HARDNESS TESTING GUIDE

QUARTER CENTURY OF
EXPERIENCE

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CONTENTS

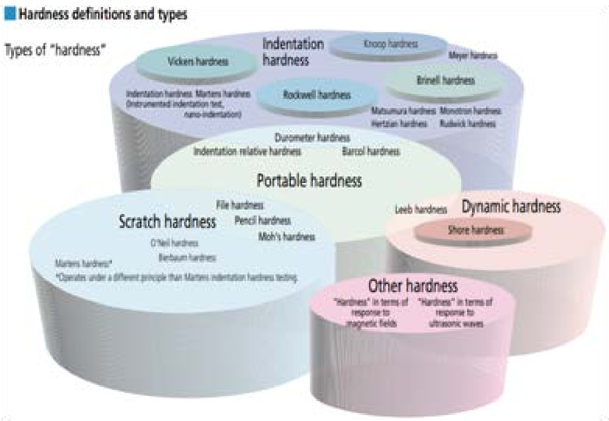
FUNDAMENTALS OF HARDNESS TESTING

Hardness is the resistance of a material against deformation. If the hardness of material is high, it is more durable against mechanical deformations such as scratch, compression, indentation or bending etc...

Hardness testing is a fast and cost effective test method comparing with other destructive material test methods such as tensile testing, toughness test etc... Hardness value also gives an idea about other mechanical properties of material such as tensile strength, yield strength, abrasion resistance etc...

There are several hardness testing types. The most common types are below:

- Indentation Hardness Testing
- Portable Hardness Testing
- Scratch Hardness Testing
- Dynamic Hardness Testing



Indentation type hardness testing are the most used method in the industry. In this document, we will mainly focus on indentation type hardness testing method.

INDENTATION HARDNESS TESTING

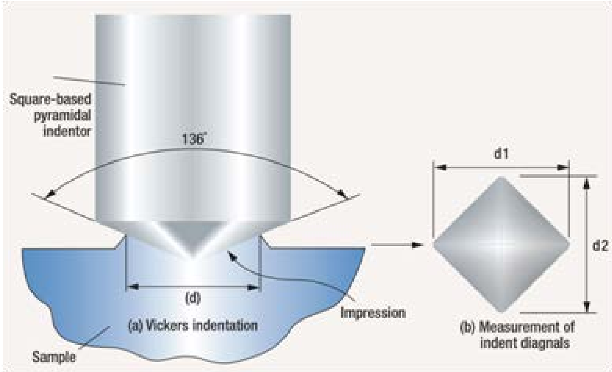
To make an indentation hardness testing, a specific force is applied on a material with a specific tip (indenter) for a specific time (force, time and tip are changes depending on hardness testing method). After force application, an indentation is occur on the sample surface. The size or depth of indentation (depending on method) is measured to determine hardness value.

The most widely used indendation type hardness testing methods are as below:

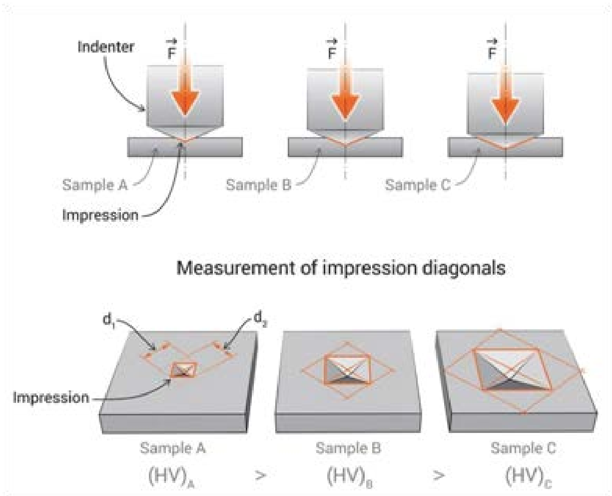
- Vickers Hardness Testing
- Knoop Hardness Testing
- Rockwell Hardness Testing
- Brinell Hardness Testing

Vickers Hardness Testing

Vickers hardness testing is the most widely used individual test method in the industry. 136° diamond pyramid indenter is used for force application. After force is applied, an indent is occur on the sample surface. Diagonals of indent are measured for hardness calculation.



The indent size depends on the hardness of the sample. If you apply same force on two different samples with different hardness, the indent size will be smaller on hard sample and will be smaller on soft sample.



Vickers hardness value is calculated with this formula:
HV = 0.1891x(Force(N)/d2)

The test force for Vickers method can be selected from 10 gf to 100 kgf depending on application or material. The indent size becomes smaller if low test force is selected. With this way, you can test very small area of sample even the phases.

Below table shows general application area of test forces. This table is not a rule but gives general idea which force is suitable for the sample.

TEST METHOD	APPLICATION / MATERIAL
HV0.01 HV0.025 HV0.05	Small Geometrics, Thin LAyer, Ceramics
HV0.01 HV0.025 HV0.3 HVo.5	Hardness Progression, CHD/EHT-NHT-RHT
HV1 HV2 HV3	Hardness Progression, CHD/EHT-NHT-RHT Surface Hardness Testing Surface Hardness Testing
HV5 HV10 HV20	Welding Test, Sintered Metals
HV30 HV50 HV100	Jominy Test, Surrface HArdness Testing Surface Hardness Testing Surface Hardness Testing

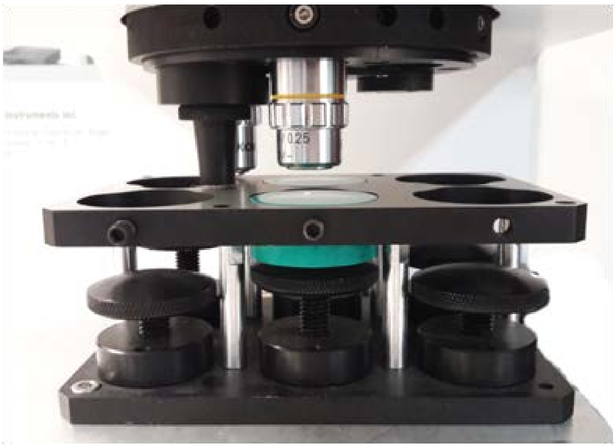
The Vickers hardness testing method is specified for lengths of indentation diagonals between 0.020 mm and 1.400 mm. The indent diagonal size is changes depending on test force applied and sample hardness. As the indent size is very small, it is necessary to use a measurement microscope to determine hardness value.

Modern hardness testing machines have integrated measurement microscope inside. Modern hardness testing softwares makes measurement and archiving results easier. Metkon DUROLINE series hardness testers are equipped with the most modern technology with advanced test & measurement software (Metkon N-Sure) to make Vickers hardness testing fully automatically.

The Vickers hardness testing method is mostly used for precise measurements. Because, indent size is much smaller than Rockwell and Brinell test methods. With the small indent size, it is possible to measure hardness on different phases, layers, structures etc...

As the indent size is very small on Vickers test method, it is necessary to have a flat and reflective surface to make possible to measure indent diagonals. Therefore, surface preparation is required for Vickers hardness testing. If indent size is large, coarse polishing is enough to make measurement. Finer polishing is required as the indent size getting smaller. Metkon sample preparation machines allow you to obtain are perfectly prepared sample surface for a very wide range of material types.

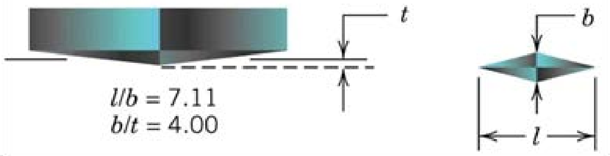
If sample has complex geometry or very small size or not parallel surface, in this case special sample fixtures should be used to ensure sample surface perfectly perpendicular to indenter. Otherwise, not possible to make correct hardness testing. Below you can see example of some special fixtures for different sample geometries.



Knoop Hardness Testing

Knoop hardness testing is similar Vickers hardness testing. 172° extended pyramid diamond indenter is used for force application. Like Vickers test method, diagonal of indent of measured. However, unlike Vickers method, only long diagonal is measured. The force range is usually from 10 gf to 1000 gf.

$$HK = \frac{14.2P}{l^2}$$



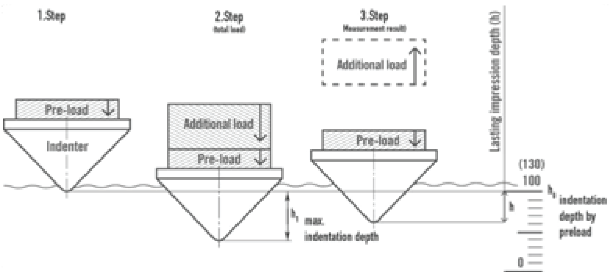
Knoop method is usually used for hardness testing of very thin layers (such as coatings) or very brittle materials (such as ceramics). The indent depth of Knoop is less than half or on third of Vickers indent with the same force on the same sample. Therefore, more precise measurements can be done on thin layers with Knoop method. However, Knoop is more sensitive the surface preparation errors. Highly polished surface is required for Knoop hardness testing

Rockwell Hardness Testing

Rockwell hardness testing method is one of the most used hardness testing method. It is the fastest hardness test method. Not sensitive to surface errors. No polished surface is required. Mostly coarse grinding is enough for testing.

Conical diamond or ball indenter is used for Rockwell testing. Indenter type changes according to Rockwell method is used. Unlike Vickers, Knoop or Brinell methods, there is no optical measurement required for Rockwell testing. The penetration depth of indenter is measured on Rockwell testing.

General principle is Rockwell test method is like that:
First step, a minor load is applied on the sample surface. The indenter penetrates a few microns inside the sample surface.
Second step, a major load is applied on the sample surface. Minor load plus major load becomes total force. During total force application, the indenter penetrates inside the sample.
Third step, major load is removed and only minor load remains. After major load is removed, the indenter lift back a few microns due to elastic resistance of material.
To calculate hardness value, the distance between the penetration depth on the first step and third step is measured and put in the Rockwell hardness formula.

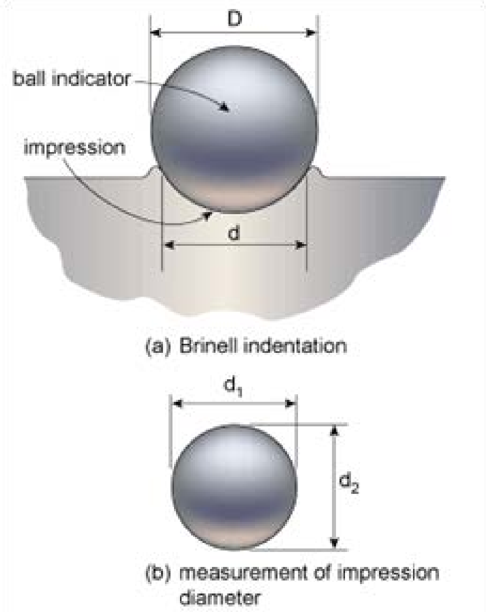


Test forces for Rockwell test method are 60 kgf, 90 kgf or 150 kgf (for Superficial Rockwell: 15 – 30 – 45 kgf). The indent size becomes larger and penetrates deeper on the sample comparing with Vickers and Knoop hardness testing method. For this reason, Rockwell hardness testing method is not as precise as Vickers or Knoop methods. However, it gives faster result.

Rockwell hardness testing method is usually used for testing huge quantity of small or large production parts, heat treatment laboratories etc...

Brinell Hardness Testing

Brinell hardness testing method is less common used method comparing with Vickers and Rockwell. A ball indenter is used for brinell testing. Like Vickers and Knoop methods, an optical investigation is required for hardness measurement. The diameter of circle indent is measured both horizontally and vertically (d1, d2) like Vickers.



The test force of Brinell method is up to 5000 kgf. The indent size becomes much larger than other indent hardness test methods. Therefore, comparatively larger area is tested.

Brinell method is good for non-homogenous samples like cast irons. However it is not as precise as Vickers or Knoop methods. Brinell method is not sensitive to surface errors, so coarse surface preparation is enough.

Vickers hardness testing can be done on both metals and non-metals samples like ceramic. Below table shows general Vickers hardness testing applications.

Metkon DUROLINE M and V-Series hardness testers can cover almost all application types for Vickers.

In this document, you can see detailed application notes for some of the most common Vickers hardness testing applications together with sample preparation steps.

