PRESENT AND FUTURE INSTRUMENTATION FOR EVALUATION OF FARM EQUIPMENT

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INTRODUCTION

The engineers designing farm implements are striving to improve the performance and increase the durability of their machines and at the same time have a unit than can be produced and sold at an economical cost to both the manufacturer and user. Instruments can play an important part in aiding the designer develop durable high performance machines.

The normal design practice has been to use some arbitrary load for computations. This load is selected on the basis of an average or peak load either expected or observed. A maximum permissible stress level is chosen for the design load. This is an easy task where a successful machine of similar design and function already exists. However, a real problem faces the product engineer on new machines and on old machines with major revisions. The conventional approach would be to determine the structural requirements by field durability tests. This type of testing requires a great length of time and if the first design is not satisfactory there is usually no time to test an alternate design before production. With the present rapid rate of introduction of new machines on the market this procedure is too costly and time consuming. Therefore, it becomes necessary to find new methods for reducing the development time and also to improve the performance of the unit both functionally and structurally. Modern instruments are used to determine the service loads in actual field operation. With the service loads known an analysis can be made to determine the structural requirements. The results of this analysis incorporated into the design give an experimental machine for durability tests which has a much better chance of performing satistorily in the field than machines designed by former methods.

The instruments for collecting field loads are not an end in themselves and have significance only as a means to collect data for use in making sound design decisions. Therefore, the use of the data will be discussed first.

DATA COLLECTION AND ANLYSIS

The field data is usually desired for one or more of the following purposes.

1. To determine the structural requirements.
2. To establish the efficiency of the machine.
3. To study the functional performance.

In order to accomplish these purposes the following quantities must be measured:

Forces, Torques, Strains, Bending Moments, Accelerations, Displacements, Temperatures, Pressures, Velocities.

Many transducers are available commercially to make these measurements. However, it is often desirable for the test engineer to design and build his own transducers for special purposes.

For dynamic measurements in the field the data is usually recorded on an oscillograph chart. The data on the charts must then be tabulated in a suitable form for analysis so that a design decision can be made.

The data are tabulated in one or more of the following forms:

Average, Extreme Peak, Average Peak, Valley, Average Valley, Peak Load Spectrum, Valley Load Spectrum, Peak-Valley Load Spectrum, Range Load Spectrum, Time at each load level.

The method of tabulating the data depends upon the type of components to be studied and the analysis to be made. Tabulating the load information consumes a tremendous amount of time. However, if the significant loads are to be obtained the data must be properly tabulated.

One of the difficult analysis to perform for a random loading is the structural durability of the machine. The usual answers required from such an analysis fall into the following categories:

A. A realistic design load and stress criterion.

B. A correlation between the test stand loads and field service.

C. The estimated life of the machine in field service.

Analysis to answer the above involve the use of S-N Curves, alternating-mean stress diagrams for the material or component, the proper service load spectrum and cumulative damage calculations. The method of analysis may be of interest but is beyond the scope of this discussion. The advantages of such an approach to the design of load carrying members are:

1. It provides a much more durable machine the first time off the drawing board.
2. The weak or over designed areas can be found and corrected quickly on the first experimental models so that durability tests can be performed on a machine which has excellent possibilities of lasting for the desired lifetime.
3. The proven machine can be released for production in a shorter time. Also the limitations of the many components will be known to such a degree that any changes required because of horsepower or weight increases will be known well ahead of time.
4. This procedure should eliminate most of the costly rework programs due to major field service failures and customer's complaints.

INSTRUMENTATION

Conventional Instruments

A wide variety of instruments are available for making the field measurements. The type of instrument to be used depends upon the character of the phenomena to be measured, the conditions of the test, and the use to be made of the data. The conventional instruments can be classified into the following categories:

Frequency Response

1. Static
2. Low frequency up to 100 cps
3. Medium frequency up to 2000 cps
4. High frequency up to 1,000,000 cps

Type of Instruments

1. Strain indicators or Wheatstone bridge and galvanometer
2. Ink, heat, or electric writing oscillograph
3. Photographic recording oscillographs
4. Cathode-Ray Oscilloscopes

Details of these instruments will not be discussed since they have been presented before. (1, 2, 3)

The instruments must be carried in the field by a suitable means when making measurements under actual operating conditions. This has been accomplished by several methods depending upon the conditions that existed at the time. The following list gives some of the methods used to carry the equipment in the field:

1. On the tractor or machine being tested.
2. On a trailer or cart attached to the test machine.
3. On trailers pulled alongside the machine being tested.
4. In trucks driven alongside of the test machine.

