Application Note
#8
BalancePRO and the Phase Clock

Version 2.5 and 3.0 BalancePRO software allows the operator to use the Phase Clock display as a troubleshooting tool during an engine run. The Phase Clock is a graphical display of the phase data computed from the 1/Fan vibration signal, and the phase dependent tachometer signal coming from the engine under test. Phase, because of its unique relationship as a function of these two signals, is a very telling piece of information. A well informed operator can gather a lot of information from this display and its relationship to other things that are taking place.

The phase clock display should be observed not only during the data collection portion of an engine test, but it should be observed during the thermal soak of the engine as well. During the thermal soak, the operator can get an advanced idea of how well the engine balance task is going to go. Towards the end of the thermal soak, when it is safe to do so, a few snap accelerations and deaccelerations of the engine will also tell the operator and viewer of the phase clock if the engine run is going to be successful.

This application note will provide the operator a few hints about what can be surmised from the Phase Clock display. Of course there is no replacement for experience and some problems are going to have to be experienced before any decisions can be made. But, this application note will assist in building a firm foundation.

Overview

The operator should clearly keep in mind that what is being measured by the BalancePRO system is the *effect* of an imbalance. There will always be an imbalance of the rotor system of an aircraft engine. The difference is that some are very smooth while others are very rough. If there is always an imbalance, there is always going to be a magnitude, and there is always going to be a tachometer signal. Phase is a dimension that ties these two signals together. It is the phase that tells the operator where the "apparent" imbalance is manifested in either the fan or the low pressure turbine of the engine. Keep in mind that this is *apparent* imbalance and *not actual* imbalance. The actual imbalance may be located somewhere else in the rotor system and not in the fan section or LPT section at all. However, it's the fan section and the LPT section that is being measured as well as where any corrective action can be made. Most of the time corrective action can be totally addressed by "trim balancing" the fan section, but sometimes it will require an LPT balance, or both to achieve optimal results.

Continuing along on this thought – corrective weight placement in either the fan section or the LPT section, or both is attempting to counter the *apparent "heavy" spot*, and has to be considered. The apparent "heavy" spot may not be a heavy spot at all. It may just be that it appears "heavy" in comparison to a "light" spot on the opposite side of the rotor system. Which, as it turns out, is most likely the case. It is far easier for material to leave a rotor system, than to have material added to an aircraft engine. It is highly unlikely that the Foreign Object that caused the Foreign Object Damage (FOD) will still be in the engine. I think it is reasonable to assume that the object is long since gone, and what you are dealing with is the results, probably made worse by an attempted repair.

It is very important that the operator keep all that is discussed in this overview in mind while observing the data presented via the Phase Clock and the other data displays.

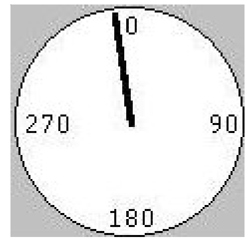
Numerical Basis

The Phase Clock display is, as mentioned before, a graphical presentation of where the magnitude that is being measured appears to be related to the "key phasor." The "key phasor" is the physical location on the rotor system that is generating the phase dependent tachometer signal. This is always a single unique "pulse" coming from the tachometer sensor. It can be a magnetic pulse, a light pulse or a uniquely shaped tooth that marks the location of blade number one or some other standard point of reference on the rotor system. It makes no difference what the source of the signal is. What is important is that it indicates a physical reference point from which things can be determined. Of course you have to go through all the gyrations of position interpretation such as "forward looking aft" or "aft looking forward" as well as angle increasing or decreasing with rotation and blade numbers increasing or decreasing with rotation, but never-the-less you do have a physical reference point from which to determine where to put the weight – and that is the bottom line. Phase clock gives you a graphic indication of where that *MIGHT* be. Note that it is a big MIGHT, because there is a lot more to phase than just position.