DUROLINE M-Series

DUROLINE V-Series

TEST METHOD	APPLICATION / MATERIAL
HV0.01 HV0.025 HV0.05	Small Geometrics, Thin LAyer, Ceramics
HV0.01 HV0.025 HV0.3 HVo.5	Hardness Progression, CHD/EHT-NHT-RHT
HV1 HV2 HV3	Hardness Progression, CHD/EHT-NHT-RHT Surface Hardness Testing Surface Hardness Testing
HV5 HV10 HV20	Welding Test, Sintered Metals
HV30 HV50 HV100	Jominy Test, Surrface HArdness Testing Surface Hardness Testing Surface Hardness Testing

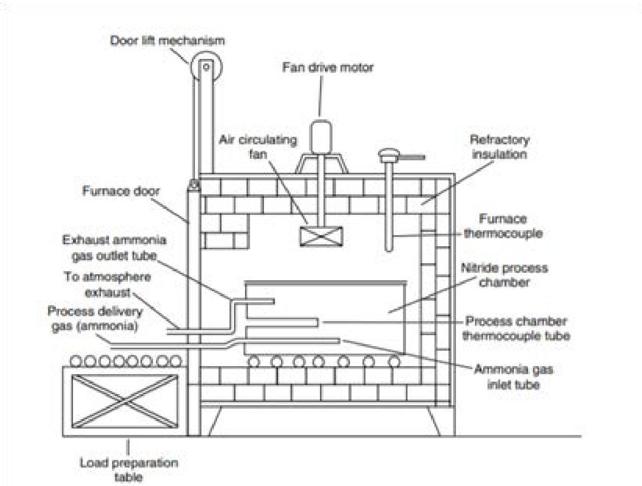
1. METALLOGRAPHIC PREPARATION OF NITRIDED PISTOL BARREL

INTRODUCTION

The nitriding process, first developed in the early 1900s, continues to play an important role in many industrial applications. The process was discovered around the same time in the U.S.A and Germany but wasn't used much until after WW 2. Along with the derivative nitrocarburizing process, nitriding often is used in the manufacture of aircraft, bearings, automotive components, textile machinery, and turbine generation systems. The secret of the nitriding process is that it does not require a phase change from ferrite to austenite, nor does it require a further change from austenite to martensite. In other words, the steel remains in the ferrite phase (or cementite, depending on alloy composition) during the complete procedure. Heat treated material we can use for many different kind of working area Automotive, aerospace, minig, defense, oil&gas, electronics, medical health etc.

The purpose of nitriding is to increase the surface hardness of the steel and improve its wearing properties. This treatment takes place in a medium (gas or salt) which gives off nitrogen. In nitriding, nitrogen diffuses into the steel and forms hard, wearresistant nitrides. This results in an intermetallic surface layer with good wearing and frictional properties.

Nitriding is done in gas at about 510oC (950oF). The process therefore requires steels that are resistant to tempering in order that the core strength is not reduced.



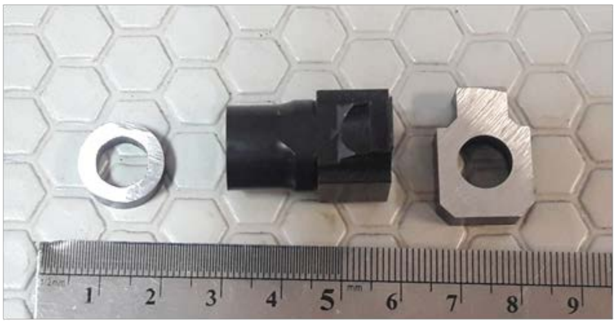
In nitriding, this can be accomplished by increasing the processing temperature and ammonia flowrate. However, in nitriding, higher processing temperatures and higher ammonia flowrates lead to an increase in the growth rate of the white layer. In some cases, it can be acceptable to have white layer on a resulting part. Since the white layer can be very hard and brittle, it may be desirable to minimize or completely eliminate it. This can be accomplished by controlling the nitriding potential during the nitriding process.

The carburizing gas, the nitriding atmosphere is not in equilibrium since the ammonia flow rate is too high to allow it to fully dissociate to nitrogen and hydrogen during the process. For this reason, the furnaces exhaust gas consists of ammonia, nitrogen, and hydrogen. It is customary to use a burette to determine the percentage of ammonia dissociation. Ammonia is the only constituent that is soluble in water. Agraduated burette filled with water can be used to measure the ammonia dissociation rate of the furnace exhaust gas. Since this method is not continuous and is manual, it introduces operator induced variability, which makes it difficult to repeat the process. For this reason, work began on a new control parameter, nitriding potential as a means to reduce the white layer thickness or eliminate the white layer altogether. Nitriding potential, Kn, is based upon the partial pressure of the ammonia still present in a furnace (the amount of ammonia that has not yet dissociated) and the partial pressure of hydrogen (H2) that has already dissociated from ammonia.

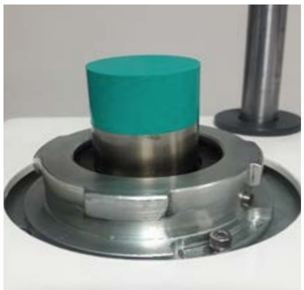
SAMPLE PREPARATION PROCESES

With the help of GR 0548 Quick Acting Clamping Vise Nitrided Barrel sample fixed to MICRACUT 202 Automatic High Speed Precision Cutter table.

Cutting Parameters	
	150 µ/sec.
	2850 r/min.
	35 mm.
	5.0 A.



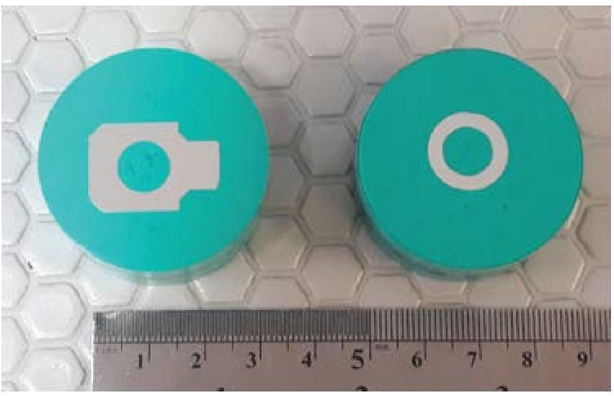
After cutting operation, samples mounted with Diallyptalat powder in ECOPRESS 102 Programmable Automatic Hot Mounting Press.



Mounting Parameters	
Heating Temperature	180°C
Pressure	260 bar
Heating Time	3 mins.
Cooling Type	Standart Cooling
Cooling Temperature	35°C

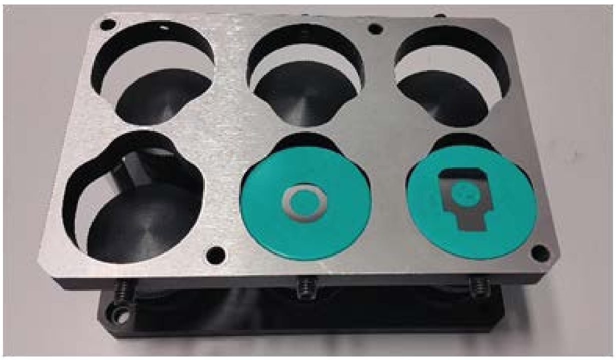
Nitrided Barrel mounted samples have been grinded&polished with the parametres below;

	Surface	Abrasive	Lubricant	Force Per Sample (N)	Time Min.	Disc Speed Rpm.	Head Speed Rpm.
Grinding Step 1	MAGNETO 38-040-054	Diamond 54 µ	Water	25 N	1 min.	300 CCW	100 CCW
Final Grinding	MAGNETO 38-040-018	Diamond 18 µ	Water	30 N	2 min.	300 CCW	100 CCW
Polishing Step 1	MAGNETO-P 38-013-250	DIAPAT-P 6µ 39-430-P	DIAPAT [39-502]	25 N	2 min.	250 CW	100 CCW
Polishing Step 2	MAGNETO-B 38-033-250	DIAPAT-P 3µ 39-420-P	DIAPAT [39-502]	20 N	2 min.	250 CW	75 CCW
Final Polishing	FEDO-1M 39-067-250	DIAPAT-P 1µ 39-410-M	DIAPAT [39-502]	15 N	2 min.	200 CW	50 CCW

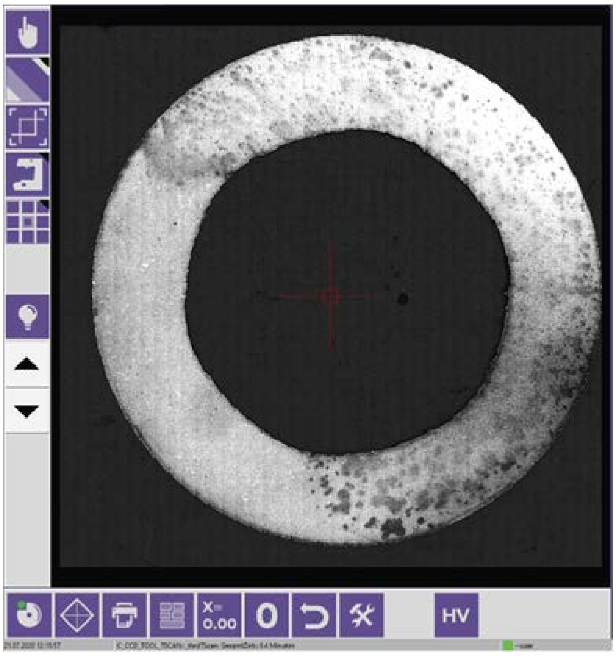


HARDNESS TESTING

We fixed the samples on GR 2037 Multiple Specimen holder to ensure the surface is perfectly perpendicular to indenter.

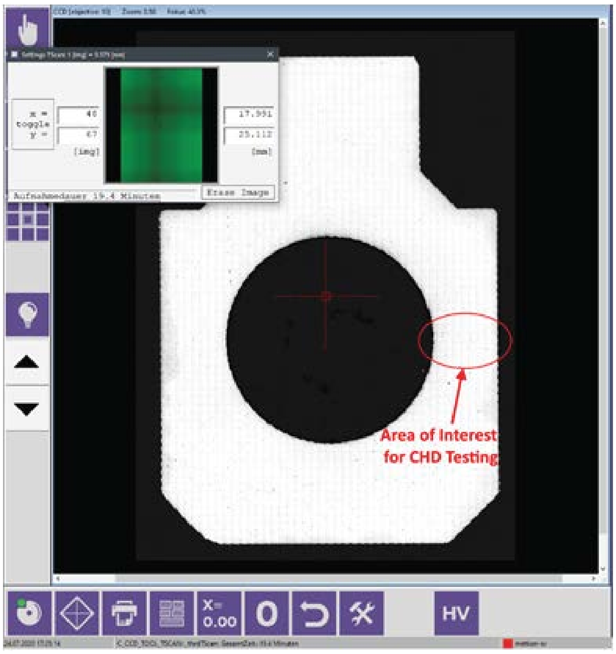


We used the Scan Overview funtion to see general image of both samples and determine measurement points. Sample on the left is normally etched. Sample on the right is slightly etched. For this sample, slightly etching is better for accurate hardness testing.



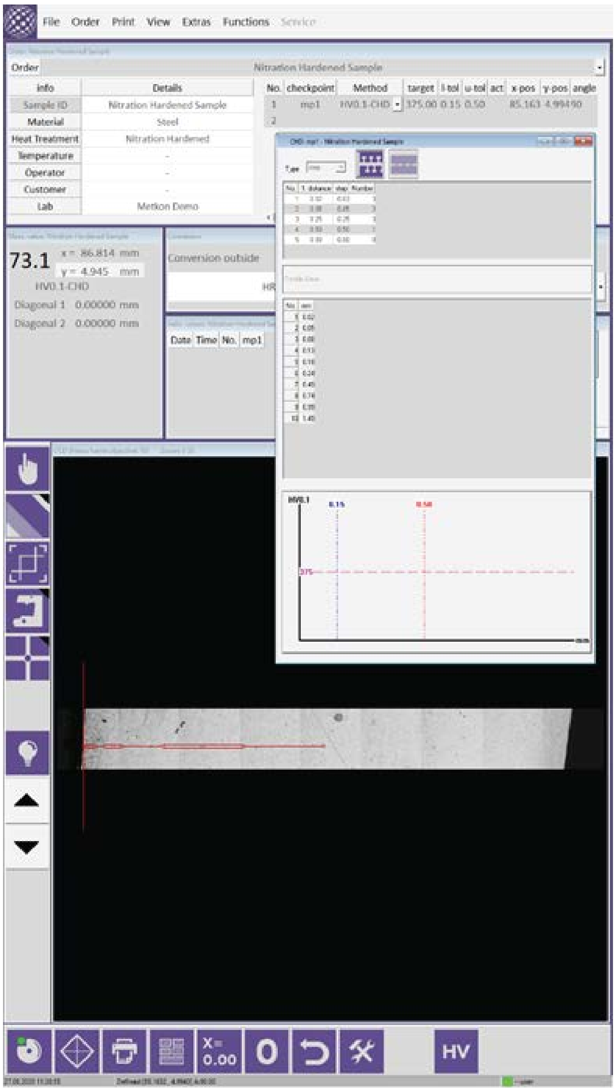
Scanning function 15x15 mm
(Normally Etched Sample)

Etching is required for discriminate hardened zone on the edges. According to hardened zone, we will determine measurement distances for Case Hardening Depth testing. If we make normally or heavy etch, in this case it is difficult to measure indent diagonals for hardness evaluation. For this reason, light etching is required.