It is advantageous to have the instruments mounted in a truck or trailer for instant use in the field if tests are to be conducted on many different machines. Sometimes it is necessary to test a machine under conditions that do not permit the use of a truck or trailer. Examples of this are combines operating on a steep hillside or in muddy rice fields. In such cases it is advantageous to mount the instruments on the machine under test. The instruments are supplied power in the field either from the tractor battery or a separate gasoline engine driven 110 v ac generator.

Figure 1 shows a truck which is equipped with direct writing oscillographs for measuring loads and stresses in the field. Space is also available for installing a photographic recorder or oscilloscopes if necessary. The truck has an air compressor and other equipment for Stresscoat. One truck is equipped with a sandblaster and large air compressor for use in sandblasting paint from machines for Stresscoating. This greatly reduces the time for preparation and provides a good surface for Stresscoat.

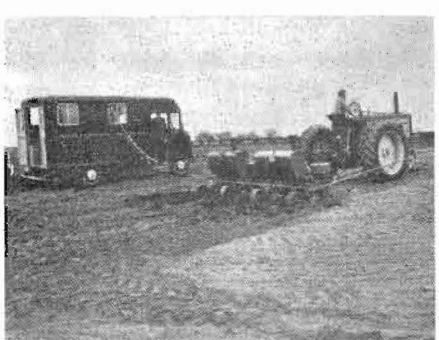

Figure 1. Instrument Truck for collecting field load data.

Figure 2 is a view inside the truck showing a portion of the amplifiers, the 6-channel oscilograph and two integrators. Many tests are conducted to study the operating characteristics of a machine. In such tests it is desirable to obtain the average load. This can be done by planimetering the area under the curve. However, this method is time consuming and tedious so integrators are used to provide a means of obtaining the average immediately in the field.

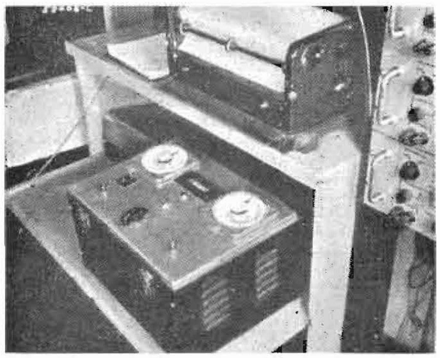

Figure 2. Amplifiers, Oscillographs and Integrator in Instrument Truck.

The two types of integrators in use are: (1) the milliampere second meter shown in Figure 2 and (2) electronic integrators using analog computor amplifiers and charged condensors.

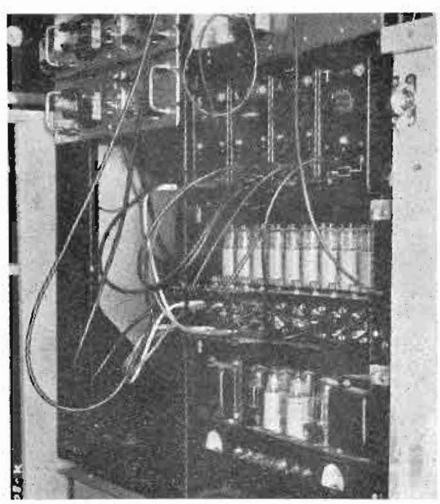

Figure 3. Analog Computor in Instrument Truck.

The analog computor is shown mounted in the truck in Figure 3. This computor is used for integration, finding resultant forces by the square root of the sum of two squares, and for multiplying and dividing the output of two or more gauges together to obtain the actual phenomenon of interest. The desired output of the computor is recorded on the oscillograph alongside the measurements from the separate strain gauge bridges.

Strain Peak Counter

The afore-mentioned instruments are in extensive use for measuring service loads on farm machines. One of the major difficulties is in making use of the data from such recordings. A quick analysis can be made using the average and peak values measured. However, these two easily obtained values are not always sufficient for a detailed analysis to determine the exact requirements of a particular component. A rigorous analysis requires the magnitude and number of repititions of the damaging stress cycles. Recording these from oscillograph charts takes a tremendous amount of time when the load fluctuates rapidly. A new instrument, called a Strain Peak Counter, was developed to reduce the amount of time required to tabulate the data.

Features of the Strain Peak Counter

The Strain Peak Counter was designed with the following features to make it easy to use in the field:

1. It uses about 120 watts from a 12 volt battery.
2. It is contained in a reasonably sized package for ease in mounting on the machine under test.
3. The data is displayed on 12 counters for easy tabulation.
4. The loads are divided into 12 levels, 8 positive and 4 negative.
5. The instrument contains a bridge balance, calibration circuits and amplifier.
6. The output of the amplifier may be fed to an oscillograph for obtaining a typical record.

