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NEW GENERATION OF UCI PROBES WITH ACCURATE FORCE DETECTION AND THEIR APPLICATIONS AND PRACTICAL BENEFITS

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Abstract: In this paper a new generation of UCI probes will be introduced. In contrast to regular UCI probes which use a spring in combination with an end switch to trigger the measurement, these probes are equipped with an internal force sensor to make them adjustable to different test loads. As this technology allows to monitor the applied test load constantly, it brings additional benefits to the user.

These possibilities will be described and explained in this paper. The advantages shall be presented and practical examples shall be given where they can be used. Furthermore, they will be supported with measurements on real test samples to quantify the real upside over traditional probes.

To conclude this paper an outlook will be given with additional options to improve the UCI measurement principle further and to show in which direction future developments will go.

Keywords: UCI, Ultrasonic contact impedance, Portable Hardness Testing, Adjustable test load.

1. INTRODUCTION

UCI is one of the most commonly used portable hardness testing methods. It was invented by Claus Kleesattel in 1968 [1] and although it is a relatively old portable hardness testing principle, it is widely established. It is popular due to its high portability, fast and simple measurements and its reliability. In addition it can be easily positioned on uneven surfaces such as welds. These are a just a few of the reasons why inspectors from a variety of industries prefer UCI over other portable hardness testing solutions.

The latest technological achievements have brought new innovations to this testing method, which enhances the UCI method and makes it capable to gather more information about the test process and the measured object. These improvements will be explained and discussed in this paper.

2. UCI MEASURING PRINCIPLE

As the name 'ultrasonic contact impedance' suggests, the principle is based on ultrasonic to determine the hardness of the test piece. The resonating rod is set into a longitudinal oscillation by a piezo element. The indenter which is mounted to the lower end of this rod is forced into the test piece. Depending on the indentation size, the resonating frequency is changed. Bigger indentations, which occur on softer materials, cause a higher frequency shift and vice versa. This frequency shift is proportional to the hardness. As this method is close to the stationary Vickers method, the native hardness unit is here HV as well. In order to indicate that results are based on the UCI method an (UCI) extension must be mentioned.

The UCI hardness testing method is a very fast and simple method, and thus highly appreciated by different industries to determine the hardness of different objects. Especially beneficial is the short measuring time and the exact positioning. One application which is often addressed with UCI is the testing of HAZ (heat affected zone) of welds or difficult to reach areas (i.e. gear tooth, bearings, etc.). Due to the simple measuring process UCI is also a preferred solution for automated applications.

Figure 1 shows a UCI probe being used to measure the gear root of a cog wheel, which is a typical application for UCI instruments.

Figure 1: UCI application

In figure 2 a schematic illustration of a typical UCI probe is shown. The left side shows a schematic cross section, while the right side illustrates the core components: indenter, resonating rod, piezo elements and bearing point. Also shown are the zero and the shifted frequency, which are measured during the measurement process.

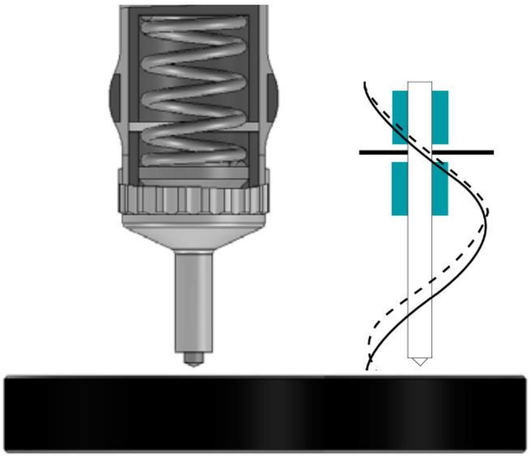

Figure 2: UCI schematic principle

For UCI probes, usually a Vickers indenter is used. This indenter is a diamond pyramid with an angle of 136° according to the standards for stationary Vickers testing machines, the ISO 6507 [2] and ASTM E92 [3].

At the other end of the resonating rod multiple piezo elements are mounted. Some are used to set the rod into oscillation. Others are used to measure the zero frequency, resp. the frequency shift under test load.

The test load is usually applied with a spring. The resonating frequency is measured as soon as the correct test load is applied. The difference between the zero frequency and the frequency under test load is then a measure to determine the hardness of the test piece.

Depending on the application for the hardness test, there are different test loads available. Regular probes have an end switch to detect when the target load is reached. Hence, each probe is adjusted to one pre-defined test load. If another test load is required, a different probe has to be used.

For the correlation of the frequency shift to the hardness in the Vickers scale, a conversion curve is required. This curve is not only dependent on the probe characteristic itself, but also on the material under test. As the UCI principle uses ultrasonic vibrations to determine the indentation size, it is not fully static and the elastic properties of the material have a relatively strong influence on the measured frequency shift.

This means any conversion curve has a limited range and can only be used on the same materials, resp. as long as the elastic modulus remains constant. Different materials with other measuring ranges require an adaptation of this conversion curve.