Scanning Function 25x18 mm
(Slightly Etched Sample)

We determined the measurement pattern for Case Hardnening Depth testing on slightly etched sample. Interested test area is partly scanned again to discriminate hardened zone.



Target value is 375HV between 0.15 and 0.50 mm from the edge. So we entered these parameters to show on the graphic automatically.

No.	checkpoint	Method	target	l-tol	u-tol	act	x-pos	y-pos	angle
1	mp1	HV0.1-CHD	375.00	0.15	0.50		85.163	4.99490	

We determined the test force as 100 gf. Because, the depth of hardened zone under nitration layer is very low. Therefore, we selected low force for a small indent. 10, 25 or 50 gf is also possible for this sample but, as the sample is etched, measurement of smaller indent maybe little difficult.

We determined 10 measurement points as a line with total length of 1.49 mm. The line is consist of four different sections.

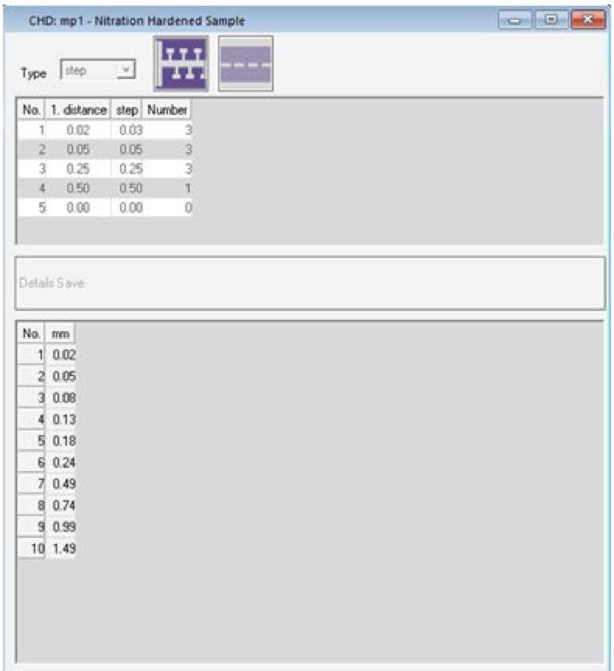
First section: We set three measurement point for the first section. Distance between the first three measurements will be 0.03. The first measurement will start from 0.02 mm depth of nitration layer. Thus, total 0.08 mm depth will be measured, which is the aproximate distance of hardened zone.

Second section: Second section is start 0.05 mm away from the last measurement of first section. We set again three measurement point but, this time the distance between measurements will be 0.05 mm. We intended to measure the area between hardened zone and core. Measurements will start from 0.13 mm and ends 0.24 mm from the nitration layer.

Third section: Third section is not heat effected zone. This section will start 0.25 mm away from the second section. There will be three measurements in this section and distance between the measurements will be 0.25 mm. Measurements will start from 0.49 mm and ends 0.99 mm from the nitration layer.

Fourth section: We intended to measure the middle of test area. This section consist of only one measurement. Distance from third section is 0.99 mm. Distance from the nitration layer is 1.49 mm.

You can see distance settings below for all sections:


CHD: mp1 - Nitration Hardened Sample

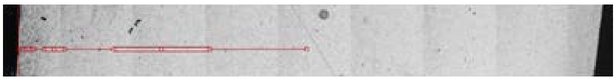
Type step

No.	1. distance	step	Number
1	0.02	0.03	3
2	0.05	0.05	3
3	0.25	0.25	3
4	0.50	0.50	1
5	0.00	0.00	0

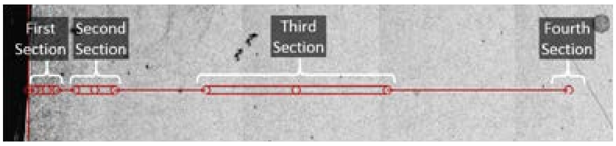
Details Save

No.	mm
1	0.02
2	0.05
3	0.08
4	0.13
5	0.18
6	0.24
7	0.49
8	0.74
9	0.99
10	1.49

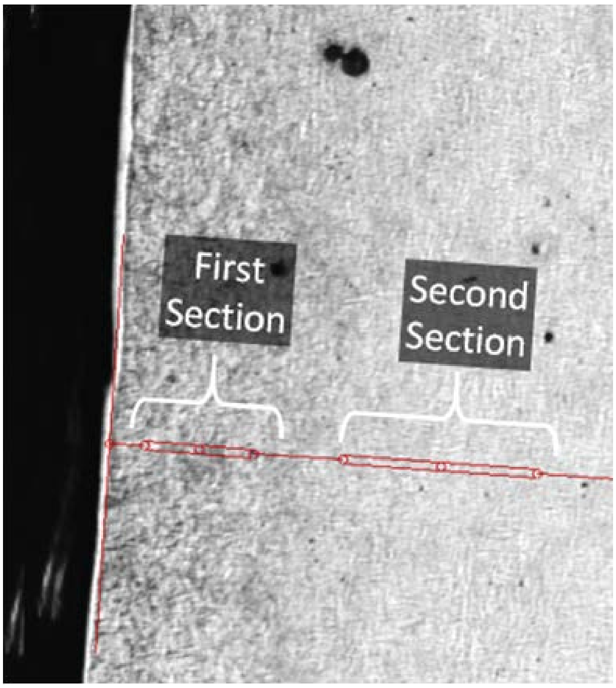
See below photo for measurement line:



Sections:

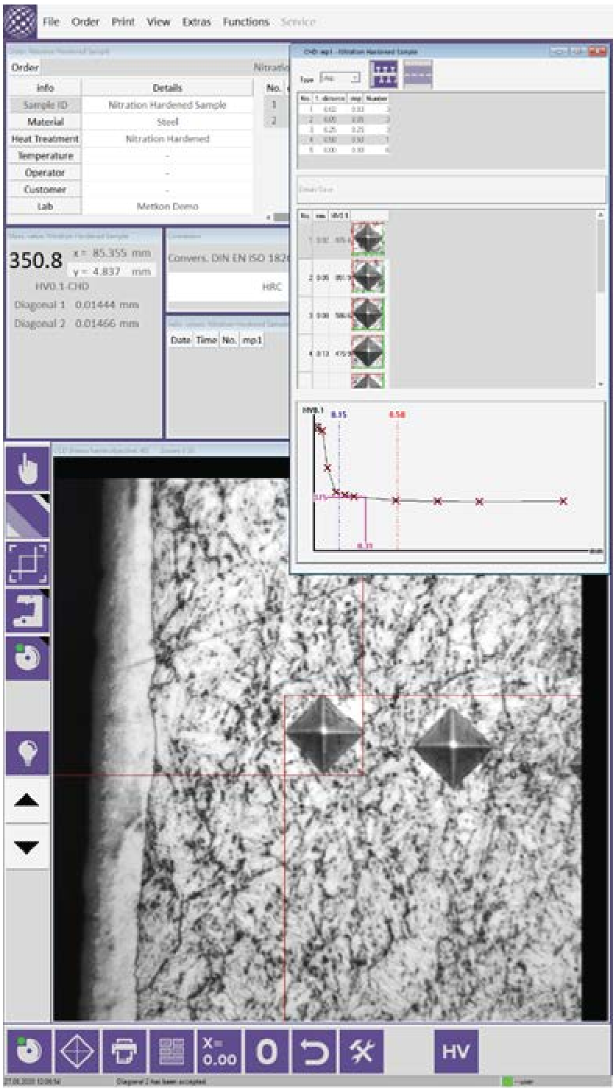


Close up view for first and second sections:
(Hardened zone under nitration layer can be seen)

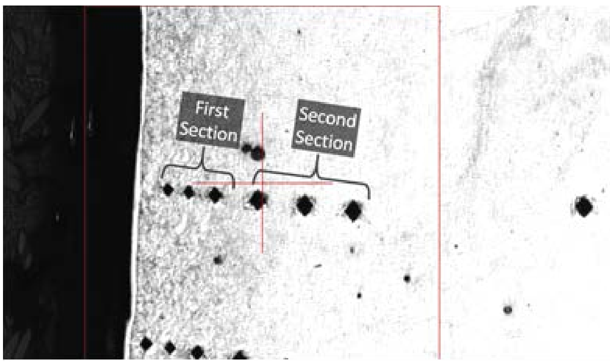


RESULT

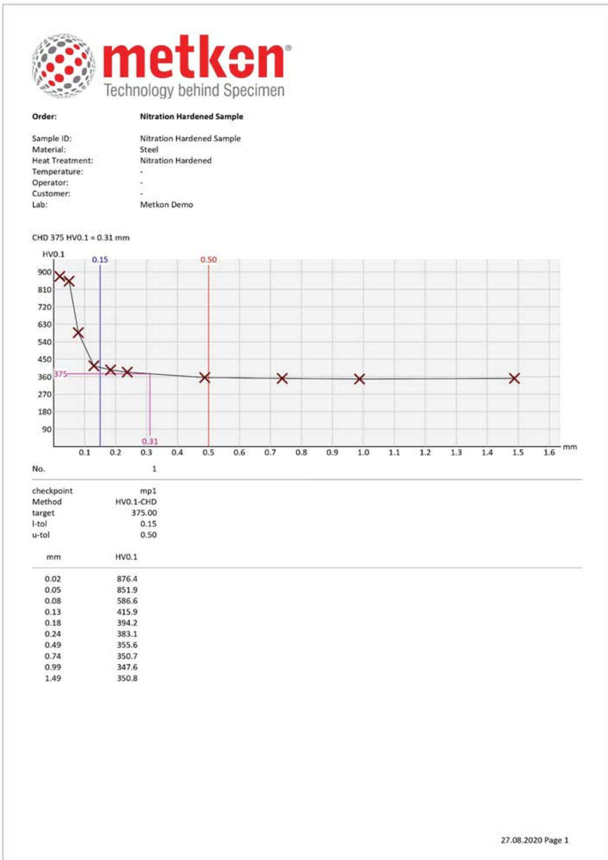
After we set all necessary parameters, we pressed start button for testing. DUROLINE M4 made indent on all 10 measurement points automatically. After that, it measured all indents automatically and generated a CHD graphic.



