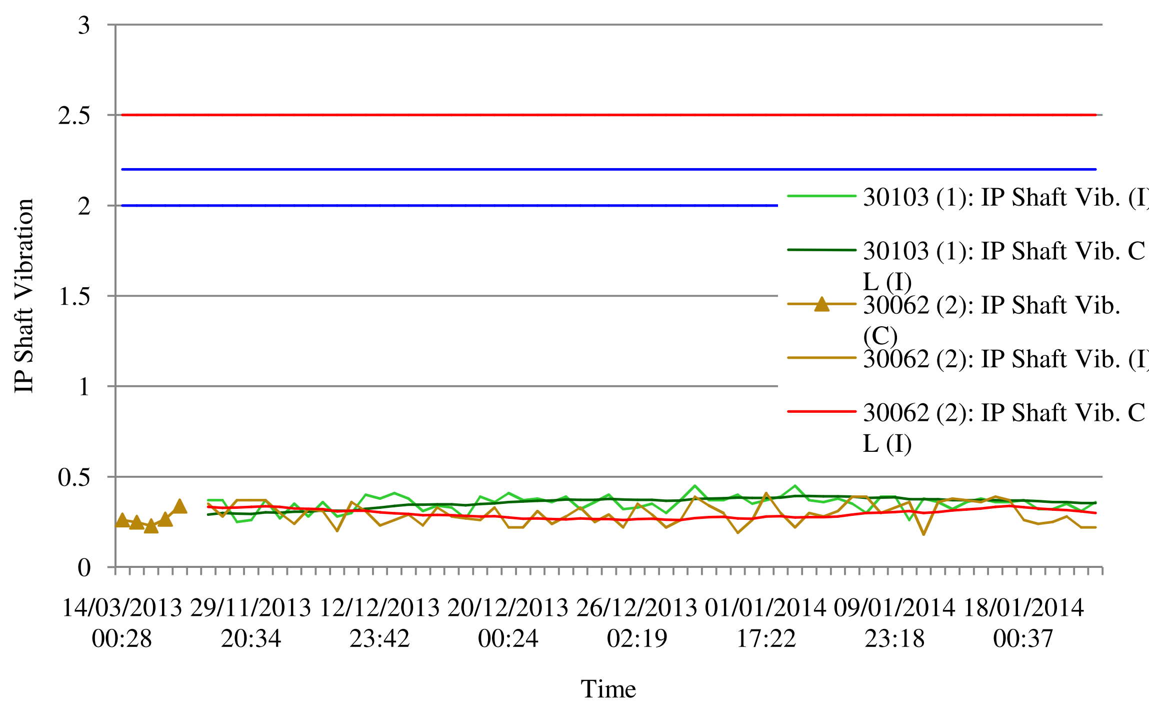

Figure-7
VT-BDJ: Smoothed IP Shaft Vibration

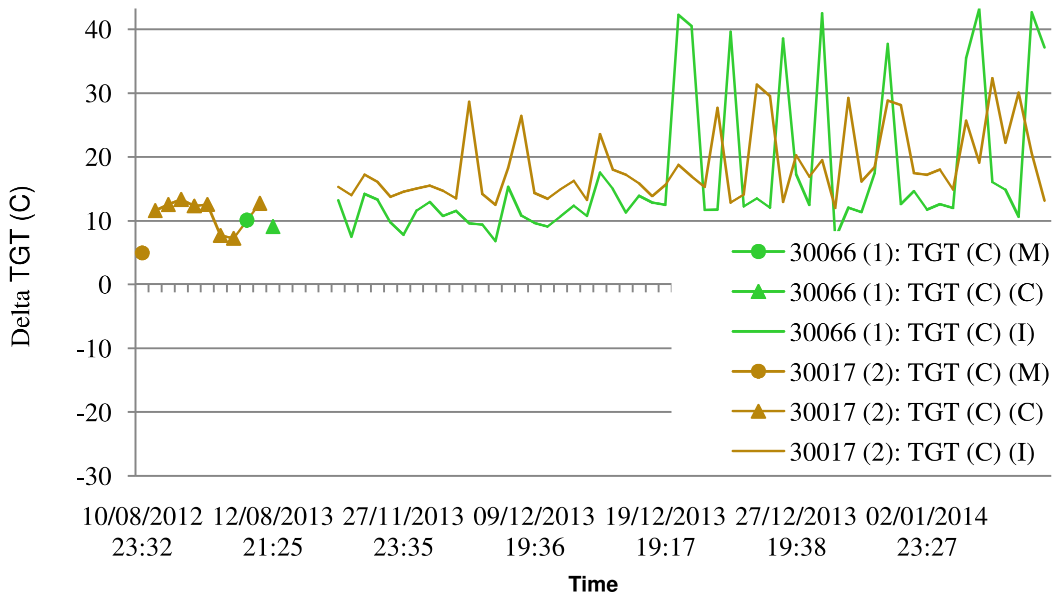

Figure-8
VT-BDK: Smoothed Delta TGT (C)