Some Examples

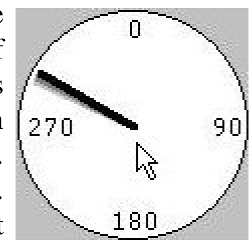
<u>*Steady Phase*</u>

The first thing that the operator must observe on the phase clock is whether or not the phase is steady or not. The picture shown here shows a steady phase signal. There is a solid black line on the display, with no indication of any motion anywhere else on the dial. If you also were to look at the phase numerical display, the number would be around 355 and perhaps the least significant digit would be moving between 354 and 356, but most of the time the number would be 355. This is an extremely steady phase number and is also very rare. More often than not there will be a little bit of jitter to the needle on the dial and the numbers on the numeric readout will be spanning a distance of perhaps three or four digits.



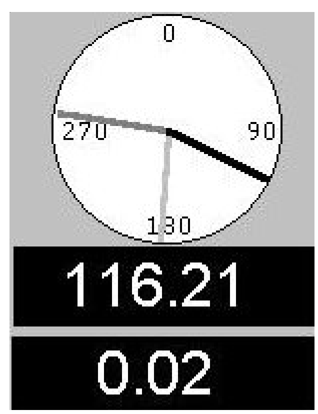
<u>*Moving Phase*</u>

The display shown here shows some definite motion. The needle is moving clockwise away from 270 and towards 0 (or 360, which ever you wish). The operator can see this because of the shadowing of the needle. There is the black of the needle itself, then immediately to the left of the needle is a gray area and then to the left of that is an even lighter shade of gray (as the needles motion moves away). The needle motion is "very tight" which means that the distance between the black needle and the lightest gray shadow is very close together. There is very little variance. This is most likely due to the fact that you have a very strong magnitude on the vibration signal. This is good news for the data collection person – there is real good data. The bad news is that the magnitude is high because the engine is severely out of balance. So, in the best interest of all conditions, it's probably a good idea to have a little bit of variance when the needle is moving.



<u>*Jumping Phase*</u>

The display shown here is bad news to the data collector in us all. The phase is "all over the map." Right now the phase is at 116.21 degrees, a second ago it was over at about 270/280 or so, and a second before that it was down around 180/185. This is known as jumping, or erratic phase.



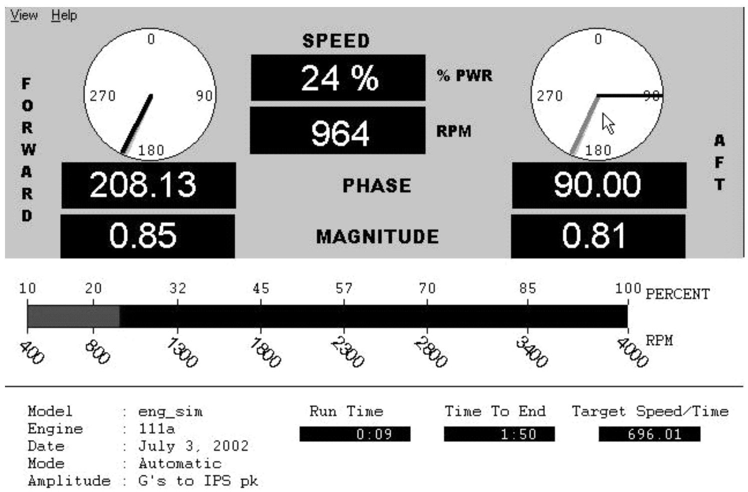
Now, have you cheated and looked at the magnitude number? As it turns out, the jumping phase is good news. The magnitude is down around 0.02. On this engine that is great news! So the phase jumping around is good news. The reason the phase is jumping around is because there isn't enough of a vibration signal for the BalancePRO to determine what the phase is. If the entire engine speed range gives results like this, you're just going to make this engine worse if you put any weight in it.

Now for the gotcha! Take a look at the other sensor's phase clock and amplitude. If that sensor's phase is steady and the magnitude is more normal, then you can start to suspect that you have an equipment setup problem. There may be something wrong with the sensor itself, the cable, or the EVM if you're getting data from it – regardless, the balance run is not going to be good for this sensor's data. If this engine run is a "must do" or you don't have the time to troubleshoot your setup, you can still proceed with the run counting only on the good sensor. BalancePRO will let you do that. Go to "Customize Solution" and turn "off" the bad channel so that its data won't be considered. Is it going to be the optimal solution? – no, but it will be better than nothing at all (if the other sensor's data is good).