Indents for first and second sections:



After that we export all test result as a pdf report:
(Possible to make customization on logo, font type, font size and information related to sample)



Technology behind Specimen

Order:	**Nitration Hardened Sample**
Sample ID:	Nitration Hardened Sample
Material:	Steel
Heat Treatment:	Nitration Hardened
Temperature:	-
Operator:	-
Customer:	-
Lab:	Metkon Demo

CHD 375 HV0.1 = 0.31 mm

No.	1
checkpoint	mp1
Method	HV0.1-CHD
target	375.00
l-tol	0.15
u-tol	0.50

mm	HV0.1
0.02	876.4
0.05	851.9
0.08	586.6
0.13	415.9
0.18	394.2
0.24	383.1
0.49	355.6
0.74	350.7
0.99	347.6
1.49	350.8

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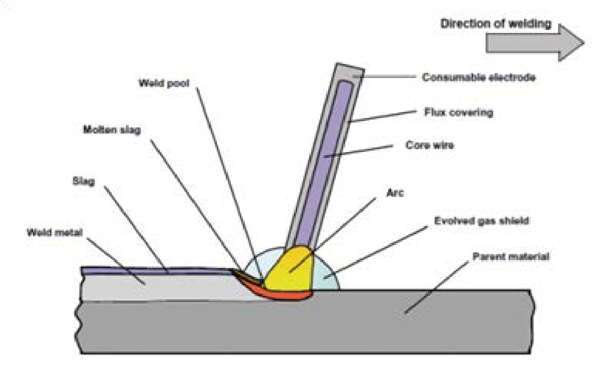
2. METALLOGRAPHIC PREPARATION OF WELDED STEELS

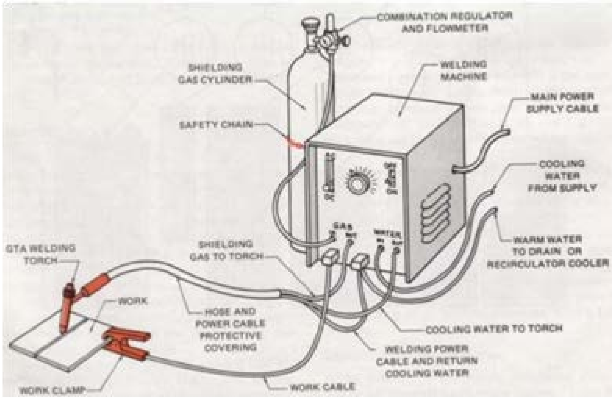
INTRODUCTION

The earliest evidence of welding can be traced back to the Bronze Age. The earliest examples of welding are welded gold boxes belonging to the Bronze Age. The Egyptians also learnt the art of welding. Several of their iron tools were made by welding. During the Middle Ages, a set of specialized workmen called blacksmiths came to the fore. Blacksmiths of the Middle Ages welded various types of iron tools by hammering. The welding methods remained more or less unchanged until the dawn of the 19th century. Edmund Davy discovered acetylene in 1836 and acetylene was soon utilized by the welding industry. In 1800, Sir Humphrey Davy invented a battery operated tool which could produce an arc between carbon electrodes. This tool was extensively used in welding metals.

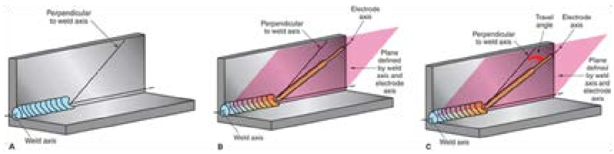


Weld can be defined as a coalescence of metals produced by heating to a suitable temperature with or without the application of pressure, and with or without the use of a filler material.In fusion welding a heat source generates sufficient heat to create and maintain a molten pool of metal of the required size. The heat may be supplied by electricity or by a gas flame. Electric resistance welding can be considered fusion welding because some molten metal is formed.Solid-phase processes produce welds without melting the base material and without the addition of a filler metal. Pressure is always employed, and generally some heat is provided. Frictional heat is developed in ultrasonic and friction joining, and furnace heating is usually employed in diffusion bonding.

Most metals, when heated, react with the atmosphere or other nearby metals. These reactions can be extremely detrimental to the properties of a welded joint. Most metals, for example, rapidly oxidize when molten. A layer of oxide can prevent proper bonding of the metal. Molten-metal droplets coated with oxide become entrapped in the weld and make the joint brittle. Some valuable materials added for specific properties react so quickly on exposure to the air that the metal deposited does not have the same composition as it had initially. These problems have led to the use of fluxes and inert atmospheres. In fusion welding the flux has a protective role in facilitating a controlled reaction of the metal and then preventing oxidation by forming a blanket over the molten material. Fluxes can be active and help in the process or inactive and simply protect the surfaces during joining.



Weld-metal composition and the conditions under which it freezes (solidifies) significantly affect the ability of the joint to meet service requirements. In arc welding, the weld metal comprises filler material plus the base metal that has melted. After the arc passes, rapid cooling of the weld metal occurs. A one-pass weld has a cast structure with columnar grains extending from the edge of the molten pool to the centre of the weld. In a multipass weld, this cast structure may be modified, depending on the particular metal that is being welded. The base metal adjacent to the weld, or the heat-affected zone, is subjected to a range of temperature cycles, and its change in structure is directly related to the peak temperature at any given point, the time of exposure, and the cooling rates. The types of base metal are too numerous to discuss here, but they can be grouped in three classes: Materials unaffected by welding heat, Materials hardened by structural change, Materials hardened by precipitation processes. This is generally known as residual stress, and for some critical applications must be removed by heat treatment of the whole fabrication. Residual stress is unavoidable in all welded structures, and if it is not controlled bowing or distortion of the weldment will take place. Control is exercised by welding technique, jigs and fixtures, fabrication procedures, and final heat treatment.



In this application Welded Steel samples, will be prepared as Metallographic purpose and hardness determination.

With the help of GR 0548 Quick Acting Clamping Vise Nitrided Barrel sample fixed to MICRACUT 202 Automatic High Speed Precision Cutter table.

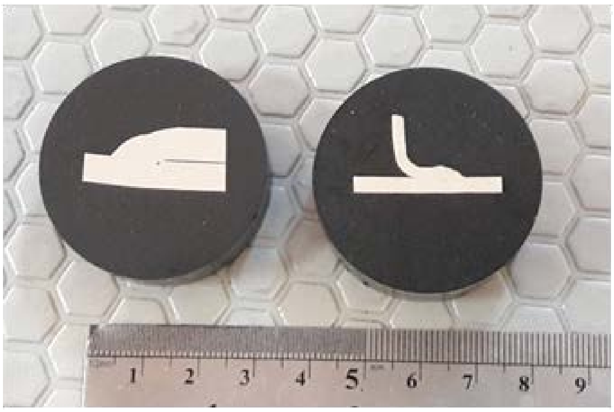
Cutting Parameters	
Feed rate	200 μ/sec.
RPM	2200 r/min.
Travel	30 mm.
Force	7.0 A.

Mounting Parameters	
Heating Temperature	180°C
Pressure	260 bar
Heating Time	3 mins.
Cooling Type	Standart Cooling
Cooling Temperature	35°C

We applied grinding&polishing recipe to welded steel specimens with the parameters below;

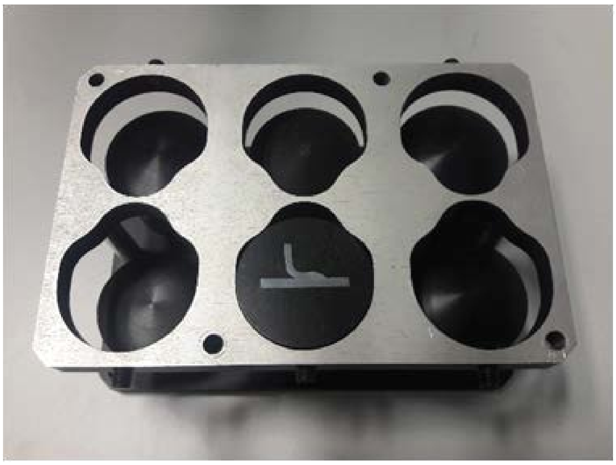
	Surface	Abrasive	Lubricant	Force Per Sample (N)	Time Min.	Disc Speed Rpm.	Head Speed Rpm.
Grinding Step 1	DEMPAX-F 38-040-240F	240 grit SiC	Water	25 N	1 min.	300 CW	100 CW
Grinding Step 2	DEMPAX-F 38-040-600F	600 grit SiC	Water	25 N	2 min.	250 CW	100 CW
Final Grinding	DEMPAX-F 38-040-1200F	1200 grit SiC	Water	25 N	2 min.	250 CW	100 CW
Polishing Step 1	FEDO-3 39-025-250	DIAPAT-P 3μ 39-420-P	DIAPAT [39-502]	20 N	4 min.	150 CCW	75 CW
Final Polishing	FEDO-1S 39-066-250	DIAPAT-P 1μ 39-410-P	DIAPAT [39-502]	15 N	2 min.	150 CCW	50 CW

*Etching with %3 Nital.

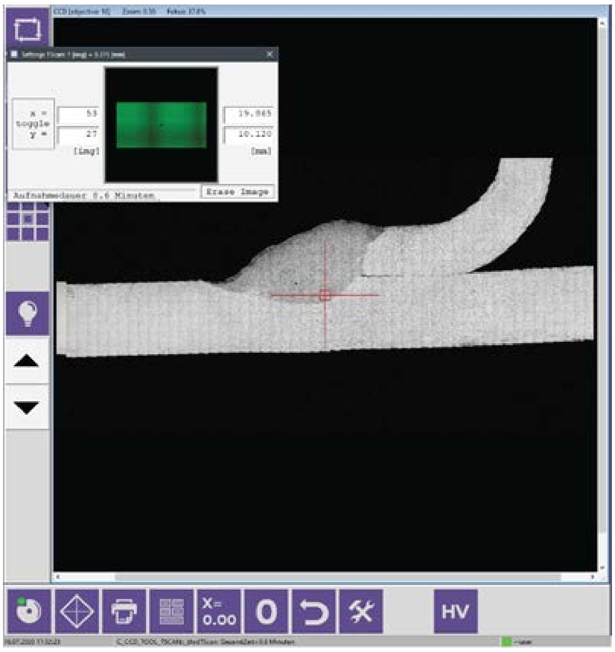


HARDNESS TESTING

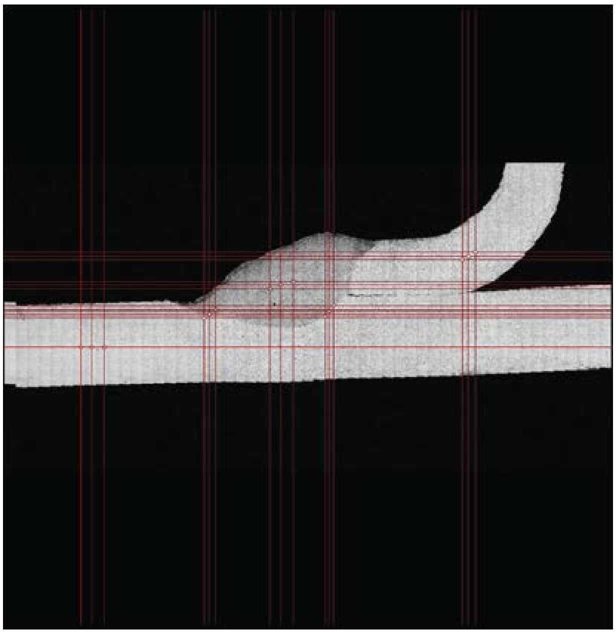
We fixed the samples on GR 2037 Multiple Specimen holder to ensure the surface is perfectly perpendicular to indenter.



We used the Scan Overview funtion to see general image of welding area. Scanning 20x10 mm area was enough to see whole welding area.



Scanning function 20x10 mm



Welding area scanned overview image 20x10 mm

RESULT

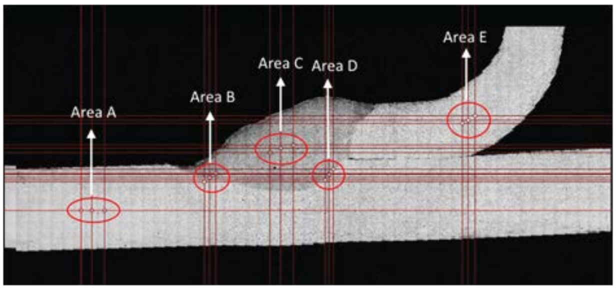
In order to discriminate the heat affected zone, we slightly etched the sample. No heavy etching is required. Heavy etching makes hardness evaluation difficult.

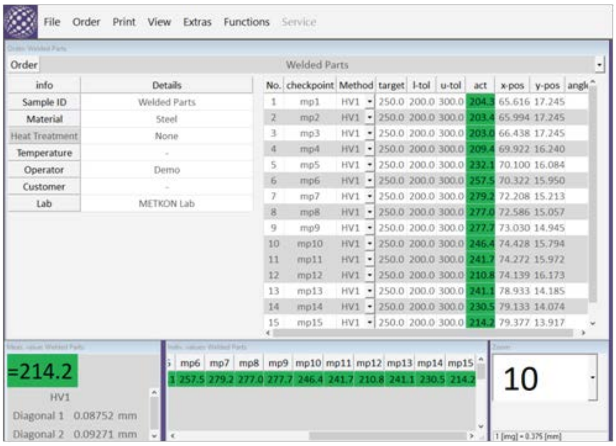
We determined 5 different test areas on the sample as show below and make 3 measurements on each area. (Total 15 test points).

