Induced Engine Damage

From time to time a field service report states that an engine has damage. After further examination of the engine, this damage may be classified as "induced damage." To clarify what is meant by this term, induced engine damage is a failure or unsatisfactory condition which results from operational or maintenance practices employed after the engine is placed in service. Although there are a variety of conditions which may fall into the induced damage category, this article will discuss two particular types of failure and the circumstances which can induce them.

Examination of an engine that is reported to have low compression, loss of power, erratic operation, metal contamination, or even complete engine stoppage may result in a determination that pistons are burned or valves stretched. (Stretched valves are sometimes said to be tuliped.) These two types of damage can be initiated in a number of ways, but the chain of events is often the same; detonation is followed by preignition and the engine damage has begun. To prevent burned pistons and tuliped (or stretched) valves, action must be taken to eliminate the possibility of detonation and preignition.

Detonation is a phenomena which can occur in any internal combustion engine. The possibility of detonation cannot be completely eliminated. By definition, detonation is a violent explosion. When used with reference to a spark ignition internal combustion engine like the Textron Lycoming aircraft piston engines, detonation indicates abnormal combustion. Essentially, detonation is an uncontrolled explosion of the unburned gases in the engine combustion chamber. Some engines are more susceptible to detonation than others. For example, turbocharged engines are more susceptible than similar non-turbocharged models and engines with higher compression ratios are more likely to exhibit detonation than engines with lower compression ratios.

Detonation may occur in an aircraft engine as a result of maintaining a manifold pressure that is too high for the specific engine speed and mixture setting being used. The engine power (i. e. speed and manifold pressure) and mixture settings recommended in the Pilots' Operating Handbook (POH) for a particular aircraft model have been determined by a detonation survey. These surveys use special instrumentation to detect and record detonation as it occurs. Based on these surveys, the detonation limiting conditions are defined. Data from the surveys indicate that detonation occurs in varying degrees; it is sometimes possible to operate an engine for relatively long periods in the first minor phase of detonation without inducing damage. Textron Lycoming does not recommend or condone engine operation which even approaches conditions which might cause detonation. The laboratory quality equipment used for the detonation survey is not practical for use in an aircraft engaged in normal flight operations. Without this equipment, the pilot may not know that detonation is occurring, and it is impossible to establish the fine line between the first phase of minor detonation and the detonation magnitude which induces preignition and/or engine damage. For this reason it is imperative that power and mixture recommendations of the POH be carefully observed.

Preignition is a circumstance that causes destructive engine damage and will be examined here briefly. Most Lycoming engines are designed for ignition of the fuel/air mixture at

20 crankshaft angle degrees before the piston reaches top dead center during the compression stroke. Some engine models specify ignition at 18ø, 23ø, or 25ø before top dead center. If ignition of the fuel/air mixture occurs before the scheduled point in the operational sequence of events, preignition exists and the compression stroke continues as the burning fuel/air mixture is trying to expand. This subjects the combustion chamber and pistons to temperatures and pressures far in excess of those experienced during normal combustion. These excessive temperatures and pressures cause damage to pistons and valves. In some cases both burned pistons and stretched valves will be found in an engine which has been subjected to preignition.

Considering the millions of hours flown each year in piston powered aircraft, engine damage from detonation and preignition is quite rare. The infrequency of the happening means little if your engine is the one affected. Therefore it seems appropriate to look more closely at some of the factors which lead to detonation and preignition.

The possibility of overboost is a characteristic of all supercharged and turbocharged engines. Generally, overboost means the application of manifold pressure which exceeds the limit specified by the manufacturer. Early versions of the manually controlled turbocharger allowed quite a few pilots to inadvertently induce damage by overboost. With this system, the turbocharger wastegate was normally left full open for takeoff; full throttle would produce 28 to 30 inches of manifold pressure. After takeoff at full throttle, gradual closing of the wastegate would slowly increase turbocharger speed and manifold pressure to maintain climb power to cruise altitude or to the critical altitude of the engine. The system worked fine until the wastegate was inadvertently left in the closed position. If the pilot then applied full throttle for takeoff or a go-round, it could produce 60 inches or more of manifold pressure and failure of the engine.

More recent turbocharger installations usually include a pressure relief valve and/or an automatic wastegate control which helps to avoid the possibility of overboost. Even with these protective devices, it is still possible to overboost by rapid throttle operation and/or inattention to limiting manifold pressures at low engine speeds.

Automatic controllers may not be capable of preventing overboost if full throttle operation is attempted before engine oil is warmed up sufficiently. Textron Lycoming Service Instruction 369F addresses the problem of overboost and recommends, depending on the severity and duration of the overboost, a log book entry, engine inspection, or complete engine overhaul including replacement of the crankshaft.

