

Engine crankshaft deflection measurement

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Understanding engine crankshaft deflection measurement will aid a diagnostic engineer

At some time in his career the Diagnostic Engineer may well have to examine the running of a compression ignition engine. Many of the defects that occur on such units are down to wear in the main bearings causing the crankshaft to change its longitudinal straightness. Usually the first diagnostic test on such an engine is to take a series of measurements between the crank webs at various points round the circle of rotation called somewhat in correctly crankshaft deflections. If a driving engine is of the compression ignition type with a cylinder bore above about 250 mm (10 inches), it is also necessary to consider the alignment of its crankshaft. Below that size, the overall stiffness and small size of the unit and the fact that the crankshaft itself is an integral forging make the measurement of crankshaft deflections both extremely difficult and unnecessary.

The crankshaft of a large compression ignition engine is a huge, bulky components usually built of a number of separate forgings interference fitted together which should remain as straight as possible during operation as otherwise it could lead to serious damage to the bearings and thence to the engine. The crankshaft is built up of crank webs, crank pins and journals along its length and its weight is supported by the main bearings at the journals. Over a period of time as the engine keeps running, the wear in the bearings may not be uniform across the entire length of the crankshaft. That means that the crankshaft will not remain in the initial straight line but will get bent either

upward or downwards to a slight degree which may not be visible with the naked eye but could be sufficient to cause dangerous levels of fatigue in the crank webs. Compression ignition engine crankshaft breakage or over bending, for example, may be the result of excessive bearing clearances. Excessive clearance in one main bearing may place practically the entire load on another main bearing and may be brought about by the same factors that cause journal bearing failure. Flexing of the crankshaft under load may result in fatigue and eventual fracture of the crank journal.

The Diagnostic Engineer should also be aware that off centre and oval journals tend to scrape off bearing material which leads to excessive wear and to the increase of the clearance between the shaft and bearing. Excessive bearing wear usually shows up as some form of fretting corrosion of the bearing surface or scoring of the shaft journals. The possibility of journal ovality can be minimized by taking measures to prevent improper lubrication, journal bearing failure, overspeeding or overloading of the engine, excessive crankshaft deflection and misalignment of parts. Crankshaft bending breakage may also result from excessive crankshaft deflection and which is usually caused by an improper alignment between the driven unit and the engine and can result in a broken or bent shaft along with considerable other damage to bearings, connecting rods and other parts. Overspeeding an engine may also cause excessive crankshaft deflection.

Hence there is a good maintenance requirement of measuring the crankshaft deflections at regular intervals to ensure that the alignment of the shaft remains within permissible limits and those deflections can be measured as described in the next sections. Crankshaft deflection readings are an excellent method of determining engine to drive alignment and main bearing wear. They should be taken in accordance with any planned maintenance system when an engine survey is conducted. In a marine installation, for example, the measurement is usually done when a problem is suspected, say, following an accidental grounding or collision or after a prolonged dry docking period. On the smaller engines i.e., those with a bore of under, say, 250 mm (10") it is not practical to take crankshaft deflection measurements. With engines over such a size it is always advisable and should be carried out regularly. The measurements should be recorded and analysed and the results of the analysis also recorded. The amount of deflection of a crankshaft may be determined by the use of a straight gauge which is simple to apply. The straight gauge is merely a dial reading inside micrometer used to measure the variation in the distance between adjacent crank webs when the engine shaft is rotated by barring the engine over.