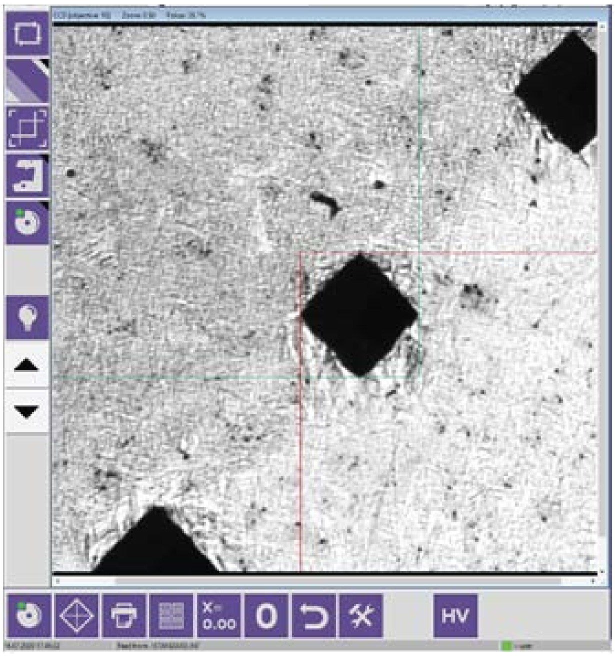
DUROLINE-M4 is equipped with a motorized XY-Stage. In this way, it is possible to make automatic hardness testing on all 15 test points without any operator intervention.

In this application, we used 1 kgf test force for all test points.

Area A: Steel Sample No:1
Area B: Heat Affected Zone (HAZ) No:1
Area C: Welding Zone
Area D: Heat Affected Zone (HAZ) No:2
Area E: Steel Sample No:2







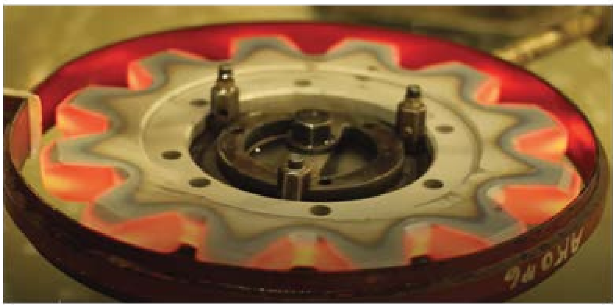
Measurement on Area D

Area A: Average HV1 Value of 3 points: 203,56 HV1
Area B: Average HV1 Value of 3 points: 233 HV1
Area C: Average HV1 Value of 3 points: 277,96 HV1
Area D: Average HV1 Value of 3 points: 232,89 HV1
Area E: Average HV1 Value of 3 points: 228,6 HV1

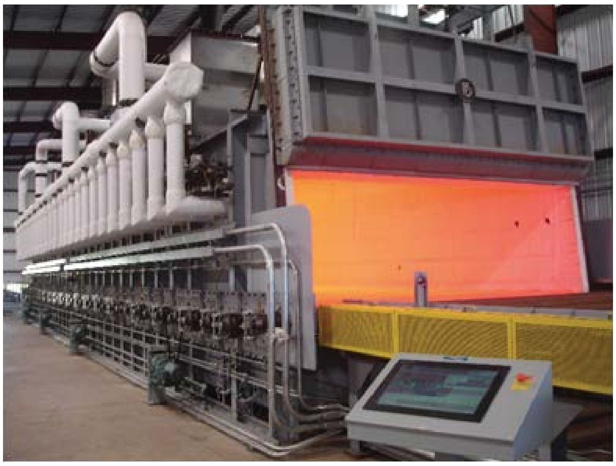
3. METALLOGRAPHIC PREPARATION OF HEAT TREATED GEAR PART

INTRODUCTION

In the present sense of the term, the 'steel industry' began around the 1870s. Of metallurgical science there was likewise essentially none previous to that day. None was possible until the modern science of chemistry came into existence in the early decades of the 19th century. Quickly thereafter, chemical analysis became an important laboratory activity, and, by 1870, the major chemical components of cast iron and steel were generally recognized. It was realized that carbon was the somewhat inconsistent heroine of the play, phosphorus and sulfur the villains, silicon and manganese controlled the action, and oxygen furnished the suspense – all these working in complicated unison to develop the character of the iron.

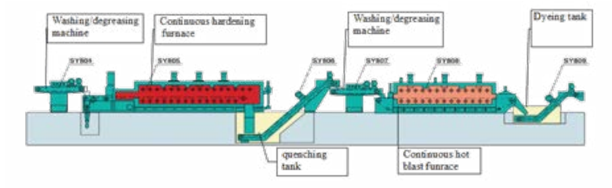


Heat treatment is an endeavor to obtain the maximum efficiency of the material under the demanding conditions of service. Steel is an outstanding versatile engineering material, with which the reader will also agree because it is used in the widest variety of products. Much of the versatility of steel arises due to the fact that the properties of the steel can be controlled and changed at will (though within reasonable good limits) by heat treatment. For example, if the steel is to be deformed into intricate shape, then, it can be made very soft and ductile by one heat treatment cycle; if on the other hand, it is supposed to resist wear, it can be heat treated to a very hard and wear resistant state by another cycle.



A process of metal heat treatment. Reheat the quenched workpiece to a proper temperature lower than the lower critical temperature, and heat treat the metal cooled in air, water, oil and other media after holding for a period of time.

Heat the quenched alloy workpiece to a proper temperature, keep it warm for some time, and then cool it slowly or rapidly. Generally used to reduce or eliminate the internal stress in the quenched steel, or reduce its hardness and strength to improve its ductility or toughness. According to different requirements, low temperature tempering, medium temperature tempering or high temperature tempering can be used. Generally, with the increase of tempering temperature, hardness and strength decrease, ductility or toughness gradually increase.



After quenching, the workpiece has the following characteristics: The unbalanced (i.e. unstable) structures such as martensite, bainite and retained austenite are obtained. There is a large internal stress. The mechanical properties can not meet the requirements. As a result, steel parts are usually tempered after quenching.

It is required that workpieces with different applications shall be tempered at different temperatures to meet the requirements in use. Tools, bearings, carburized and quenched parts and surface quenched parts are usually tempered at low temperature below 250 ˚C. After low temperature tempering, hardness changes little, internal stress decreases and toughness slightly increases. The spring can obtain high elasticity and necessary toughness by tempering at 350 ~ 500 ˚C. The parts made of medium carbon structural steel are usually tempered at 500-600 ˚C to obtain a good fit of strength and toughness. The heat treatment process of quenching and high temperature tempering is generally called tempering.

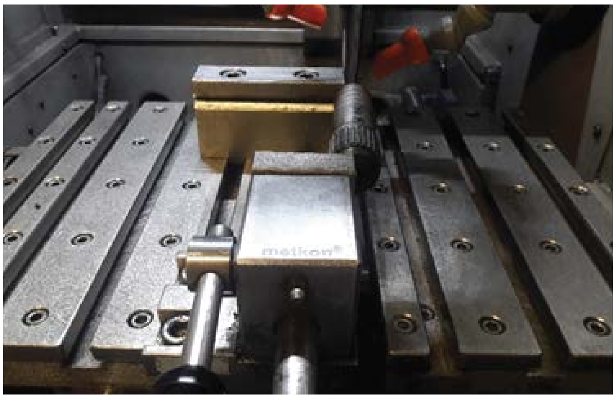
The first kind of temper brittleness is also called irreversible temper brittleness. Low temperature temper brittleness mainly occurs when the temper temperature is 250-400 ˚C, characterized.

In this application, Heat-treated gear samples, which we are using in automotive industry, will be prepared for Vickers hardness testing purpose.

A parallel, reflective and clean sample surface is needed for Vickers hardness testing. There should be no structure deformation due to heat generation and mechanical deformation during sample preparation process. To obtain required surface quality and to avoid deformations, suitable equipment and correct parameters should be used.

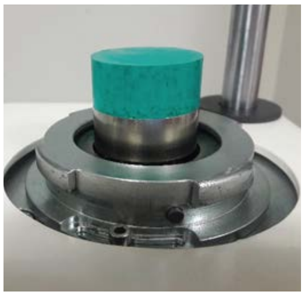
SAMPLE PREPARATION PROCESES

With the help of GR 0172 Quick Acting Clamping Vise Gear sample fixed to SERVOCUT 302 Automatic Abrasive Cutting Machine table.



Cutting Parameters	
Feed rate	250 µ/sec.
RPM	2200 r/min.
Travel	35- 115 mm.
Force	6.5 A

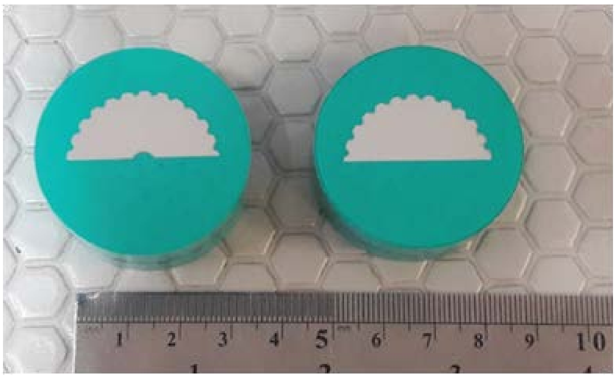
After cutting operation, samples mounted with Diallyptalat powder in ECOPRESS 102 Programmable Automatic Hot Mounting Press.



Mounting Parameters	
Heating Temperature	180°C
Pressure	260 bar
Heating Time	3 mins.
Cooling Type	Standart Cooling
Cooling Temperature	35°C

We applied grinding&polishing recipe to welded steel specimens with the parameters below;

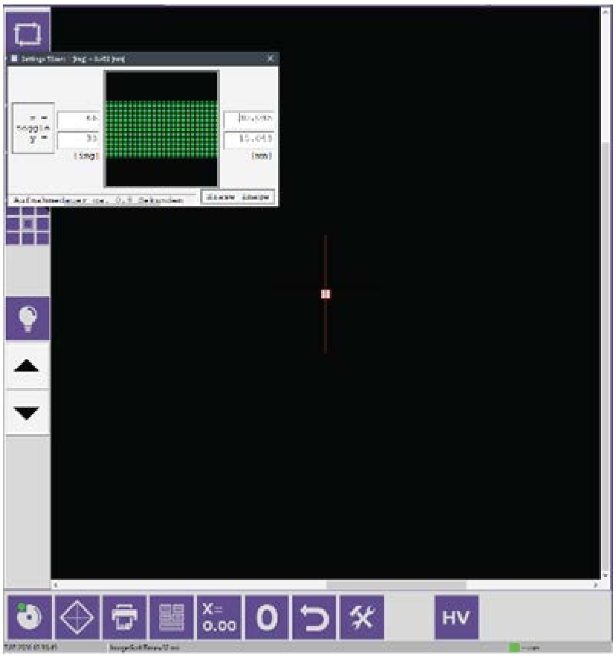
	Surface	Abrasive	Lubricant	Force Per Sample (N)	Time Min.	Disc Speed Rpm.	Head Speed Rpm.
Grinding Step 1	DEMPAX-F 38-040-320F	320 grit SiC	Water	25 N	2 min.	250 CW	100 CW
Grinding Step 2	DEMPAX-F 38-040-600F	600 grit SiC	Water	25 N	2 min.	250 CW	100 CW
Final Grinding	DEMPAX-F 38-040-1200F	1200 grit SiC	Water	25 N	3 min.	250 CW	100 CW
Polishing Step 1	FEDO-3 39-025-250	DIAPAT-P 3µ 39-420-P	DIAPAT [39-502]	20 N	3 min.	150 CCW	75 CW
Final Polishing	FEDO-1M 39-067-250	DIAPAT-P 1µ 39-410-P	DIAPAT [39-502]	15 N	2 min.	150 CCW	50 CW



