14. EXTENDING MACHINERY LIFE

CHAPTER OBJECTIVES:

- ***To introduce the reader to the importance of maintenance as a way of extending machinery life;***
- ***To describe the benefits of oil analysis to predict engine failure;***
- ***To explain the influence of storage on the trade in value of machinery;***
- ***To discuss the importance of regular engine tune-ups on fuel efficiency;***
- ***To warn the reader against the disadvantages of engine modifications.***

Manufacturers set out maintenance schedules in their manuals. Planning is necessary to ensure that routine maintenance is as far as possible done at times when the machine is not required for farm operations.

A detailed analysis of a sample of engine, transmission and hydraulic oils is a valuable preventive maintenance tool for a farmer. In many cases it enables identification of potential problems before a major repair is necessary, has the potential to reduce the frequencies of oil changes, and increases the resale value of used equipment.

Storing machinery inside will contribute to fewer repairs and less downtime. Furthermore, trade-in value of machinery stored inside will also be higher, compared to the same equipment stored outside.

The power produced and the fuel consumed should be checked and compared to the tractor's test data. If there is a significant power loss, the engine should be tuned up for better fuel efficiency.

Every machine design is a compromise. The designer must compromise between strength, reliability and cost to come up with a tractor rugged enough to do a job, but still meets an affordable price. Therefore, it is not advisable to modify a tractor for better performance.

14.1. MACHINERY MAINTENANCE

Machinery repair cost can be reduced with as much as 25% by improving routine maintenance procedures. This savings can be significant on a full set of farm machinery. Timely preventative maintenance and inspection not only will help reduce major problems and downtime, they will also help identify developing problems while they can still be rectified with relatively minor repairs.

An effective machinery service program requires good record keeping. It shouldn't be based on the operator's feelings or memory as to when a machine needs attention. The maintenance program must be based on fact, determined by an accurate service record for each machine, as recommended by the operator's manual and adjusted to the farmer's own conditions.

As discussed in Chapter 6, manufacturers set out comprehensive maintenance schedules in their machinery manuals and these should be carefully followed. Planning is necessary so that routine maintenance is as far as possible done at times when the machine is not required for farm operations. Machines subject to seasonal use, for example harvesting equipment, should be serviced and cleaned before going into storage, to ensure that they are ready for operation when required.

14.2. OIL ANALYSIS

Oil analysis involves sampling and analyzing oil for various properties and materials to monitor wear and contamination in the engine, transmission or hydraulic system. Sampling and analyzing on a regular basis establishes a baseline of normal wear and can help indicate when abnormal wear or contamination is occurring.

14.2.1. HOW DOES IT WORK?

Oil that has been inside any moving mechanical apparatus for a period of time reflects the exact condition of that assembly. Oil is in contact with engine or mechanical components as wear metallic trace particles enter the oil. These particles are so small that they remain in suspension. Many products of the combustion process will also become trapped in the circulating oil. The oil becomes a working history of the machine.

Particles caused by normal wear and operation will mix with the oil. Any externally caused contamination also enters the oil. By identifying and measuring these impurities, one gets an indication of the rate of wear and of any excessive contamination. An oil analysis will also suggest methods to reduce accelerated wear and contamination.

The typical oil analysis tests will check for the presence of a number of different materials to determine sources of wear. It will also find dirt and other contamination and even check for the use of appropriate lubricants. Oil analysis can detect:

- Fuel dilution of lubrication oil;
- Dirt contamination in the oil;
- Antifreeze in the oil;
- Excessive bearing wear;
- Misapplication of lubricants.

Some wear is normal, but abnormal levels of a particular material can give an early warning of impending problems and possibly prevent a major breakdown. Early detection can:

- Reduce repair bills;
- Reduce catastrophic failures;
- Increase machinery life;
- Reduce non-scheduled downtime.

Early detection with oil analysis can allow for corrective action such as repairing an air intake leak before major damage occurs. One of the major advantages of an oil analysis program is being able to anticipate problems and schedule repair work to avoid downtime during critical time of use.