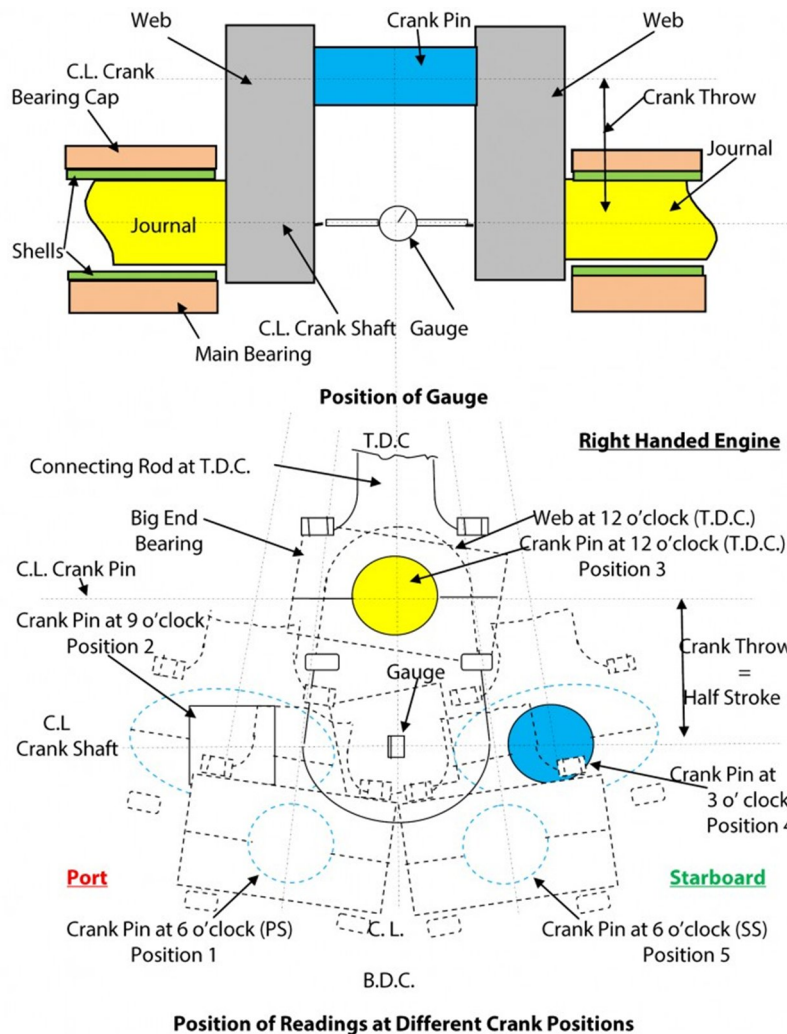


Figure 1 Taking Crankshaft Deflection Readings

Figure 1 gives an idea of which measurement is taken to find the deflections of the crankshaft.

The sketch indicates the aftermost cylinder unit (No. 1) looking forward. The solid line shows the top dead centre (T.D.C.) position (3) and the dotted lines the 3 o'clock and 9 o'clock positions (respectively 4 and 2) and the position either side of the bottom dead centre (B.D.C.) (1 and 5). The various views of the webs have been omitted for clarity reasons. The latter two readings are taken with the connecting rod swung as close to the gauge as is practical. As can be seen from the sketch a dial gauge is inserted between the crank webs to find out the distance between them.

If the deflection is measured after an interval of time, it is both important and necessary that it is taken at the same point otherwise the reading will not give a real reflection about the degree of deflection. The ends of the indicator should

rest in the punch marks in the crank webs. If these marks are not present, they must be made so that the indicator may be placed in its correct position. Normally a centre punch is used to make markings so that each time the deflection is taken at the same point. Ideally the deflection needs to be taken at four points of the crank namely top, bottom and the two sides. In actual practice however the bottom reading is not taken due to chances of fouling by the connecting rod and instead reading is taken on either side of the bottom position, thereby in total five readings are taken from each crank web at the positions stated. Having taken crankshaft deflections the practical work might be considered to be finished but a theoretical analysis and interpretation of those results is certainly required in order to be able to make any meaningful decisions regarding the shimming of the main bearings based on the lifted and recorded data.

The actual method of measurement is easy. With a right hand turning engine, the engine is barred over so that the number 1 unit is just past bottom dead centre (BDC) to port and the micrometer is inserted on the centreline of the shaft and set to zero. The engine is then barred over 90° to in the normal direction of rotation and a reading of the micrometer taken. The process is then repeated with the pin at top dead centre (TDC) and again with the crank pin at 270° . Finally the engine is barred over to as close to bottom dead centre as the micrometer will allow and a final reading taken. The final reading should also be zero. The micrometer is then moved to the next crank and the process repeated. The repetition should be carried out at each unit until all have been measured. The readings are then set down in a table and analysed. A typical set of readings (1/100 mm) for a six cylinder 300 mm bore marine compression ignition engine is shown in the table below. A little thought will show that, as the crank is turned, the aspect of the gauge also turns making it difficult to read in the confined space inside the crankcase. A mirror and a torch will be found of invaluable use in such circumstances and the Diagnostic Engineer must not forget the five P rule.