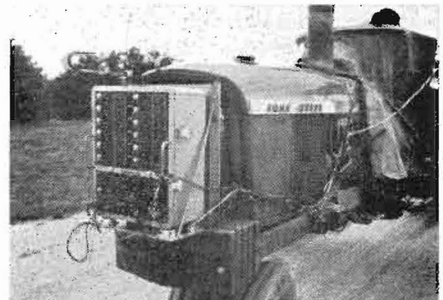

Figure 4. Strain Peak Counter mounted on tractor.

Figure 4 shows the Strain Peak Counter mounted on the front of a tractor for use in measuring the loads on the wagon pulled by the tractor. A single channel recorder was mounted on the fender of the tractor for use in obtaining an oscillograph record of the strain analyzed by the Strain Peak Counter. The recorder was powered from the 12 volt battery through an inverter mounted on the side of the tractor.

Functions Performed

The Strain Peak Counter can analyze the data in the time, count and range modes provided. If the data must be analyzed in two or more modes it is necessary to duplicate the test. The mode selected is governed by the use to be made of the data and the factors most influential in fatigue damage to the part under consideration.

Time Mode. In the time mode a count is registered, on the appropriate counter every 1/1000 of a second the strain or load remains in a load level. This is illustrated on Figure 5 where it is shown that 8 counts are recorded on counter +3 during interval A, and 9 counts are recorded on counter +4 during interval B.

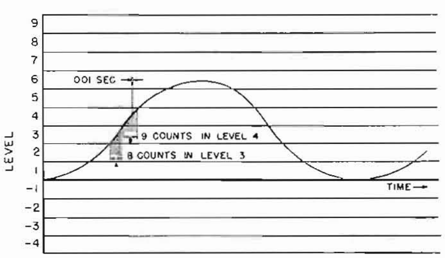

FIG 5 TIME MODE

The data from this mode of operation is useful for gear design. The normal method of determining the loads on gears is to measure the torque on the shaft. The load fluctuations on the shaft do not tell the true fatigue loading on the gear teeth since the teeth receive a 0 to maximum load cycle every time they contact the mating gear. Therefore, the important information is the number of times the teeth receive a load of each magnitude. If the shaft is running at a uniform speed, the time at each load level can be converted to revolutions of the shaft or the number of times each tooth receives loads of various magnitudes. The counter is equipped to accept signals up to 2000 cps to indicate counts in terms of revolutions of the shaft when the shaft fluctuates at operating speed.

Count Mode. The count mode is for counting the peaks that occur in the 8 positive and 4 negative levels. Figure 6 illustrates the counts registered in this mode of operation. Only the extreme excursions are counted and not one count for each level crossed. A hysteresis adjustment is provided for controlling the amount of fluctuation that must precede and follow a count. For a hysteresis setting of 1 the signal must cross one level on the way up before a peak and one level on the way down after a peak for a count to be registered.

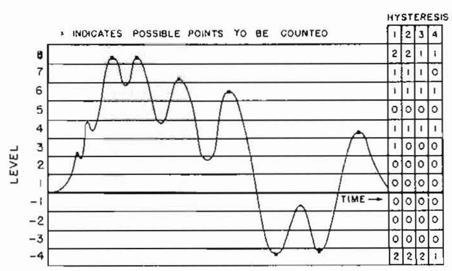

FIG 6 COUNT MODE

When the hysteresis is set at 2 the signal must cross two levels on the way up before the peak and also cross two levels on the way down after the peak to register a count. The hysteresis of 3 and 4 works in a similar manner. Each level has its own hysteresis control so the hysteresis can be different for each level. The table at the right of figure 6 illustrates what is counted with the hysteresis set at 1, 2, 3 and 4.

The data from this mode of operation is useful for fatigue studies where the fatigue life depends upon the magnitude of the peak stress as well as the range of stress.

The Range Mode. The fatigue life of many components depends to a large extent upon the range of stress between a peak and valley with only a small effect from the mean stress. For this application the SPC is equipped to record the number of levels passed through from a peak to a valley. Figure 7 shows how the data is counted in this mode of operation.