14.2.2. LOOKING INSIDE

One purpose of oil analysis is to provide a means of predicting possible impending failure without dismantling the equipment. One can look inside an engine, transmission or hydraulic systems without taking it apart. Some of the physical properties tested for and usually included in analysis of an oil sample are:

- **Antifreeze** forms a gummy substance that may reduce oil flow. It leads to high oxidation, oil thickening, high acidity, and engine failure if not corrected;
- **Fuel dilution** thins oil, lowers lubricating ability and might cause oil pressure to drop. This usually causes higher wear;
- **Oxidation** measures gums, varnishes and oxidation products. High oxidation from oil used too hot or too long can leave sludge and varnish deposits that thickens the oil;
- **Total base number** generally indicates the acid-neutralizing capacity still in the lubricant;
- **Total solids** include ash, carbon, lead salts from gasoline engines, and oil oxidation;
- **Viscosity** is a measure of an oil's resistance to flow. Oil may thin due to shear in multi-viscosity oils or by dilution with fuel. Oil may thicken from oxidation when run too long or too hot. Oil also may thicken from contamination by antifreeze, sugar and other materials.

Some of the metals tested for and usually included in analysis of an oil sample, and their potential sources, are:

- **Aluminum (Al):** Thrust washers, bearings and pistons are made of this metal. High readings can be from piston skirt scuffing, excessive ring groove wear, broken thrust washers, etc.

- **Boron, Magnesium, Calcium, Barium, Phosphorous, and Zinc:** These metals are normally from the lubricating oil additive package. They involve detergents, dispersants, extreme-pressure additives, etc.

- **Chromium (CR):** Normally associated with piston rings. High levels can be caused by dirt coming through the air intake or broken rings.

- **Copper (CU), Tin:** These metals are normally from bearings or bushings and valve guides. Oil coolers also can contribute to copper readings along with some oil additives. In a new engine these results will normally be high during break-in, but will decline in a few hundred hours.

- **Iron (Fe):** This can come from many places in the engine such as liners, camshafts, crankshaft, valve train, timing gears, etc.

- **Lead (Pb):** Use of regular gasoline will cause very high test results. Also associated with bearing wear, but fuel source (leaded gasoline) and sampling contamination (use of galvanized containers for sampling) are critical in interpreting this metal.

- **Silicon (Si):** High readings generally indicate dirt or fine sand contamination from a leaking air intake system. This would act as an abrasive, causing excessive wear.

- **Sodium (Na):** High readings of this metal normally are associated with a coolant leak, but can be from an oil additive package.

Most maintenance experts realize the oil change intervals for both engines and transmissions are decided by the average need. No two pieces of equipment have the same preventive maintenance needs. Each machine has different imperfections and is used under different conditions. When using oil analysis to determine maintenance intervals, there is little guesswork. Records show that some equipment can safely run two or three times longer than recommended intervals. The oil analysis may show that the oil is changed more often than necessary, or not often enough. By eliminating too frequent oil changes, the cost for oil and servicing can be reduced.

14.2.3. THE RESULTS

A typical analysis report is shown in Table 14.1.

TABLE 14.1: ENGINE PROBLEMS PREDICTED WITH OIL ANALYSIS

Indicator	Acceptable Levels	Engine Problem	What to Check
Silicon (Si) and Aluminum (Al)	10 to 30 ppm	Dirt ingestion	Air intake system, oil filter plugging, oil filler cap and breather, valve covers, oil supply
Iron (Fe)	100 to 200 ppm	Wear of cylinder liner, valve and gear train, oil pump, rust in system	Excessive oil consumption, abnormal engine noise, performance problems, oil pressure, abnormal operating temperatures, stuck/broken piston rings
Chromium (CR)	10 to 30 ppm	Piston ring wear	Excessive oil blow-by and oil consumption, oil degradation
Copper (CU)	10 to 50 ppm	Bearings and bushings wear, oil cooler passivating, radiator corrosion	Coolant in engine oil, abnormal noise when operating at near stall speed
Lead (Pb)*	40 to 100 ppm	Bearing corrosion	Extended oil change intervals
Copper (CU) and Lead (Pb)*	10 to 50 ppm	Bearing lining wear	Oil pressure, abnormal engine noise, dirt being ingested in air intake, fuel dilution, extended oil drain intervals
Aluminum (Al)	10 to 30 ppm	Piston and piston thrust bearing wear	Blow-by gases, oil consumption, power loss, abnormal engine noise
Silver and Tin	2 to 5 ppm 10 to 30 ppm	Wear of bearings	Excessive oil consumption, abnormal engine noise, loss in oil pressure
Viscosity Change		Lack of lubrication	Fuel dilution, blow-by gases, oil oxidation, carburetor choke, ignition timing, injectors, injector pump, oil pressure
Water/Anti-freeze		Coolant leak or condensation	Coolant supply, gasket sealed, hose connection, oil filler cap and breather