Proper Preparation Prevents Pathetic Performance

Apart from using the same point on the crank web for measuring deflection there are other factors which need to be kept in mind if it is a marine installation and they include the load on the ship, trim, hog, sag etc. The vessel must be afloat at the time the readings are taken and the Diagnostic Engineer should carefully read the draughts forward, aft and, if possible, amidships (both sides) and record them in his report. Strictly the vessel ought to be unladen if she is a cargo carrying vessel. To some extent those points are a bit like gilding the lily

with a vessel under about 60 m (200 ft) in length but, if he to be a professional, the Diagnostic Engineer should note those points down and record them. The report should also include the engine maker and type, its brake power and revolutions, its bore, stroke and the distance between the cylinders. It should also include, obviously, the name of the vessel, the reason for carrying out the work and the place and date of the measurement. Such comments may seem to be obvious but they are, nevertheless, frequently forgotten. The chief engineer should also note the table of deflections and that they were taken – when, where and why – in his engine room logbook.

Cylinder Number	1 Aft	2	3	4	5	6 Forward
B.D.C.	0.0	0.0	0.0	0.0	0.0	0.0
Port	+1.0	+1.0	+1.0	0.0	-1.0	+1.0
T.D.C.	+1.0	+0.5	+0.2	-2.5	+1.0	+1.0
Starboard	-1.0	-1.0	+1.0	-1.0	+1.0	0.0
B.D.C.	0.0	+0.1	0.0	0.0	-0.1	0.0
Difference	+1.0	+0.4	+0.2	-2.5	+0.9	+1.0

The results are tabulated in a manner shown in the example table. The numbers in the first row represent the unit or cylinder number and the first column shows the position at which those readings are taken. The final row shows the difference between top and bottom readings which gives the vertical misalignment of the crank shaft. The values of the vertical misalignment need to be compared to the maximum permissible limits specified by the engine manufacturer.

The method of numbering the cylinders i.e. whether from forward or aft should also be recorded. Number 1 unit is usually but not necessarily that next to the flywheel. The analysis of the vertical deflections (i.e. the difference between those at TDC and BDC) given in the table above are shown in Figure 2 below. A majority of people find that the graphical representation of data is more appealing and easily understood than a list of numbers hence the above data is best plotted as a deflection curve. A straight line is drawn representing the length of the crankshaft and the centre lines from each unit are drawn through the line. That now acts as the basic infrastructure upon which to start plotting the deflection curve. Since the first deflection is +1.0 (remember they are normally mm/100 unless otherwise specified) that distance is plotted to scale downwards from the reference line on the centre line of unit 2 (not unit 1) and the line ab

drawn. That is at an angle proportional to the deflection at the point a and is further extended to intersect the centre line of the next unit. The next step is to measure the deflection from the point of intersection (upwards for negative value and downwards for positive value) and join the point from the previous point which gives rise to the line bc. The same step should be repeated until the last unit has been covered. The line through the points should be a fair curve but rarely is.

A smooth curve is drawn between these points and the position of this curve with respect to the base line XY gives an idea about the state of various bearing. For example in this particular example it can easily be made out that the bearings of units 3, 4 and 5 are too far away from the faired acceptable line and hence need attention. The experienced Diagnostic Engineer may have realized by now that why only comparing the values of vertical misalignment against the manufacturer's specifications is insufficient. That is so because even if the values are within limits, the relative wear and tear might be sufficient to cause excessive misalignment. Hence the recommended method gives an addition assurance about the crankshaft's alignment. After correcting the alignment by means of shims, the Diagnostic Engineer should take another set of deflection readings to check that the adjustment to a catenary curve is satisfactory. The same method of analysis can be used for the transverse deflections but that is usually only undertaken if severe transverse misalignment of the shafting is suspected.