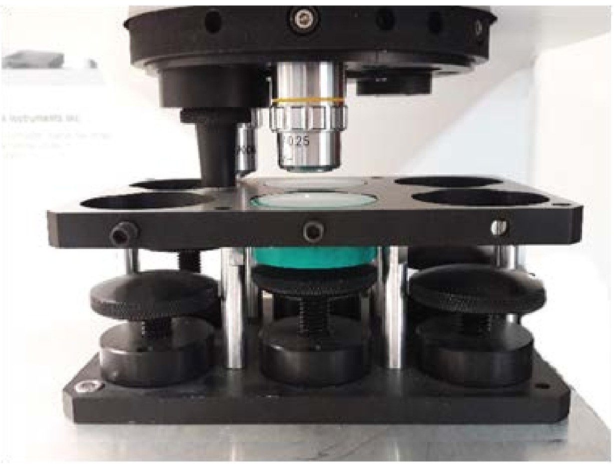
HARDNESS TESTING

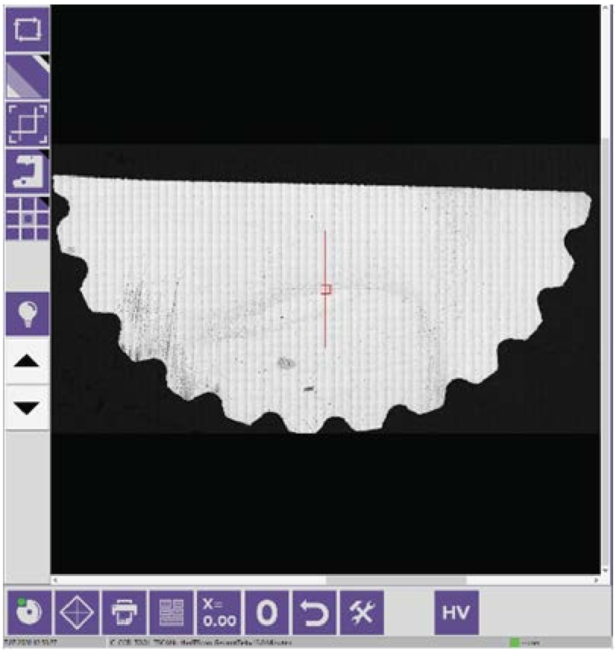
We fixed the samples on GR 2037 Multiple Specimen holder to ensure the surface is perfectly perpendicular to indenter

We used the Scan Overview funtion to see general image of gear sample. Scanning 30x15 mm area was enough to see whole sample.



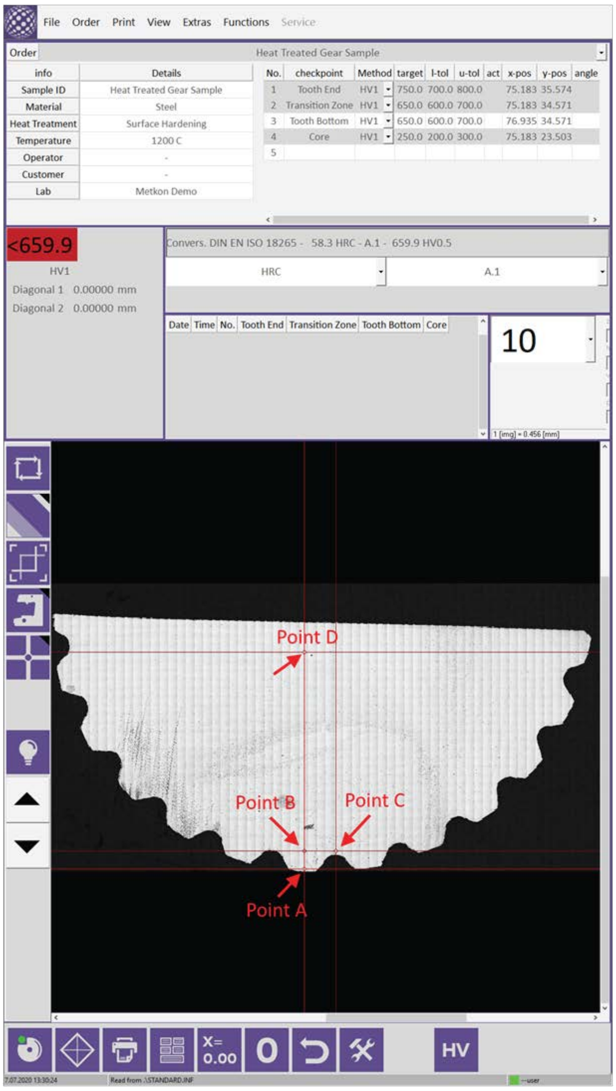
Scanning function 30x15 mm.





Gear Specimen scannned overview image 30x15 mm.

We determined four measurement points on the overview image. DUROLINE-M4 is equipped with a motorized XY-stage. The all marked measurement points will be measured automatically.

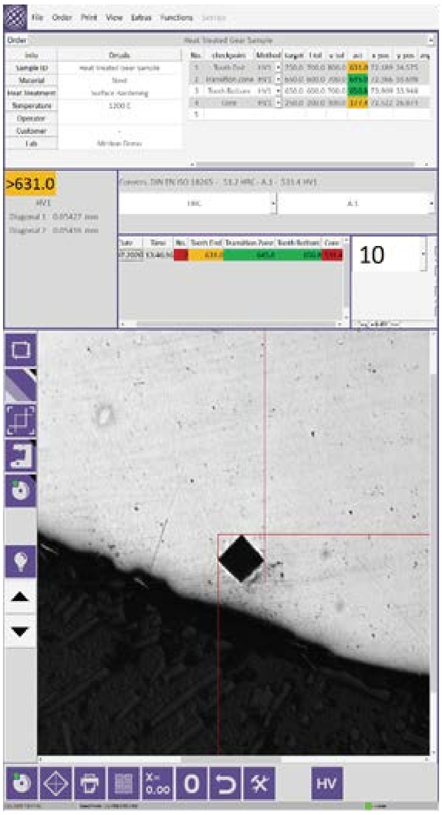


RESULT

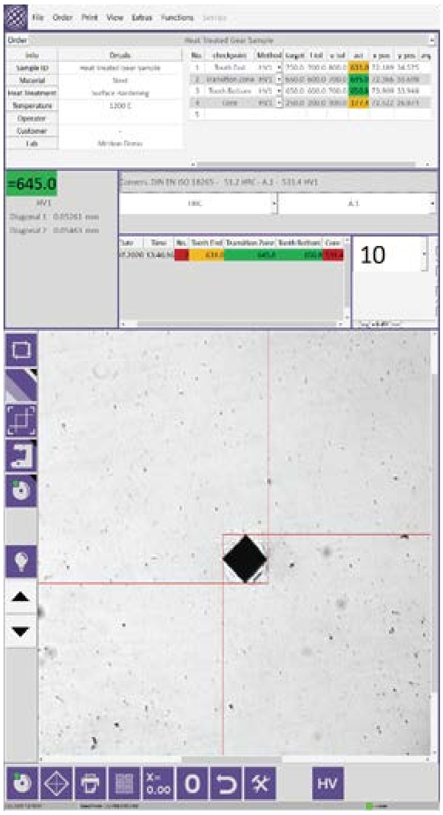
We used 1 kgf test force (HV1) on this application. Indentation is placed automatically on all marked points, than measured automatically with the combination of autofocus, autolight and automeasurement features.

The statictic feature of DUROLINE series, automatically color the hardness values according to upper and limit tolerance settings. All measurement result can be printed in a report format.

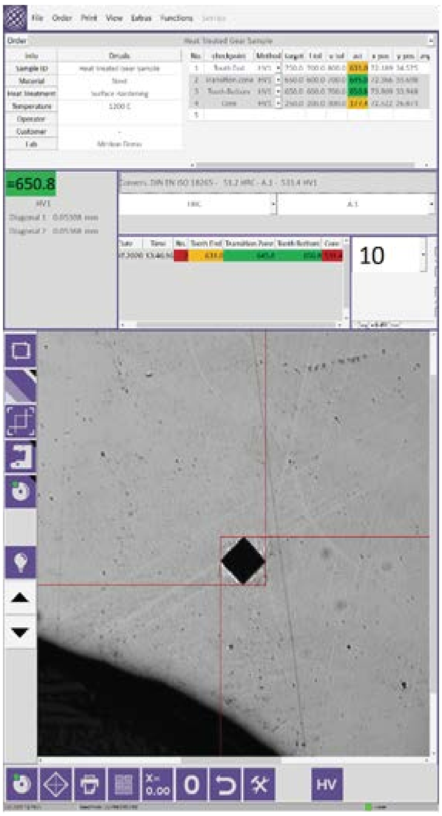
Point A: Tooth End 631.0HV1



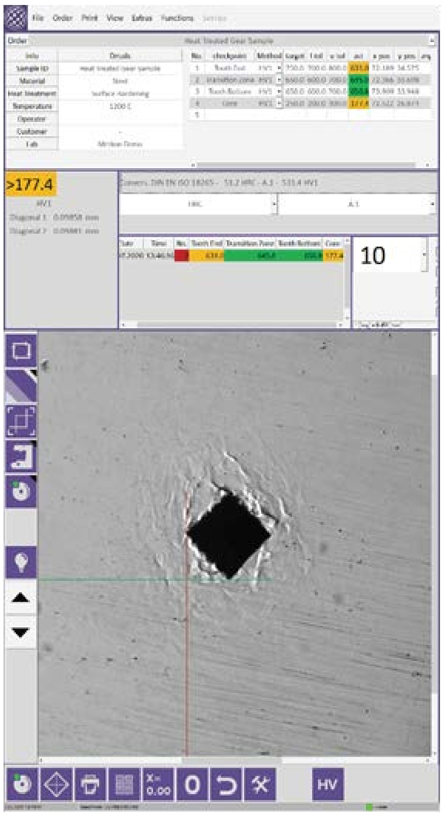
Point B: Transition Zone 645.0HV1



Point C: Tooth Bottom 650.8HV1



Point D: Core 177.4HV1

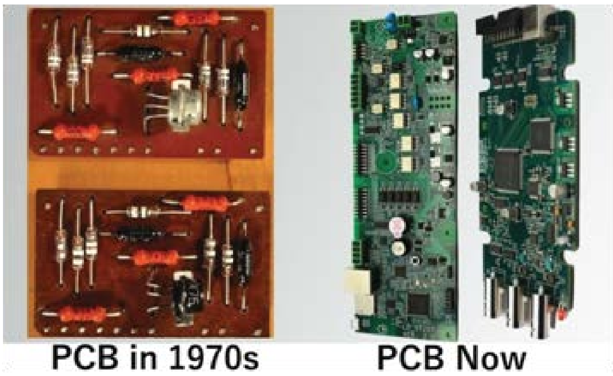


4. METALLOGRAPHIC PREPARATION OF CONNECTOR

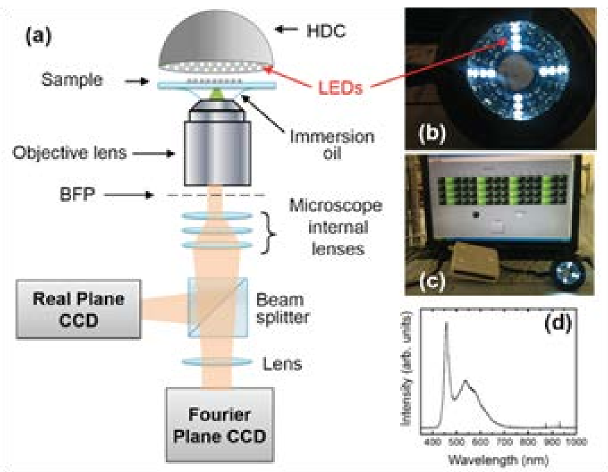
INTRODUCTION

Paul Eisler, was the genius who invented the PCB in 1936. Seeing his inventions and its contribution to the electronic industry, one undoubtedly assumes he must have seen a lot of fame and fortune. At that time, all circuits were made by point to point connections using wires. It made circuits complicated to manufacture and very prone to error. Eisler wanted to print the wires on the board using conducting ink.