Additional limitations come from the size and mass of the test sample. To prevent self-oscillation, the test object shall fulfil certain requirements regarding the sample thickness and mass. A minimum thickness of 5mm and a sample mass of 300g are usually required for a proper hardness readings with the UCI method. If these requirements cannot be fulfilled, there is still the option to couple the test piece to a bigger and heavier support plate.

As with any other hardness testing method, there are also requirements for UCI measurements regarding surface preparation and roughness. These requirements depend on the hardness and the applied test load, but are typically around 5µm for the average roughness depth.

There are two standards available, in which the UCI method is explained in detail, and key parameters are specified. Additionally, requirements on the test pieces and measurement preparations are given. These standards are the American ASTM A1038 [4] and the German DIN 50159 [5].

3. ADJUSTABLE TEST LOADS

As described in the chapter above, the UCI test method is close to the stationary Vickers principle. To cover a wide range of applications, Vickers works with different test loads to achieve best possible results under the various configurations. The same is true for UCI. As some measurement tasks require a higher and some a lower test load, different probes are available. Unlike stationary testing methods the load is usually applied manually by the user and therefore lower. Typical test loads are in the range of HV0.1 and HV10, which corresponds to 0.1 … 10kg for ~1...~100N. The following table gives an overview of the most popular applications with their requirements on the test load.

Test load	**Typical applications**
HV10	Cast material, forgings, weld inspection
HV5	General UCI applications, machine parts, shafts, weld inspection, etc.
HV1	Thin walled parts, coatings, bearings, tooth flanks, etc.
HV0.1	Thin layers and coatings

Table 1: Test loads and their applications

Probes with test loads below HV1 are usually motorized. This is to reduce vibrations, caused by the user, which would have a negative influence on the hardness readings. Test loads of HV1 and higher are always manual probes.

Usually, for each test load a separate probe is required. Most manufacturers offer different probes which can be used on one and the same instrument.

The latest generation of UCI probes offers an adjustable test load feature. These probes are based on an integrated force sensor instead of the end switch to trigger the measurement at a pre-set load. This makes them much more flexible of course, but further advantages can be provided as well.

4. BENEFITS OF ADJUSTABLE TEST LOAD

One probe fits all: There is the obvious benefit, of having one probe to cover all applications. That means less investments and the advantage of less equipment to carry for the user. With just one instrument he is able to accomplish a wide variety of hardness testing tasks. The test load can be adjusted to the application with a simple click.

With the currently available probes, the range from HV1 up to HV5 is covered, addressing most applications.

User guidance: One disadvantage of UCI is the user dependency. Depending on how the load is applied, the measurement results can be influenced. Here not only the speed of applying the load, but also the load curve has an influence on the final result. To achieve a stable and reliable result, a constant and continuous load application is essential. With regular probes this lies completely in the responsibility of the user and cannot be measured or recorded for further analysis.

Another influence is coming from the correct angle. The UCI principle is dependent on the measurement angle as the probe must always be kept nicely perpendicular to the test surface. An angle of ±5° is allowed by the ASTM [3] and DIN [4] standards.

The existence of a load sensor in the UCI probe makes it possible to gather more information about the measurement process itself. With such probes, the test load and frequency shift can be monitored during the whole measurement process. Based on this data, the user can be guided through the process with hints and step by step information to achieve a proper UCI reading. A warning or error message can be shown to inform the user about any infringement if the process was incomplete. Afterwards, the quality of the measurement can be judged and stored for later reference.

Another benefit is that the user has more control over the test process. He can see in real-time what he is doing and gets direct feedback of the test load he is applying. This leads the user intuitively to apply the exact load which is required, without exceeding it. Therefore, indentation depth and the strain on the device can be reduced.

With this user guidance, the relatively user dependent measurement process can be improved, and quantified. Hints can be given to continuously instruct the user finally leads to a higher accuracy of the measurements.

Multi-measurement: Absolutely new is the opportunity of collecting multiple measurement results during one single measurement process or indentation. During the indentation process, the frequency shift and therefore the hardness can be measured on different test loads. This allows multiple hardness readings at different test loads at exactly the same location. There is no other measurement principle which allows this.

This opens up completely new possibilities. With these multi-measurements on the same location, additional information can be gathered about the test pieces. I.e. theoretically the depth of the case hardening can be calculated, how homogenous the surface layer is, or a depth hardness profile can be recorded. All this can be done with one single measurement and one single indentation within approximately one second.

On both features user guidance and multi-measurements patents were filed and are currently pending.

5. RESEARCH

The benefits described above of improved measurement accuracy through user guidance and the multi-measurements on one test location shall be proved with measurements on real samples.

Improve measurement performance: To prove and to quantify the increase of the measurement performance through user guidance, tests shall be performed with different inexperienced users. The difference between measurements with user guidance and those without shall be compared. It shall also be investigated which kind of user guidance is more beneficial, resp. which guidance doesn’t result in any measurable improvement. Additionally, the test persons shall give their feedback which guidance they liked and would prefer to use in the future.

Multi-measurements: To demonstrate the practical advantage of multi-measurements, samples with different surface treatments shall be analysed. Samples with homogenous hardness, but also samples with different hardened layers shall be measured to prove the capabilities of the new probes and to show the advantages for end users.

6. REFERENCES

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