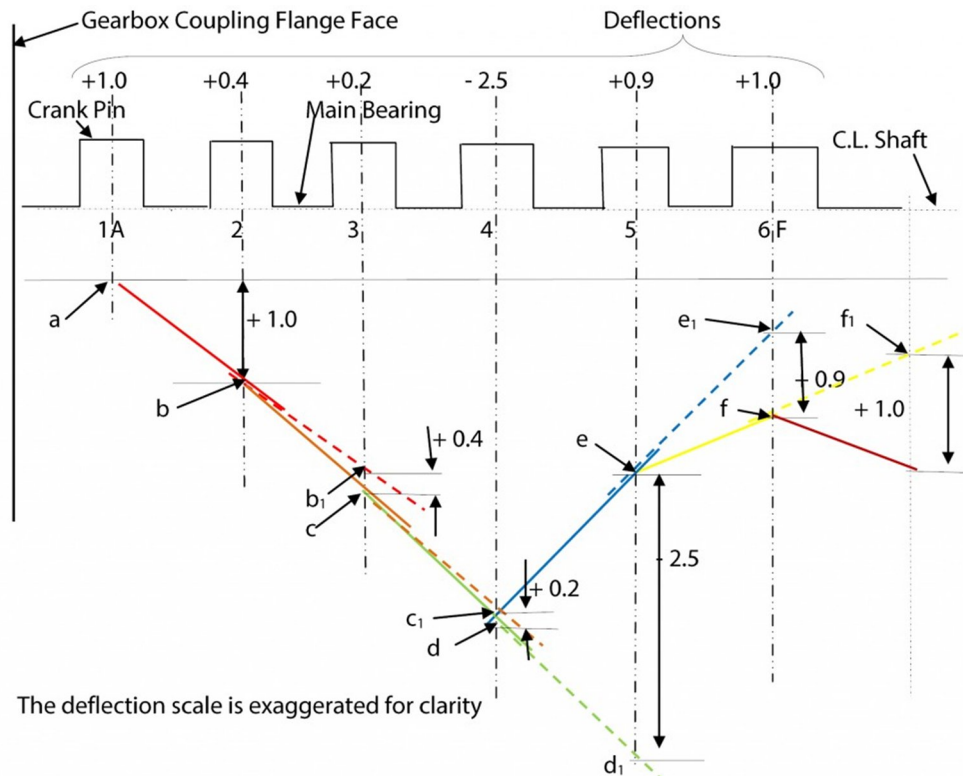


Figure 2 Plot of Deflection Readings

In an engine survey, the following points should be covered.

1. The connecting rods should also be sighted using a straight edge looking for straightness.
2. Check the bearing surfaces for bright areas which usually indicate excessive wear.
3. The condition and wear of both big and little end bearings should be examined and, if wear is found excessive, the bearing shells should be renewed. The diameter of the crank pins should be calibrated by measuring them with a micrometer and recording the results again looking for ovality.
4. The condition of the crankshaft should be examined paying special attention to the wear of the main bearing journals and, if excessive wear is found, the bearing shells should be renewed. The diameter of the main crankshaft journals should be calibrated by measuring with a micrometer taking two readings at right angles to each other and, again, the measurements recorded and looking for any ovality of the journal and also the crank pin.

5. All items of the engine must be thoroughly cleaned and all oil ways proven clean and clear and the items wiped dry with a soft cloth.