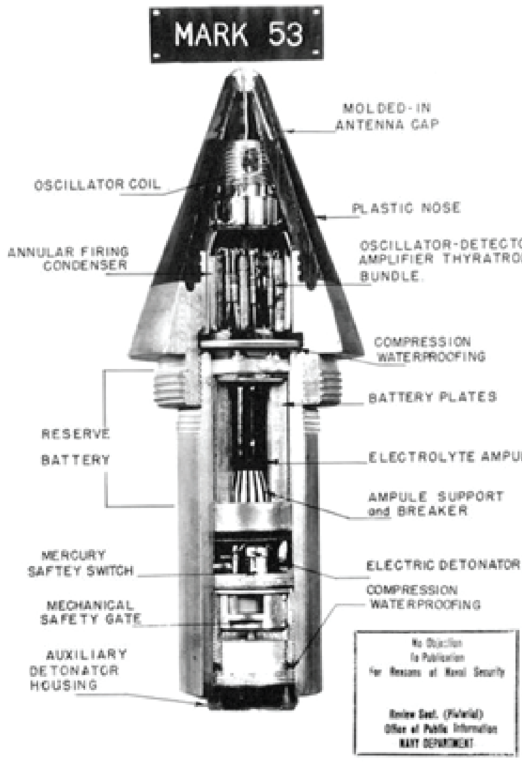
Sometime around 1943, he formed a radio with a PCB and filed a patent for the use of PCB in a variety of electronic products. The PCB is thus, swiftly being transitioned to meet the demands of this era. The future of PCB is a PCS (Printed Circuit Structure). A 3 dimensional PCS will allow faster data transfer, with fewer wires and components. 3D structures will allow the placement of components and traces around and inside the structures.



Printed circuit boards, PCBs, can be made from a variety of substances. The most widely used in a form of glass fibre based board known as FR4. This provides a reasonable degree of stability under temperature variation and is does not breakdown badly, while not being excessively expensive. Other cheaper materials are available for the PCBs in low cost commercial products. For high performance radio frequency designs where the dielectric constant of the substrate is important, and low levels of loss are needed, then PTFE based printed circuit boards can be used, although they are far more difficult to work with. In order to make a PCB with tracks for the components, copper clad board is first obtained. This consists of the substrate material, typically FR4, with copper cladding normally on both sides. This copper cladding consists of a thin layer of copper sheet bonded to the board. This bonding is normally very good for FR4, but the very nature of PTFE makes this more difficult, and this adds difficulty to the processing of PTFE PCBs.



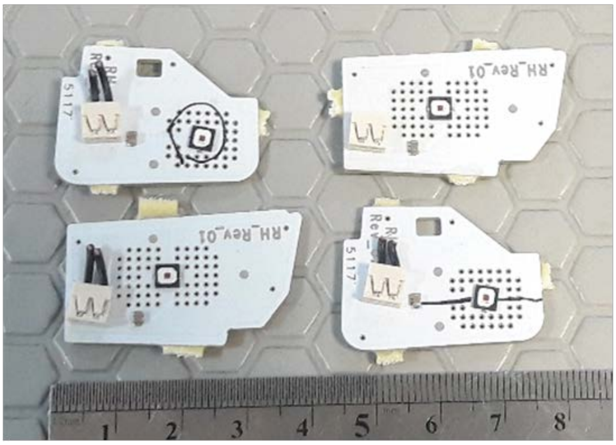
With the complexity of electronic circuits increasing, it is not always possible to provide all the connectivity that is required using just the two sides of the PCB. This occurs quite commonly when dense microprocessor and other similar boards are being designed. When this is the case multilayer boards are required. The manufacture of multi-layer printed circuit boards, although it uses the same processes as for single layer boards, requires a considerably greater degree of accuracy and manufacturing process control. The boards are made by using much thinner individual boards, one for each layer, and these are then bonded together to produce the overall PCB. Additionally the registration between the layers must be very accurate to ensure that any holes line up.



There are three main types of circuit boards that get manufactured on a consistent basis, and it's important to understand the differences between each so you can decide the right circuit board for your requirements. The three main types of circuit boards in current manufacture are:

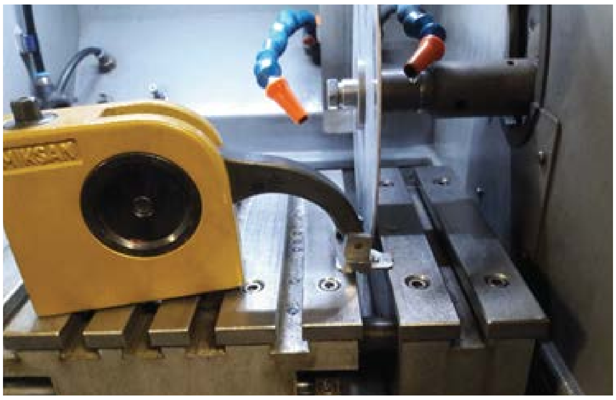
Single-Sided Circuit Boards: These boards when made with a FR4 base have rigid laminate of woven glass epoxy material, which is then covered on one side with a copper coating that is applied in varying thicknesses depending on the application.
Double-Sided Circuit Boards: Double-sided boards have the same woven glass epoxy base as single-sided boards — however, in the case of a double-sided board, there is copper coating on both sides of the board, also to varying thicknesses depending on the application
Multi-Layer Boards: These use the same base material as single and double-sided boards, but are made with copper foil instead of copper coating — the copper foil is used to make "layers," alternating between base material and copper foil until the number of desired layers is reached.

In this application Connector samples, which we are using in electronics industries will be prepared as Metallographic purpose.

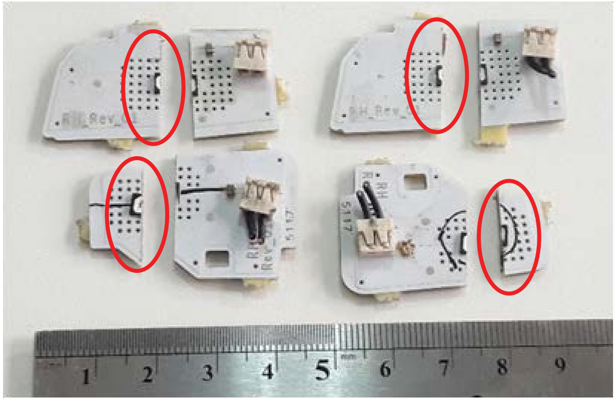


Processes

By the help of 15 02 Clamping Shoe, samples fixed to the MICRACUT 202 table and cut requested lines.



Cutting Parameters	
Feed rate	75 µ/sec.
RPM	2850 r/min.
Travel	30 mm.
Force	5.0 A

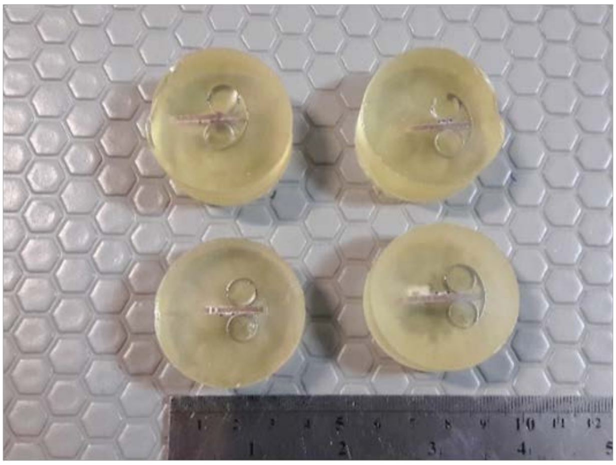


After cutting operation, Connector samples were prefered cold mounting method and EPOCOLD consumables were used.

Mounting Parameters	
Resin	5 part
Hardener	1 part
Mixing Time	About 2 min.
Curing Time	About 8 hours.

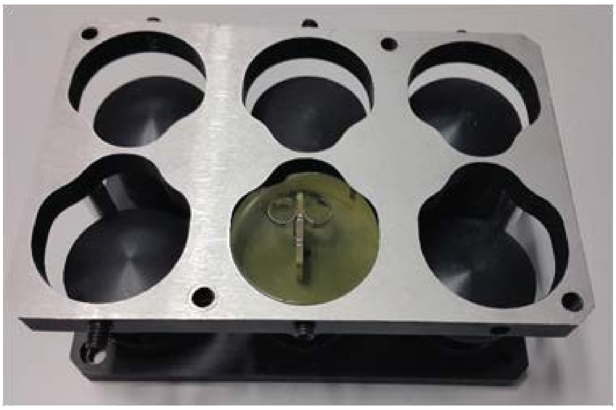
After mounting operation samples grinded and polished with parametres below:

	Surface	Abrasive	Lubricant	Force Per Sample (N)	Time Min.	Disc Speed Rpm.	Head Speed Rpm.
Grinding Step 1	DEMPAX-F 38-040-320F	320 grit SiC	Water	15	1,5 min.	250 CW	100 CW
Grinding Step 2	DEMPAX-F 38-040-600F	600 grit SiC	Water	15	1,5 min.	250 CW	100 CW
Grinding Step 3	DEMPAX-F 38-040-1200F	1200 grit SiC	Water	15	1,5 min.	250 CW	100 CW
Final Grinding	DEMPAX-F 38-040-2500F	2500 grit SiC	Water	15	2 min.	250 CW	100 CW
Polishing Step 1	METAPO-B 39-033-250	DIAPAT-P 3μ 39-420-P	DIAPAT [39-502]	20	4 min.	150 CCW	75 CW
Polishing Step 2	FEDO-1M 39-067-250	DIAPAT-P 1μ 39-410-P	DIAPAT [39-502]	15	1,5 min.	150 CCW	75 CW
Final Polishing	COLLO 39-085-250	COL-K(NC) 39-600	Colloidal Silica	10	2 min.	150 CCW	50 CW

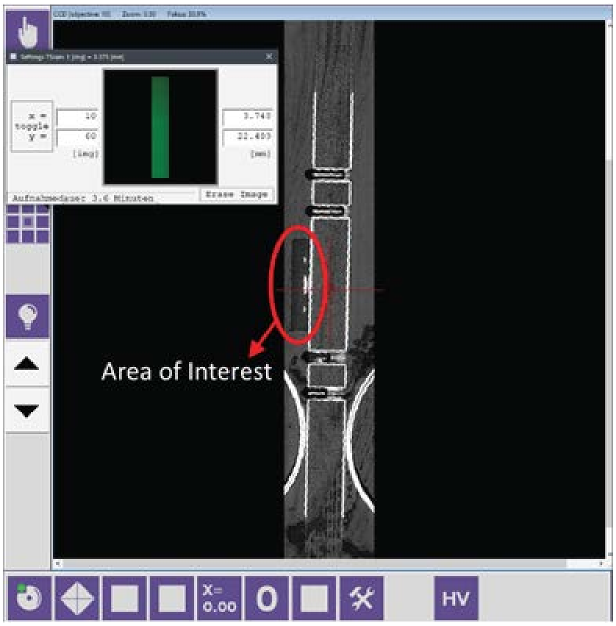


HARDNESS TESTING

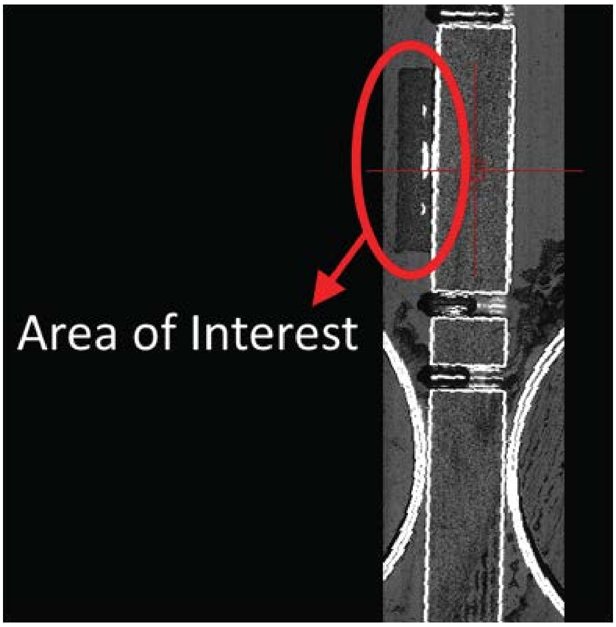
We fixed a mounted sample on GR 2037 Multiple Specimen holder to ensure the surface is perfectly perpendicular to indenter.



We used the Scan Overview funtion to see general image of sample and determine the measurement points of connector area.