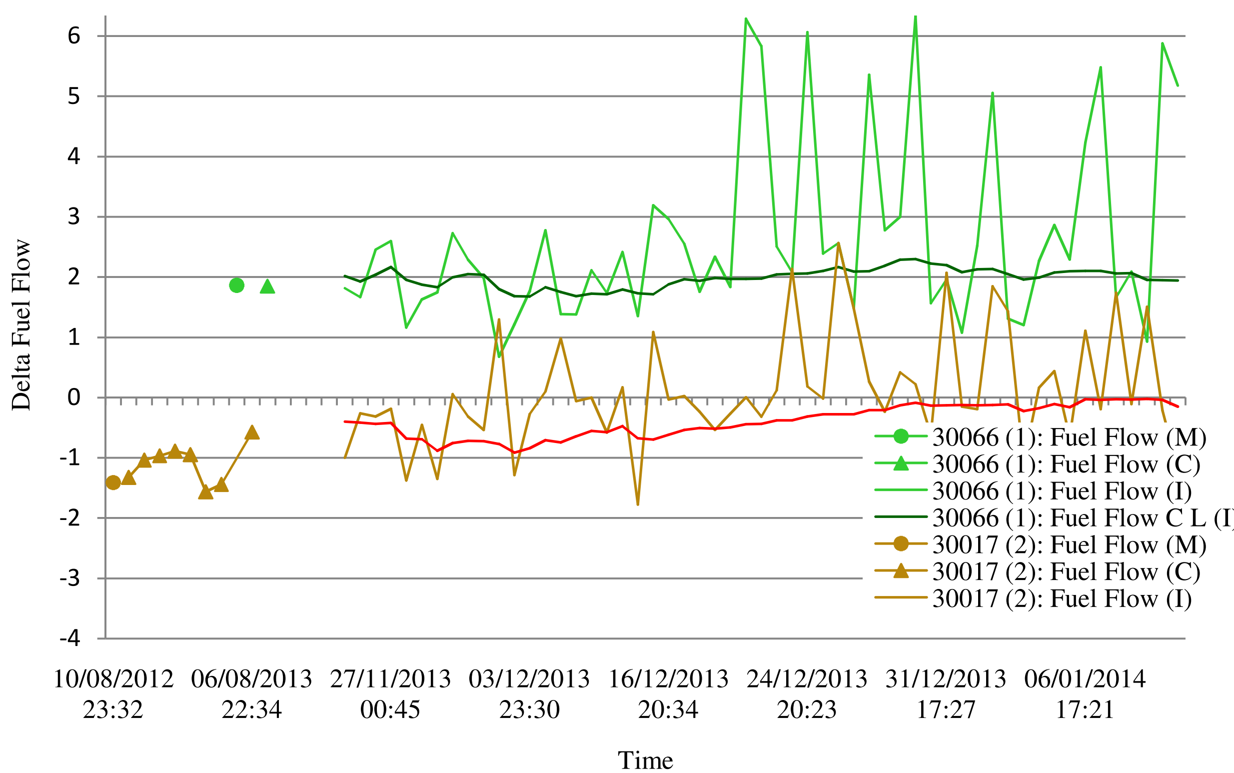

Figure-9
VT-BDK: Smoothed Delta Fuel Flow

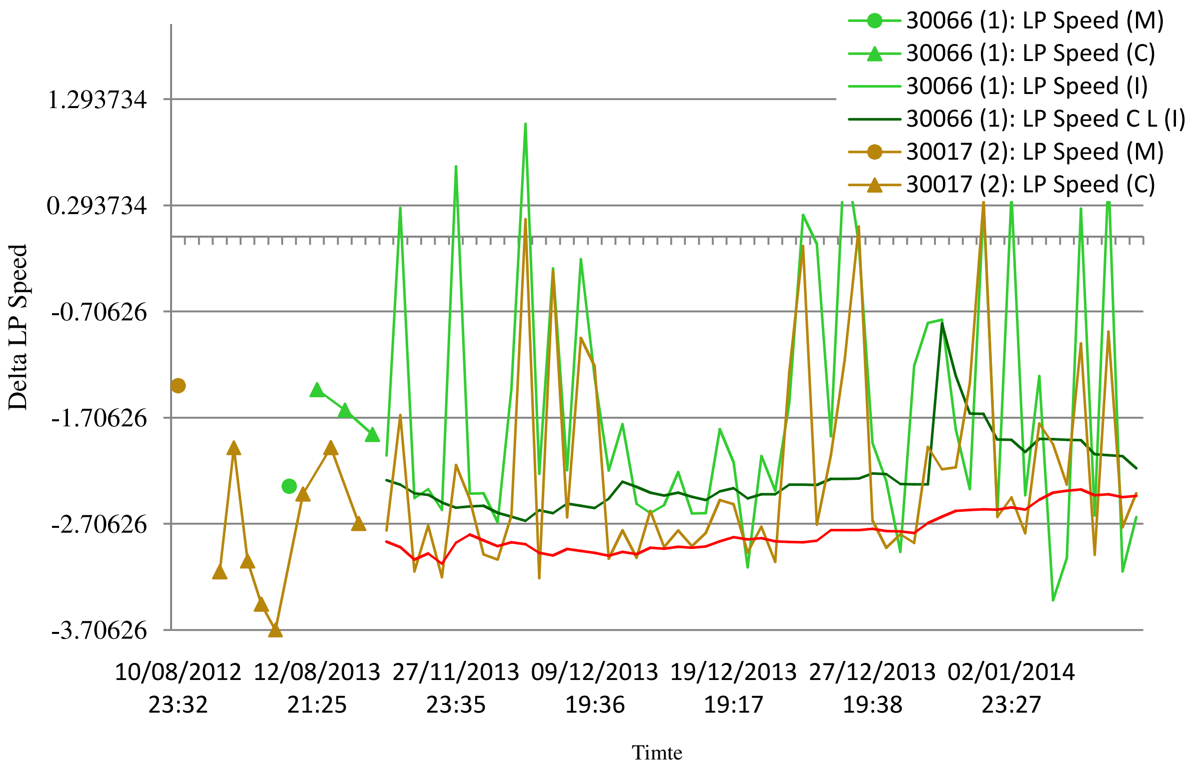

Figure-10
VT-BDK: Smoothed Delta LP Speed

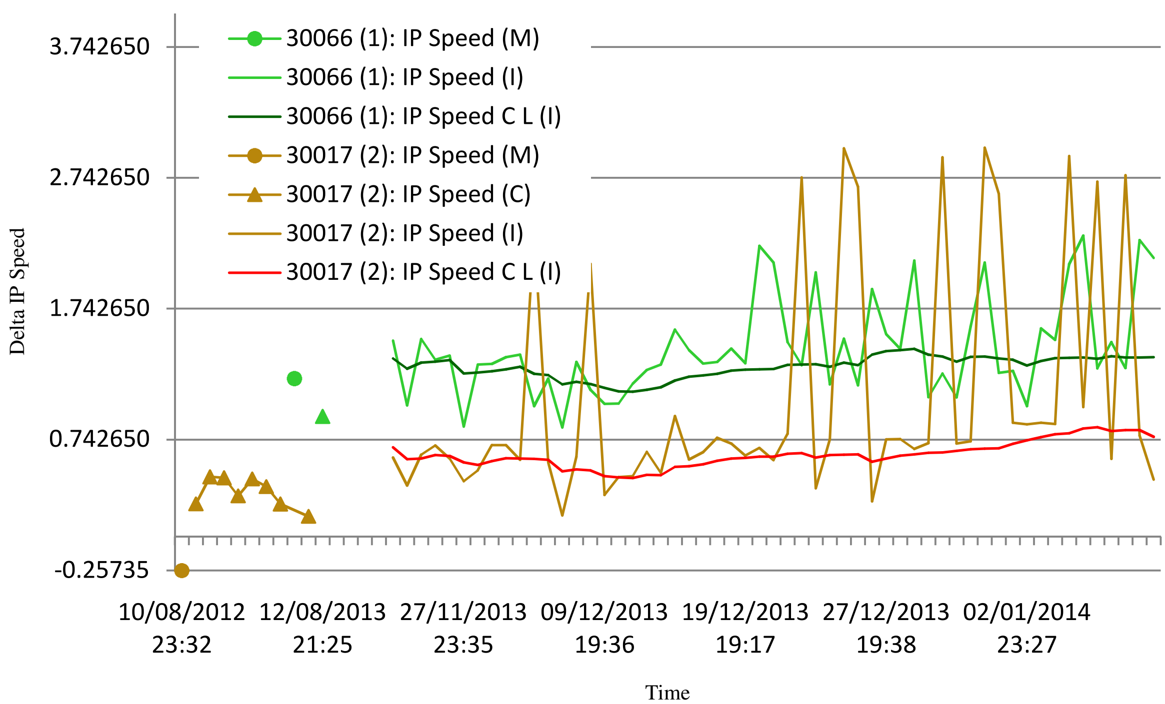

Figure-11
VT-BDK: Smoothed Delta IP Speed

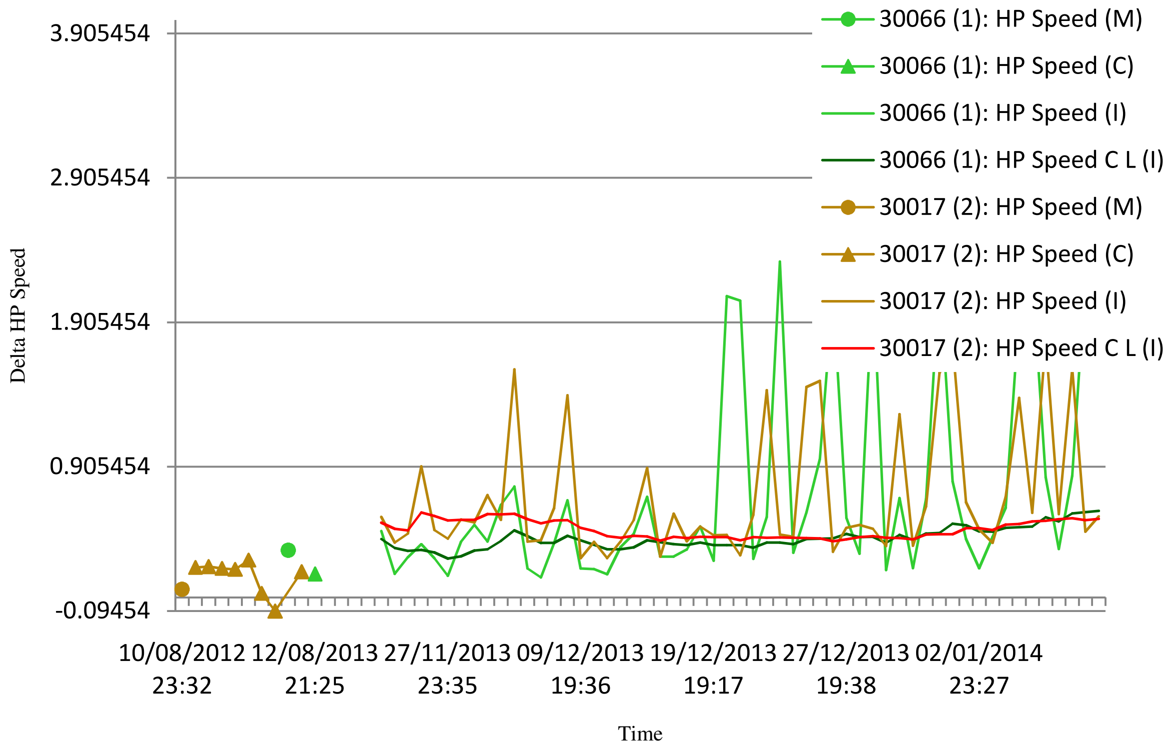

Figure-12
VT-BDK: Smoothed Delta HP Speed

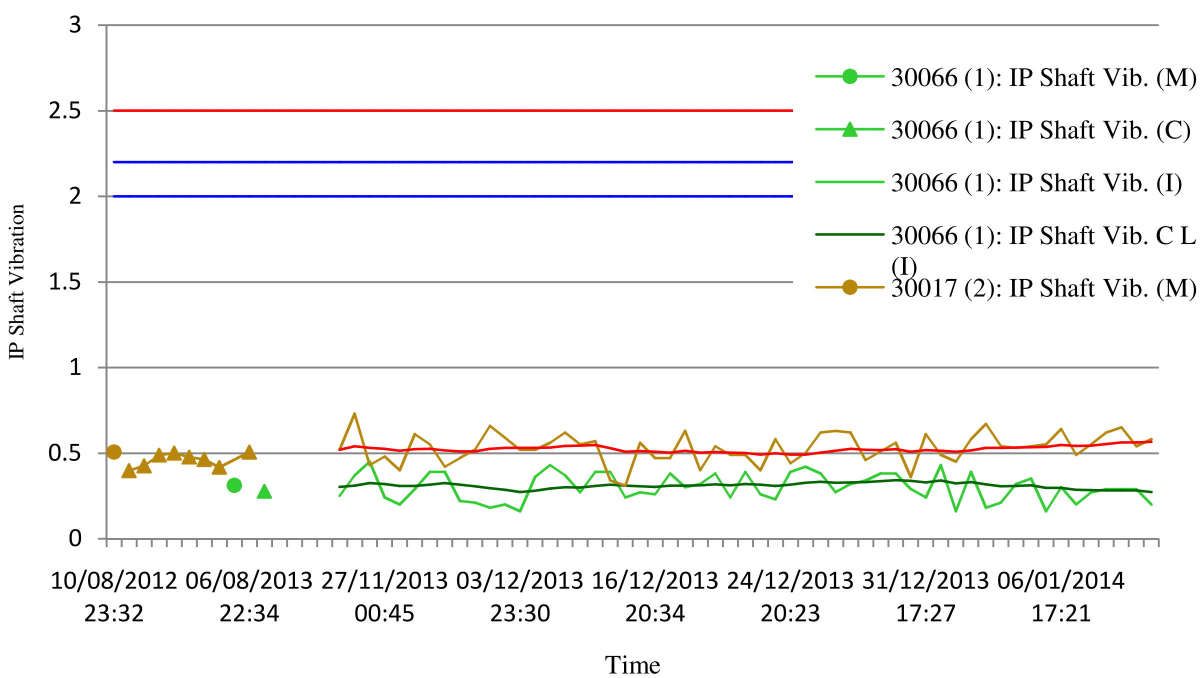

Figure-13
VT-BDK: Smoothed IP Shaft Vibration

Engine interface and vibration monitoring unit (EIVMU). It interfaces with various aircraft systems. Essential communication with the ECU (thrust lever position, air data, ECAM primary indications). Non-essential communication (auto thrust, central maintenance system) is routed through the EIVMU of each engine. Engine vibration monitoring is also accomplished by the EIVMU. Each