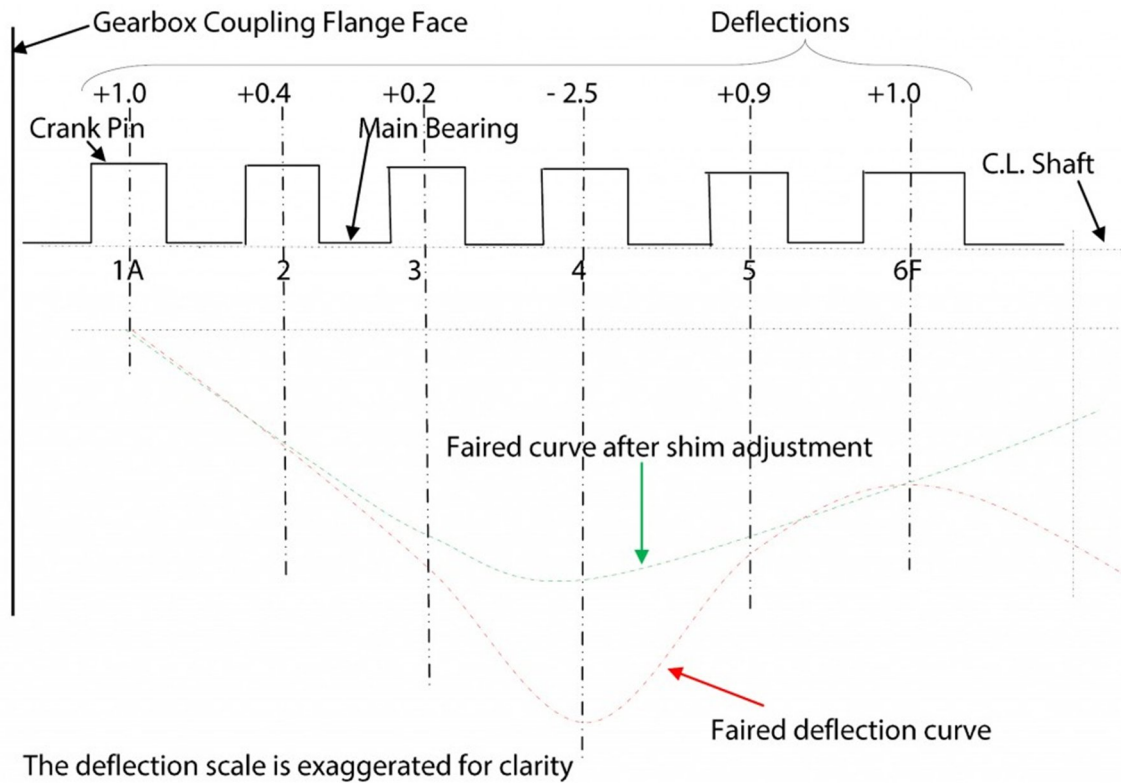


Figure 3 Faired Deflection Curves

Many main and big end bearings effectively cannot be repaired so that when they are heavily scored or show signs of severe wear they must be renewed. The Diagnostic Engineer will find the acceptable levels of wear for a given engine in the manufacturer's handbook. To measure the wear of a crankshaft journal or crank pin a suitably sized micrometer is needed and to make measurements of the inside of a shell bearing a ball ended micrometer is necessary. Split shell bearings can be measured for wear by bolting up the unit on the appropriate part of the crankshaft over a propriety brand of plasticine material, afterward measuring the thickness of that and checking against a chart supplied with the material.

Ovality is checked by taking a pair of micrometered diameters of the journal or pin at the centre of the bearing and at each end and at right angles to each other. The manufacturer's handbook will give the allowable amount of ovality or wear. If there is severe scoring of the crankshaft and bearings at either the main or the big end bearings this must be taken as a clear indicator of the necessity to

replace the bearings and to thoroughly wash out and clean the whole lubrication system. Repair of the crankshaft can only be contemplated if there are, at most, two scores which are not part of the general deterioration. Repair is often carried out by regrinding the crankshaft undersize – there are strict limits to the amount of regrinding that may be affected – and then fitting under sized bearing shells. Particles are characterised by their shape, quantity and size which enables the Diagnostic Engineer to decide how far along the stage of wear and breakdown the bearing has progressed. The various stages of wear degradation are shown in Figure 4 below where the surfaces are exaggerated for clarity reasons. Wear as a phenomenon causes changing debris formation through the period of its operation on interacting surfaces changing from fine particles during the running in period to a surface reminiscent of the surface of a badly ploughed field at the final stage of deterioration.

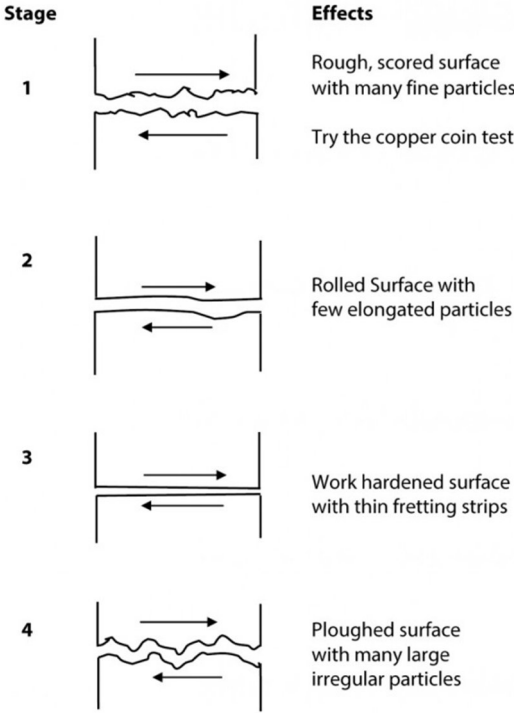


Figure 4 Stages of Wear and Debris Formation

Upon completion of all these examinations and tests the engine should be rebuilt using new gaskets and similar consumables, filled with clean lubricating oil and slowly turned over by hand a number of times to ensure that the lubricating oil is reaching all parts of the engine before firing up. After running the engine for, say, an hour to bed the bearings in the gear box flange should be broken, the bolts removed and the clearance taken by feeler gauge at top, bottom and each side, again rotating the shaft at 90° intervals and taking further measurements until the shaft has been rotated back to its original position. If the alignment is

good there should be no more than 0.1 mm difference between the maximum and minimum readings.

