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ABSTRACT

NDE in the mass production automotive industry uses single frequency eddy current test systems for component parts integrity testing. Typical measures accomplished are: surface hardness (R_c), depth of hardened layer (case depth), core hardness, and soft spots on the surface caused by incorrect quench. Additionally, gross crack and seam defects are detected in production processes by this type equipment, on the order of .005" deep and .2" long. Some special results occur, such as: fillet combined hardness and case depth tests result in a direct correlation to fatigue life for the crankshafts of diesel engines.

Material sorting for alloy differences is another important inspection performed on incoming stock. Many low to high carbon steel alloys may be sorted; however, there are combinations which cannot be separated. However, multiple frequency testing is now improving this situation considerably. The equipment used must be highly reliable with MTBF's of 10,000 hrs. and long-term stability of months for successful high speed production testing at rates of 3600 to 72,000 parts per hour.

My business is primarily with the automotive industries. We're eddy current manufacturers who are staffed with highly technical people doing research and development in that area, but primarily on a commercial basis. In other words, we're not funded. That was a long way of saying it, but eddy current people don't get very many funds for this kind of thing because the techniques are not so applicable to many of the problems that go on in the military industry.

What I am going to tell you about is what we can do with so-called single frequency eddy current. I say "so-called" because we're finding out we can do an awful lot more if we use multiplexed frequency techniques.

We have a couple of speakers who will fill you in on multiple frequency testing as we proceed. We have two areas for eddy current testing. One is the non-ferrous materials. There, we don't do a lot of work, but we do have conductivity testers that can do many of the things with which you are familiar, such as materials sorting and the actual measurement of conductivity for its own purposes to monitor or check the quality of products that are supposed to have certain conductivity ranges. It can detect thickness of thin materials and we can do some heat treatment checking. For instance, many of the aluminum materials change conductivity when they are heat treated, as do some stainless materials that are non-magnetic. Thus we can do some heat treatment testing in this area with conductivity eddy current methods.

Most of our techniques are in the low frequency range. We operate from a hundred hertz to a hundred thousand hertz. Most of what I have seen in the aerospace industry is up in the higher frequency ranges, 500 kilohertz and megahertz ranges, but our primary business is in the ferrous industry.

To give you a little idea of what we can do there, I am just going to enumerate some of the tests that we perform. Most of what we do, of course, is in production. For instance, an automobile manufacturer makes piston pins and he has several things he wants to check that he cannot do destructively. Nondestructive evaluation is something, however, that he can do, and he can do it very rapidly - 3600 parts an hour. We can check

such a part for surface hardness, decarburization on the surface or total lack of carburization. We can also check things like soft spots where parts will pass through the quench improperly, or what is called slack quench conditions. This occurs when the part does not quench rapidly enough. Things like this are giving automobile engines, as they become more highly sophisticated, a lot of problems. We can do cracks and seams, but not with the selectivity that you might be interested in in some of your work.

We can detect cracks five thousandths in depth and maybe a quarter inch in length. We can also detect soft spots. It means that if we have a very good material, say 52100 bearing steel, or we have a highly processed part like a piston pin or a part that is machined and ground, we can then check it for that kind of defect, but that is not a really large part of our applications.

There are two areas in which eddy currents are especially valuable. One is in the high frequency range (high for us). Ten thousand cycles per second is a frequency we typically would use to look at the surface hardness and look for shallow case depth in a part like the piston pin. The case depth is supposed to be 20 thousandths to 35 thousandths. At a high frequency, if it is a little shallower than twenty, we can usually detect it. Then we go to a lower frequency to look inside the part, because the eddy current penetrates into the surface of the part inversely as a function of the square of the frequency. Typically at 10 thousand hertz we're penetrating, maybe, 15 to 20 thousandths. At a hundred hertz we're penetrating on the order of one hundred fifty thousandths. That will vary from one hundred thousandths to two hundred thousandths, depending on the material.

Carbides in cast structures are of interest and are detectable. Cylinder sleeves for a diesel engine are spin cast. For some reason this process brings out carbide conditions on the surface of the part and this ruins the cutting tools. Also, it can create cracks, and we can detect both carbide and cracks.