So why was my first "guess" that it was good news and the engine is very smooth? Well I considered the 0.02 magnitude. The sensor was reading something. If I had no vibration data coming in from a bad sensor or a bad cable the number would have been reading 0.00 or no data at all. The fact that I was reading something/anything, is what led me to my first guess – that the engine was just fine. That, coupled with the fact the other sensor was doing the exact same thing, sort of gave it away. The chance that two data paths were bad is highly unlikely. But, if I showed the entire display, I couldn't have used it as an example here; the cat would have been out of the bag way too early.

Momentary Glitch

The entire engine run page is shown here and you are going to need the entire screen in this situation to evaluate what is going on. What is shown here is a momentary glitch. This "glitch" is not going to affect this particular engine run, but it could, and you need to be able to recognize it. Note the phase on the aft sensor. It is indicating 90 degrees whereas up until just this instant in time it was over at about 210 degrees. The question is, "Is this erratic phase?" The answer is, "Yes," but it's only this one speed point. If it remains only this one speed point, the rest of the run is probably okay. The magnitude is okay – it's about the same as the forward sensor, so you have plenty of signal. Take note of the Run Time, Time to End, and Target Speed/Time. You are 9 seconds into the run with a minute fifty left go. You are not that far into the run and you could cancel and restart the run if you wish. The key here is a judgment call on the Target Speed/Time. According to the slow smooth accel rule, the engine run is going a little faster than it should be. The Target Speed/Time reading is telling you that you should be around 700 RPM (696) and you are actually up closer to 1000 RPM (964). So there is a strong chance that the engine acceleration rate is smearing the data collection.

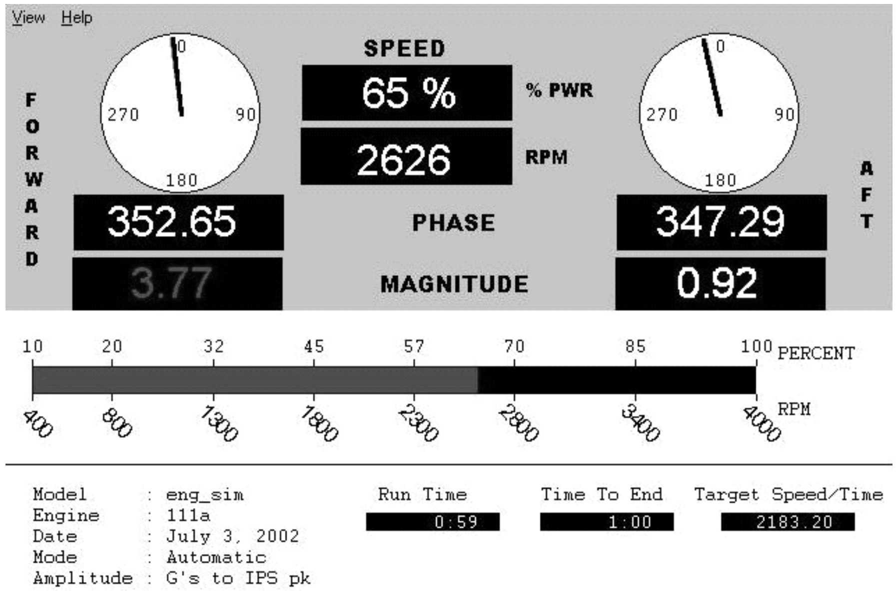


Behind the scenes of a Momentary Glitch

Perhaps what will also help you in making this judgment call is if you know what is going on in the background on the BalancePRO. Mentioned above is the fact that if this one speed point is the only speed point that has corrupted phase then you may still be okay. That's because the engine configuration file on this particular engine is taking data every fifty RPM. So 3600 RPM divided by 50 should give you 72 speed points for your balance solution calculation. One bad point is not going to adversely affect your solution. If there are 10 or more speed points that are glitched, then you may have a problem.

Also, the BalancePRO takes three averages of speed points that are within 25 RPM of the target speed which is then used in the balance calculation. In this case the closest target speed is 1000 RPM (the previous speed point was 950). Looking at the two previous "hits" down around 210, and the one "hit" at 90 there is a good chance that the target speed average is going to be 170 degrees and not the 90 that gets displayed, because of the three "hits" used in the average. The angle of 170 degrees used in the data file that gets created is most likely going to be surrounded with two numbers close to 210, which is only a 40 degree error. And, again, in the balance calculation the smoothing of the weight placement vector is going to place the weight around 197 degrees or within 13 degrees of where it is supposed to be. Considering the number of holes in which you can place weight on this engine (36), or 10 degree spacing – you're only off by one weight location – if indeed only these three speed points were used, and you still have 69 others that would be considered.