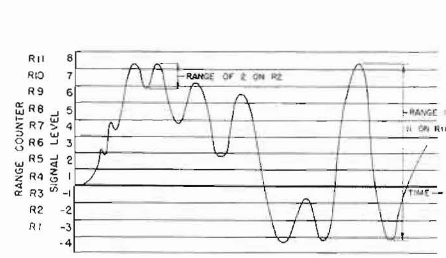

Fig. 7. RANGE MODE

Tape Recorder

The Strain Peak Counter can analyze only one channel of information at a time and in only one mode. Therefore, thought has been given to the use of multichannel tape recorders for recording the data in the field. The tapes would then be played back in the lab and anlyzed through the strain peak counter, other specialized data analyzing equipment, or digital computors. This method of recording is used in aircraft and missile tests and provides some advantages that make it desirable for testing farm equipment.

Figure 8 shows a tape recorder and the associated electronics that could be used for recording data on the field. The package is small enough to mount conveniently on most tractors and implements. It can be powered directly from the batteries on the tractor. This particular unit will record 7 channels of information and can be used for 14 channels with a small additional electronic package.

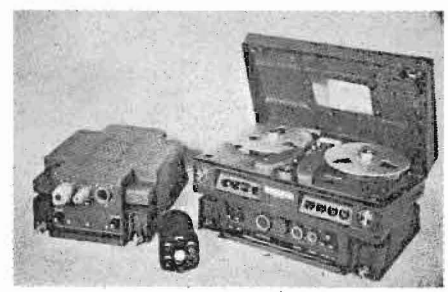

Figure 8. Portable Field Tape Recorder.

Along with the field tape recorder a laboratory playback unit is needed. If the data are to be processed by a computor some additional equipment is necessary to convert it into a suitable form that can be handled by the computor. Three tape recorders have been tried on farm implements in the field with encouraging results. This approach appears to be the method for a completely automatic data processing system.

SUMMARY

The product engineers designing and developing farm machines have been faced with designing for field loads which were hard to evaluate. Instruments have been available for measuring these loads under actual operating conditions. However, a tremendous amount of time was needed to tabulate the data recorded by the conventional instruments. New instruments are on the market in the form of Strain Peak Counters, that will perform this tedious task in the

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Different operating conditions place different demands on combines and thus a machine that is flexible to meet varying conditions and operate as efficiently as possible is desired. Labor and fuel costs, the value of the grain being harvested and weather conditions influence the selection of the rate of work on a combine. A combination of low labor costs, high crop price and lack of risk of unfavourable weather will usually result in operation at a capacity giving highest efficiency. A low price for a crop or the risk of unfavourable weather will usually result in operation at a higher capacity with a slight reduction in efficiency.

The above remarks illustrate some of the factors which affect the very complex question of combine capacity and efficiency and why it is necessary to consider all these factors when rating a machine for comparative purposes. In the final analysis however, it is the responsibility of the user to obtain maximum output at minimum cost under the conditions encountered.

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equations. Solutions to problems of system stability and critical damping appear in the values for system coefficients.

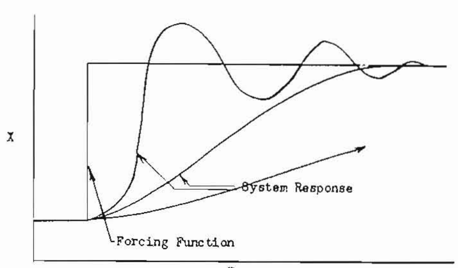

Figure 5.

It should be mentioned that as the same general diferential equations appear in many other engineering areas, including electrical circuits containing inductance, capacity and resistance, that a great deal of useful simulation of control circuitry can be carried out by means of an analog computer. This important tool with its natural ability to directly simulate physical phenomena is often overlooked in favor of digital computers. Digital machines have caught the public fancy, but are only capable of handling differential problems that lend themselves to numerical approximations. Analog machines on the other hand can even include human elements in system simulation.

A second characteristic of such a system as that illustrated in figure 3, is the decision to be made by the system as to whether or not an error signal is a true indication of an error or whether it is a random impulse or "noise". This aspect of control involves the theory of statistical quality control and communications theory, both of which generally fall outside of standard undergraduate curricula.

These are briefly, the technical areas in which solutions to problems of farmstead mechanization and control circuitry wherever found, are to be located. Much of this is unfamiliar ground to Agricultural Engineers. Nevertheless if Agricultural Engineers are to make a high level contribution to advanced mechanization then some understanding of these fields is necessary. It is hoped that educators will keep these needs in mind, particularly in developing graduate programs of study and research, and that all keep in mind that technical libraries contain all of the technical material that has been referred to. The responsibility to make use of this information rests with individual Agricultural Engineers.

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field as the test is conducted. Multi-channel tape recorders and digital computors can be used for an automatic data processing system. Through proper analysis of data collected in this manner engineers can design and develop new machines of proper durability and performance in a much shorter period of time.

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