As stated earlier, ignition of the fuel/air mixture must take place at precisely the right time. A spark plug which has been dropped, or damaged in some other way, may induce preignition by causing a "hot spot" in the combustion chamber which self-ignites the fuel/air mixture. This could also occur from use of unapproved spark plugs. Flight with defective magnetos or flight in excess of certified aircraft limits may allow cross firing within the magneto, improperly sequenced ignition of the fuel/air mixture, and engine damage. Proper magneto to engine timing is also an important factor. The timing is affected by wear and therefore should be checked and reset at specified intervals.

Regular, meticulous spark plug and magneto maintenance will help to avoid preignition and possible engine damage from these sources.

Although overboost and incorrect ignition timing are causes of induced engine damage, this damage can often be attributed to fuel and the fuel/air mixture. The first problem related to fuel is simply having improper fuel in the aircraft tanks. A piston powered aircraft refueled with jet fuel would have a fuel blend with greatly reduced octane level. A piston engine should not be started when even small amounts of jet fuel have been added to aviation gasoline because engine contamination and detonation are likely; attempted flight under these conditions will certainly result in destructive detonation and preignition. The use of 80 octane aviation fuel in an engine certified for 100 octane aviation fuel will produce similar results.

The lubricating oil may be a source of octane reducing fuel contamination. Excessively worn piston rings may allow enough oil into the combustion chamber to dilute the fuel/air mixture. The dilution will reduce the octane rating of the fuel and can lead to detonation and engine damage. While this scenario is not entirely typical of the engine that uses large amounts of oil because of worn or broken piston rings, it is possible for this situation to occur.

Even the use of 100 octane fuel in an engine in good mechanical condition does not eliminate all the possibilities of induced engine damage. Most engines operated at takeoff power or at a power setting in the high cruise range need a relatively rich fuel/air mixture to help cool the engine and reduce possibilities of detonation. Since lean fuel/air mixtures and high power settings promote detonation, it is recommended that Lycoming engines not be leaned at power settings which produce more than 75% of rated engine power unless this operation is approved in the POH. The pilot, by simply leaning the mixture excessively at power settings above the cruise ranges, may be responsible for inducing the detonation and preignition which leads to tuliped valves and burned pistons.

And finally, a small amount of dirt in the fuel system may be responsible for clogging a fuel injector nozzle or nozzles. A partially clogged fuel injection nozzle will reduce fuel flow to that cylinder and will cause a lean fuel/air mixture. A nozzle which is partially clogged in an aircraft that has a pressure operated fuel flow indicator will cause that indicator to display a higher than normal fuel flow. Leaning in an attempt to correct the high indicated fuel flow will result in an even leaner mixture in the affected cylinder. Again it is possible that a burned piston or tuliped valve will be the final result.

Understanding and avoiding those factors which lead to induced engine damage is certainly preferable to the discovery of tuliped valves or burned pistons in your engine. This entire discussion is aimed at promoting an understanding which will allow pilots and maintenance personnel to direct their efforts to those elements which will reduce the possibility of induced engine damage. Observing the refueling of the aircraft and checking the fuel system for indications of contamination are tasks expected of the pilot. Meticulous management of power and fuel/air mixture as recommended by the POH is also a pilot activity which will enhance the possibility of avoiding induced damage.

Maintenance personnel play an equally important role. Troubleshooting a fuel injected engine for rough idle may lead to the cleaning or changing of partially clogged fuel injector nozzles. Damage could result if the engine were operated at takeoff or climb power with reduced fuel flow to one or more cylinders. A close check of magneto timing and magneto condition at regular inspection intervals will help to insure the continued satisfactory operation of any engine.

There are some "after-the-damage" factors that maintenance personnel should consider. Suppose that a power loss has been reported. A compression check reveals low compression; a stretched or tuliped valve may be found. This is an indication that the engine has experienced detonation and preignition. A borescope examination should be conducted to see if a piston has been burned. A burned piston often results in damage to cylinder walls and piston skirts; it also may contaminate the engine with metal particles. There is no healing process for this damage. In some cases it is possible to repair the engine by removing the metal contamination from the engine and oil system, including the oil cooler, and by replacing all damaged parts, but often it is necessary to replace the entire engine. If an engine is to be repaired, it must be remembered that repairing the damage is not enough; the cause of the malfunction which induced detonation and preignition must also be found and corrected. Did a magneto malfunction produce ignition outside the normal firing sequence? Were manufacturer-approved spark plugs installed in the engine? Did a cracked spark plug induce preignition? Was an approved fuel used, and if so, is there evidence of fuel contamination? Whatever the malfunction, it must be corrected along with the damage or the same problem could reoccur.

To conclude, induced damage in the form of tuliped valves and burned pistons can usually be avoided by understanding the sequence of events which lead to this form of engine damage. Careful attention to detail is required of pilots and maintenance personnel. Compared to the expense of repairing or replacing a damaged engine, it is worth the time and effort necessary to avoid induced engine damage.