EIVMU collects vibration data from three vibration sensors from same engine. The vibration information is displayed on the ECAM in units and also available through the CMS for trouble shooting.

Conclusion

An analytical study of the trend monitoring parameters on Rolls Royce RB211-535C engine was performed in this paper. Trend monitoring parameters were collected and the Delta parameters were calculated with softwares and these values were exported to Microsoft Excel to plot as graphs. From this project we can conclude that:

After analysing the trend pattern of the engine # 1/30103 on aircraft VT-BDJ, it has been observed that steep increase in EGT, Fuel flow, LP Speed, IP Speed and HP speed during cruise in the period between 18th December 2013 to 28th December 2013. From this Data we can be able to conclude that the particular engine has undergone surging or stalling, as the entire engine parameters were affected.

Table-2
VT-BDJ engine monitoring

VT-BDJ Aircraft Engine Sr. no. 30103		
Parameter	**Period**	**Fault**
EGT	18/12/2013	Rise in EGT
Fuel Flow	18/12/2013	Fuel flow sharp rise
LP speed	20/12/2013	Increased LP speed
IP Speed	20/12/2013	Increased IP speed
HP Speed	18/12/2013	Increased HP speed

After analyzing the trend pattern of the engine # 1/30066 on aircraft VT-BDK, it has been observed that erratic increase in EGT, Fuel flow, LP Speed, IP Speed and HP speed during cruise in the period 10th Jan 2014. From this Data we can conclude that the fault is between this period as all engine parameter has abnormal reading during same time.

Table-3
VT-BDK engine monitoring

VT-BDK Aircraft Engine Sr. no. 30066		
Parameter	**Period**	**Fault**
EGT	10/01/2014	Rise in EGT
Fuel Flow	10/01/2014	Fuel flow sharp increase
LP speed	10/01/2014	Increased LP speed
IP Speed	10/01/2014	Increased IP speed
HP Speed	10/01/2014	Increased HP speed

Future Enhancement: Further testing is required to determine how robust trending of performance parameter maxima is on other flight tests; in particular, for the method to be viable diagnostically there should be a characteristic level for the maxima on normal data for a particular engine. This is contrary to the behaviour seen earlier in the sequence of flight tests. A diverging trend might be a sign that the engine is moving towards an anomalous state; this would need to be tested in further work.

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