** Significant as wear metal, only for engines using unleaded and diesel fuel.*

Table 14.1 shows how detection can predict engine problems. Other typical recommendations can be:

- **Example 1:** Bearing metals indicate wear. Inspect all bearing areas for wear. Resample at 1/2 interval;
- **Example 2:** Unit is in satisfactory condition. Resample at normal interval;
- **Example 3:** Abrasion indicated. Inspect air filtration system. Upper cylinder wear indicated. Excessive fuel dilution. Resample at 1/2 interval.

Oil sample analysis saves repair and maintenance costs and has the potential to reduce used oil and increases resale value of equipment.

14.3. MACHINERY STORAGE

Equipment stored inside has a significantly higher trade-in value compared to the same equipment stored outside. Parts such as belts, tires and hoses, deteriorate rapidly when unprotected. Other problem areas are places where water can collect and freeze. Storing machinery inside will therefore also contribute to fewer repairs and less downtime, as shown in Table 14.2.

TABLE 14.2: ANNUAL SAVINGS DUE TO MACHINERY STORAGE

Machinery	Saving as a percent of initial price				
	Greater Value	Fewer Repairs	Less Downtime	TOTAL	Over Lifetime*
Tractor	1.6%	1.5%	1.2%	4.3%	43.0%
Combine	2.0%	3.5%	1.2%	6.7%	67.0%
Planter	1.2%	2.5%	1.2%	4.9%	49.0%
Tillage	0.5%	0.5%	0.6%	1.6%	16.0%

**Assuming 10-year life.*

According to Table 14.2, 1.6% of the trade-in value of a tractor can be saved annually by storing it inside. If the savings due to fewer repairs and less downtime is added to this, the total saving over the lifetime of the machine can be as high as 43%. In the case of combines, the saving can amount to 67% of the initial price.

Machines, including tractors, combines, planters, drills, forage choppers, trucks and pickups should be kept inside. Tillage implements should be the last to be placed inside. They take up a lot of space and decline in value only slightly faster when left outside. After five years, tillage equipment kept inside is worth only about 5% more than if left outside. Usually, the deterioration that occurs to the tires and bearings is less than the cost of providing building space.

14.4. ENGINE TUNE-UPS

Diesel and gas engines require periodic tune-ups. As engines operate, they lose power and fuel efficiency. To obtain the optimum performance from an engine, the power produced and the fuel consumed should be checked and compared with tractor test data. Test results include several ratings for each tractor. For comparative purposes, look at the figures that indicate tractor PTO power and fuel efficiency at maximum PTO power.

The tractor should be tested on a certified PTO dynamometer found at most equipment dealers. Attach the tractor's power take-off to a dynamometer, warm the engine up and check to see if it produces the rated PTO power. If the tractor power is down by more than 5%, adjustments are needed. A tune-up may include changing air and fuel filters, cleaning and adjusting injector nozzles and adjusting engine timing.

Another important part of tractor operation is to check for fuel efficiency. This can be done at the time the tractor is operating on the PTO dynamometer. After the tractor is warmed to operating temperatures, the tractor can be stopped and the fuel tank filled to completely full. Operate the tractor at the rated speed and load for 30 minutes (longer for more accurate results), then stop the tractor and refill the tank to the previous level, keeping track of the amount of fuel needed. Fuel efficiency will give an idea of the engine's condition.