Another thing with which we have had some correlation is microstructure. When you heat treat certain ferrous materials, the phase at which the

hardness just goes correctly into the value that you want is detectable as a function of the micro-structure of the part. In many ferrous materials, this is determinable with eddy currents and causes a very easy way to sort correctly heat treated parts from incorrectly heat treated ones at a single frequency. We, of course, are depending somewhat on resonance characteristics or resonance effects of the materials as a function of the processing. The heat treating changes the structure, and then if you induce an eddy current frequency in it, the response of a particular alloy with a particular heat treat condition may occur at a different frequency than for another alloy of steel, heat treated in the same way to bring it up to the same kind of Rockwell C hardness. Primarily, we're attempting to determine that these parts have been processed properly and are correct for their use in terms of a Rockwell C scale hardness. It is almost exclusively used in the automotive industry as a measure of heat treat condition, right or wrong.

We're able to determine the Rockwell C hardness in most ferrous materials within a half a point on the RC scale of what you would normally do with a penetration test. In other words, we can almost match the average hardness of a series of parts with the average hardness as measured by the penetration test at the high hardness ranges up around 57 to 63 or 64 RC. When we get into lower hardness ranges with eddy currents, we become a little less discrete, and we cannot compare directly with the penetration test. For instance, at 40 to 45 RC hardness, we might be within two points of correlating with the average penetration tests. At lower hardnesses than that you can almost forget eddy currents as a method for measuring the hardness of the material.

Because there are these so-called resonance effects, one of our analysis techniques is to put parts within a coil, scan the frequencies, and plot the results from the eddy current instrument to separate parts that are properly heat treated and parts that have all of these other faults - decarburization, slack quench, etc., whatever the characteristics are that have created the reject part. If we do that, we then often find that there is a particular frequency, say, 750 hertz, at which we will be able to sort these reject parts. At other frequencies we may not be able to see any difference.

The same frequency sensitivity applies to attempting to sort steel alloys. You may find that certain alloys will sort well at five kilohertz and other alloys will not sort at all at that frequency, but you go to another frequency like four hundred hertz and you can sort those that did not respond at the five kilohertz.

Because of these considerations, we are now going into a series of tests at different frequencies. They are still single frequency tests in that we're not applying all the frequencies at one time, but we have developed multiplexing microprocessor systems where we can switch to four different frequencies and look at the results with two threshold levels at each of the four frequencies. The part tested sits inside or passes through a coil, the microprocessor system has let us do very rapid changes of frequency and very rapidly look at three or four frequencies while we're inspecting a single part and still be able to inspect at rates of two or three thousand parts an hour. This has created a big advantage in the ability to examine a part with more than a single frequency. In the past we have run tests in which we have had multiple coils in a row, each one operated at one or two frequencies. This is cumbersome, however, and leads us to the microprocessor approach.

The automotive industry has decided to lighten the weight of their cars to help meet the energy-mileage characteristics that are being promulgated by the department of transportation. In order to lighten the weight of an automobile, you have to go to higher strength steels. You have to go to light-weight metals, aluminum and plastics. The part we are involved in right now is in the high strength steel area which turns out to be a very difficult situation for the automobile manufacturer. In the new front-wheel-drive vehicles, they have gone away from the conventional, very heavy axle and very heavy differential gear assembly associated with the transmission, and gone to a much simpler, direct coupled front wheel drive that naturally removes a lot of weight in the car. In addition, they have gone to an integral spindle and hub assembly, in which the spindle and the hub have bearing races formed in the part instead of using the typical taper roller bearing assembly. This is a ball-bearing device. When they assemble the spindle and the hub together with the ball bearings, they have a very critical but light weight, small part that is high strength and carrying a much higher load than has ever been required of those kinds of parts in the past.

Using the microprocessor system, we are testing these parts using four different windings that inspect different bearing surfaces in different critical areas of the part simultaneously; in each of these windings we're cycling up to four different frequencies in order to completely insure that the induction hardened bearing races are correctly heat treated and that the rest of the part is not heat treated in a way that would make it fracture or fail in service.