The Diagnostic Engineer will know that it is in the nature of things that bearings suffer wear. They are, when the engine is running, highly loaded and subject to constant variations in temperature and the direction in which the load is applied. They also suffer from poor quality lubricating oil which picks up all sorts of metallic and chemical debris on its journey through the engine.

These conditions result in a number of related phenomena which are illustrated in the defects tree in Figure 5 below. Again, the Diagnostic Engineer should be familiar with them as these phenomena are the first visible, audible and tangible signs of trouble to come.

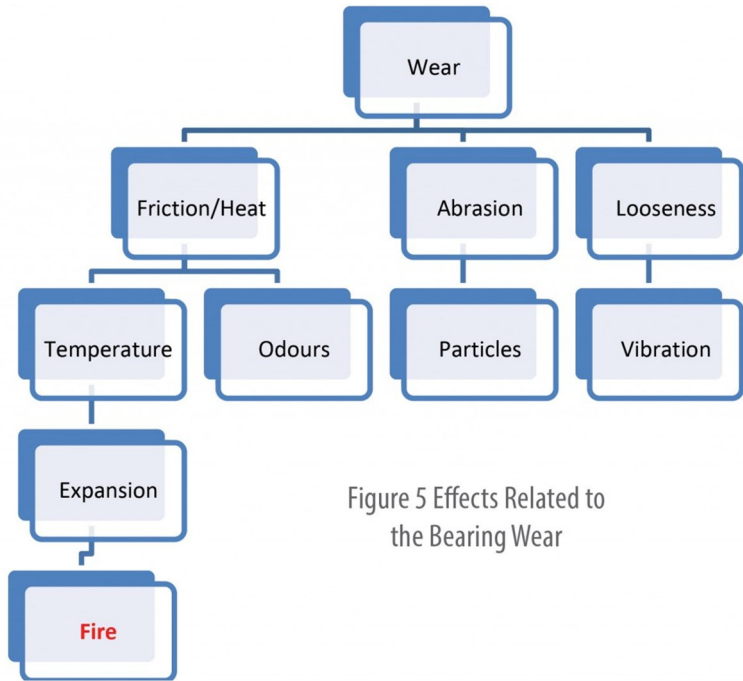


Figure 5 Effects Related to the Bearing Wear

Figure 6 gives an indication of the lead time to failure given by various conventional condition monitoring techniques and the Diagnostic Engineer should be familiar with all of them and their relative value.

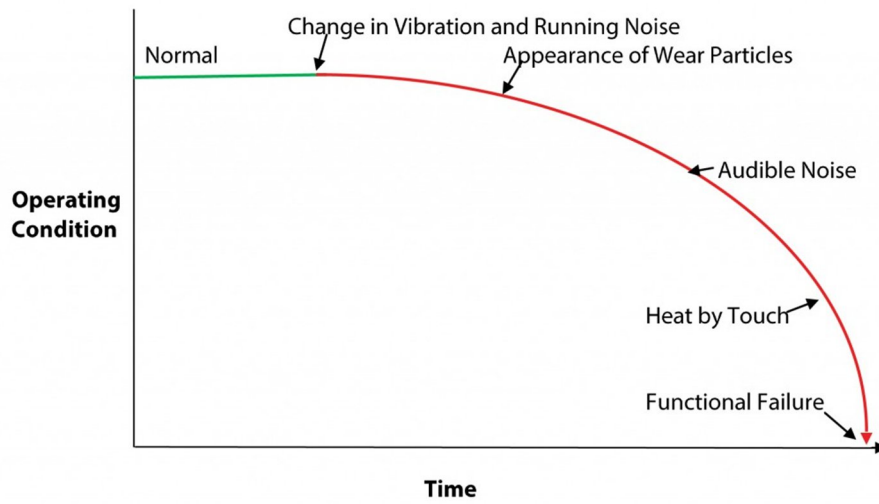


Figure 6 Lead Time to Failure as shown by Various Condition Monitoring Techniques

This feature article, entitled engine crankshaft deflection measurement, was written by Eur. Ing. Jeffrey N. Casciani-Wood HonFIIMS and was first published in 2015 by the Society of Diagnostic Engineers.