Fuel efficiency or economy is measured in horsepower-hours per gallon (hp-hr/gal) or kilowatt-hours per liter (kW-hr/l), much as automobile fuel efficiency is measured in miles per gallon or kilometers per liter. To calculate the efficiency of the tractor, first determine the units of fuel used in one hour. For example, a diesel tractor producing 155 hp and using 5.5 gallons in 30 minutes, would use 11 gallons in an hour. Divide the 155 horsepower by 11 gal/hr, which gives a fuel efficiency of 14 hp-hr/gal.

Compare this figure to tractor test data during the PTO tests at the rated horsepower. If the current efficiency is 5 to 10% less than original, there may be a problem that needs correction. If an engine is showing a 5% reduction in fuel efficiency, it is wasting about 5% of the fuel. If a 155 horsepower tractor is burning 11 gal/hr, this adds up to 0.55 gallons of fuel wasted every hour or 275 gallons wasted every 500 hours of use.

14.5. MODIFICATIONS

A tractor engine may be modified to get more power. Frequent claims about pulling bigger loads, getting new life from older models and more power from new models are true. Engine modification can be done by several means. The most common are over fueling, while others include adding alcohol or LP gas injection and turbo-charging naturally aspirated engines.

These all sound tempting when an operator is faced with covering a bigger area in less time but the consequences of boosting engine power beyond the original ratings is not really worth it in most of the cases and will result in the following problems:

- Most manufacturers do not allow any changes from standard specifications without voiding the warranty, so the modifications are done at own risk;

- The modifications will almost surely reduce service life. Every machine design is a compromise. The designer must compromise between strength, reliability and cost to come up with a tractor rugged enough to do a job, but still meet an affordable price.

Power is a function of torque and engine speed. Tractors are designed to operate at different travel speeds, but the final drives are not designed for all possible torques theoretically available. If power is increased by 20% on a tractor, it must be assumed that the manufacturer built the engine parts, clutch, transmission and final drive 20% stronger than originally needed. Speed also has an effect on service life. For the example just stated, the 20% increase of power could be used by keeping the tractor weight the same and travel faster. This would reduce the life of the transmission by about 15%. Conversely, if one uses the 20% additional power for 20% larger pulls and drives at a slower speed, the transmission life is reduced by 50%. Usually, to take advantage of the increased pulling ability, more ballast must be added to maintain effective traction. Then, all parts will be overloaded, and service life will suffer. In the end, the tractor probably will end up in the repair shop long before it should.

If more power is needed, it is more economical to trade the smaller tractor for a bigger one. Larger tractors are built for higher power from the radiator to the wheels and should give good service. Trying to get more power by modifying a tractor may prove to be extremely expensive.

14.6. CONCLUSION

There are a number of strategies to follow that will enable the farmer to achieve maximum life from his machinery. A combination of practices can have a large impact on costs, improve machine reliability for many years to come and increase profit margins.

Machinery management must contribute to total management in a cost effective manner. Understanding the different cost components and applying sound economical principles throughout the machinery system will contribute positively to the profit of the farm business.

The objective of physical machinery use is to match and schedule the machinery operations in such a way that the maximum amount of work can be achieved within the appropriate time frame. The result of this will be that the overall performance will return the biggest profit to the farm business.

There is a definite relation between machinery use and machinery cost. The more a machine is used, the higher the cost will be. The higher the usage, the more repairing needs to be done. Thorough maintenance can prevent unexpected repairs. The proper balance between maintenance and repairs as well as keeping track of costs, will result in more economical machinery use.

A complete line of machinery is one of the largest investments that a farmer can make. Yet, unlike land or buildings, machinery must be constantly monitored, maintained, and eventually replaced. How and when equipment is replaced can mean a difference of thousands of dollars in annual production cost.

A tractor is an investment in power. It has the ability to complete a certain amount of work within a specific period of time. The more effective a tractor work during this time period, the more economical the cost of the tractor will be.

An economical approach to machinery management means that the farmer must plan the optimal size of his machinery set around the farm operations and his available financial resources. If he keeps his machinery well maintained and replace the wear out items at an optimal time, the machinery will increase his profits.

14.7. REFERENCES

Nebfacts G95-1261-A. 1995: *Five Strategies for Extending Machinery Life*. Co-operative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, USA.

Nebfacts NF95-225. 1995: *Oil Analysis.* Co-operative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, USA.