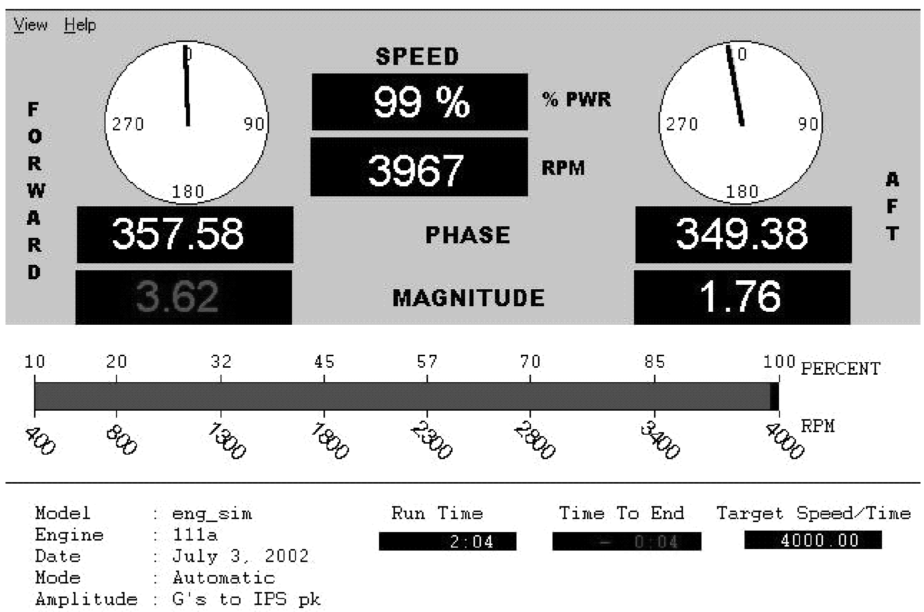
The bottom line is – one bad speed point – not an issue. More than one – start thinking. The key to making the right or wrong call during an engine run is that you have to weigh the data that is being observed, place it all in context of the measurement and the end goal while the engine is accelerating. If this sounds like a lot of pressure on you, BalancePRO can solve that problem as well. It will wait. Slow or stop the acceleration for a moment and evaluate what you are seeing. The BalancePRO is not hard over for the two minute data collection run. It has all the time in the world. The only hard requirement for the two minute acceleration is the amount of fuel you will be using. If you feel you have to stop the acquisition of data and restart the run, that evolution only takes about 15 seconds – weigh this against having to do additional runs if the first solution you compute is corrupted with bad data and you put the weights in the wrong place.



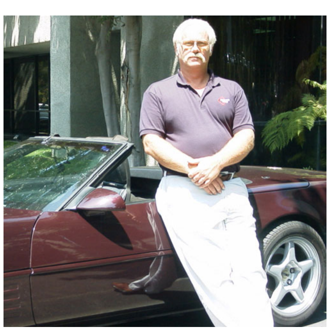
Finishing the Run

The final two displays of this paper show the completion of the run that generated the previous screen captures. These two screen captures are shown in their entirety.

Note that the forward sensor has gone over limit with the engine at 65% power. It is important to note here that the phase from both sensors is the same, and that the amplitude of the aft sensor is well within specs. This is a prime indication that the entire out of balance condition resides in the forward plane only. Any thought of a dual plane solution or a rear plane only would be a totally wasted effort.



This final screen capture shows the engine nearly at 100% power and the out of balance condition on the forward plane still exists, and at this speed it has most likely brought the aft plane up as well. The first half of the run was a little faster than normal and the second half was slower than desired. Notice that the "Time to End" has gone red, or over the expected two minute time frame. Slowing down and "going red on time" does not make up for possible bad data from going through the first half too quickly. Remember collecting engine data is not a race. It's a nice slow smooth data collection process that should be as controlled as possible.



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