Scanned Overview Image of Electronic Sample

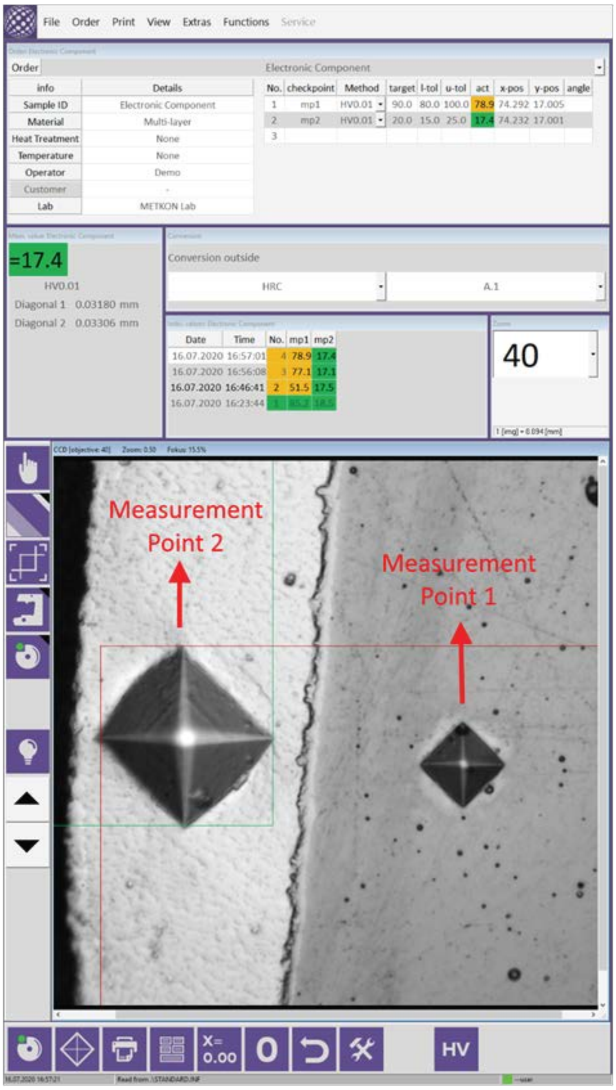


Interested Test Area (Connector Part)

RESULT

Connector area is composed of two different thin metal layers. The thickness of layers is very low. Also, both material has very low hardness value. Low hardness value means larger indentation size. In order to make possible to hardness test on these layers, the indentation size must be small enough to fit in this area.

For this reason we used 0.01 kgf test force (HV0.01) for this application. Over the 0.01 kgf test force was not suitable for this test area. Because the indentation size was larger than layers. DUROLINE M-Series Microhardness testers are very suitable for this kind of applications.



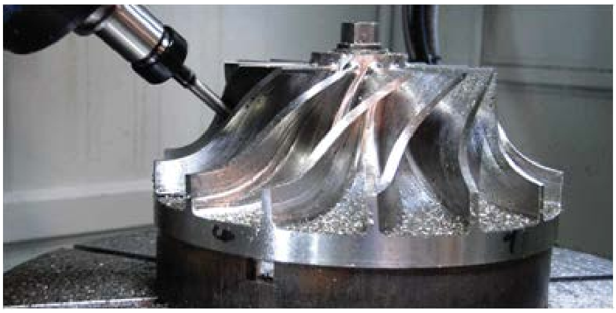
Indentation size of connector layers with 10 gf test force

Measurement Point 1: Connector surface 78.9HV0.01
Measurement Point 2: Copper substrate material 17.4HV0.01

5. METALLOGRAPHIC PREPARATION OF CUTTING TOOLS

INTRODUCTION

This is the first installment of a two-part article about the history of the cutting-tools industry. Before the industrial revolution metal workpieces were mostly cut and shaped using hand-operated tools. The first metal-working lathe was developed in France in the 16th century, and the first engine cylinder boring machine and screw-cutting lathe in England in the 18th century. This was followed by the first metal shaping machines and machine tools, and the steam hammer. The invention and widespread use of industrial metal cutting tools and tool bits began during the industrial revolution in the 19th Century, in parallel with the invention of the steam-engine and steam powered machines.



Cutting tools has a wide range of applications in rapid production industries. There are different kinds of cutting tools depending upon their use. Very basic types of cutting tools are made by casting or powder metallurgy. But these cutting tools are not efficient on rapid industrial units. Industrial cutting tools are mainly coated carbide tools (advancement of contemporary cutting tools). Coated carbide tools are made by mainly two different different ways.

1. CVD- Chemical Vapour Deposition.
2. PVD- Physical vapour Deposition.

But both in the cases some coating materials deposited up on CT. CVD involves interaction between a mixture of gases and heated CT surfaces, causing chemical decomposition upon CT surfaces and formation of solid films up on it. Inside a closed heat chamber chemical reactions.

You need a very durable grade of steel or tungsten carbide (a material which is stronger than steel) to start the precision cutting tool manufacturing process. These materials are highly durable and can withstand the heat and the force that is generated during an average cutting procedure. Now steel, in its raw form, is quite easy to work with. Now that the raw material has been sourced, the next step would be to cut it up into usable sized units which would be shaped into the final product. Band saws are used, along with lubrication, to cut the groups of steel bars into small length units called blanks. From here, the process actually takes off. Computer operated ladles then help to keep the blanks in place while the machine first removes some material from one end of the blank to form a sharp point.

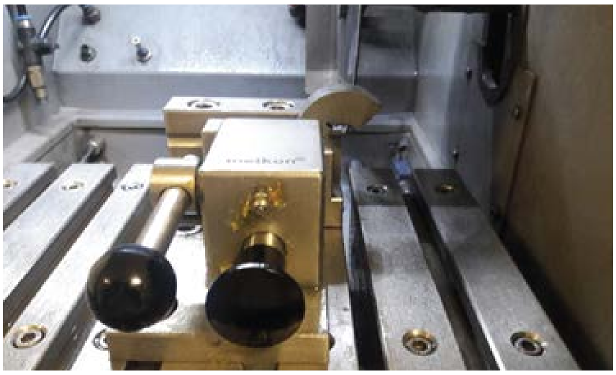
The use of drilling to flatten the other end and carving a central hole. Once this is done, the diameter is trimmed down to the correct measurements.

This is by far the most important part of the process. The prepared blanks are put in a computer operated milling machine which carves out flutes on the blanks and this marks the creation of the precision cutting tool. Flutes are actually ridges that run the full length of the blank and form the basis of the actual precision cutting tool. These flutes are responsible for ensuring the type of cut shape made by the tool and the level of accuracy achieved by it. With the steel being brought into the desired shape and specifications, the tool needs to be cured to make harden the steel. This is done using a two-step heating process. The tools are in fact soaked in salt baths, Each bath being progressively hotter than With the metal being hardened and the shank being made flexible, the tool becomes ready to be finished off. The tool is processed through a computer operated high precision grinding machine for finishing off the cutting end. Diamond based grinding wheels are used for this process as precision is the most crucial requirement at this stage.

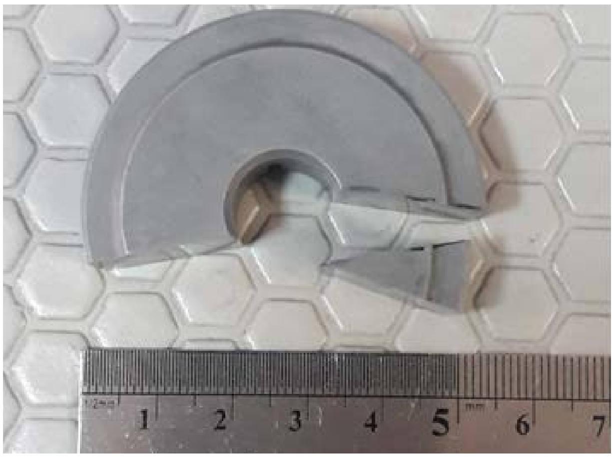
In this application cutting tool sample, will be prepared as Metallographic purpose and hardness determination

SAMPLE PREPARATION PROCESES

With the help of GR 0548 Quick Acting Clamping Vise Cutting Tool sample fixed to MICRACUT 202 Automatic High Speed Precision Cutter table.



Cutting Parameters	
Feed rate	150 µ/sec.
RPM	2850 r/min.
Travel	55 mm.
Force	5.0 A.



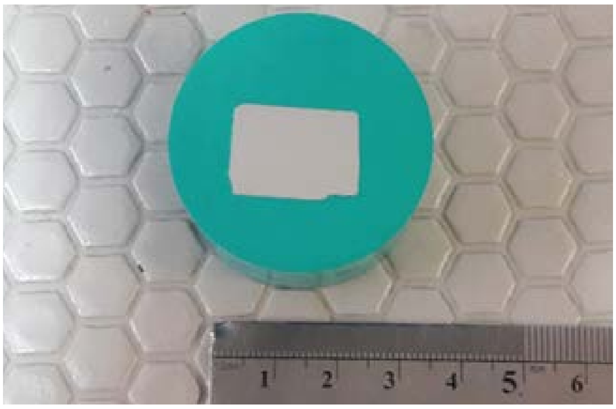
After finished cutting operation, sample mounted with hot mounting powder Diallyptalat (DAP) in ECOPRESS 102 Progammable Automatic Hot Mounting Press.

After finished cutting operation, sample mounted with hot mounting powder Diallyptalat (DAP) in ECOPRESS 102 Progammable Automatic Hot Mounting Press.

Mounting Parameters	
Heating Temperature	180°C
Pressure	260 bar
Heating Time	3 mins.
Cooling Type	Standart Cooling
Cooling Temperature	35°C

Mounted sample have been grinded&polished with the parametres below;

	Surface	Abrasive	Lubricant	Force Per Sample (N)	Time Min.	Disc Speed Rpm.	Head Speed Rpm.
Grinding Step 1	DEMPAX-F 38-040-320F	320 grit SiC	Water	20 N	2 min.	250 CW	100 CW
Grinding Step 2	DEMPAX-F 38-040-600F	600 grit SiC	Water	15 N	2 min.	250 CW	100 CW
Grinding Step 3	DEMPAX-F 38-040-1200F	1200 grit SiC	Water	15 N	2 min.	250 CW	100 CW
Final Grinding	DEMPAX-F 38-040-2500F	2500 grit SiC	Water	15 N	2 min.	250 CW	100 CW
Polishing Step	WOOL 39-095-250	DIAPAT-P 3µ 39-420-P	DIAPAT [39-502]	20 N	4 min.	150 CCW	75 CW
Final Polishing	FEDO-1M 39-067-250	DIAPAT-P 1µ 39-410-P	DIAPAT [39-502]	15 N	2 min.	150 CCW	75 CW

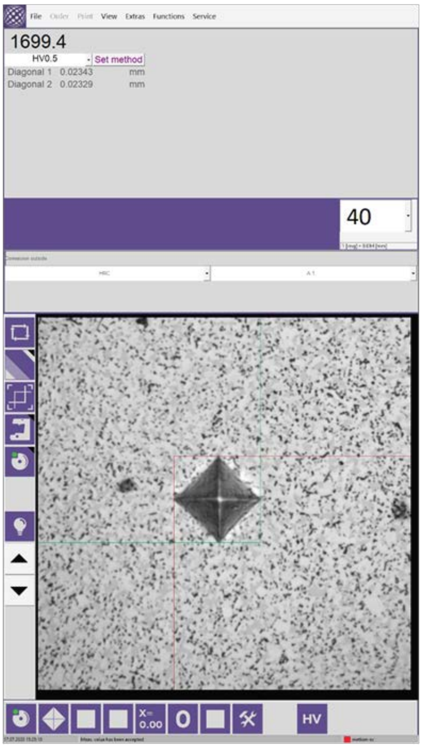


HARDNESS TESTING

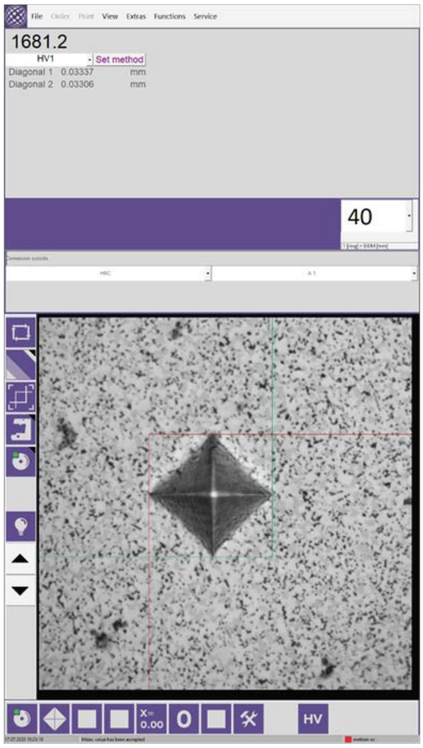
The sample mount was parallel enough for Vickers hardness testing. So, we did not use any sample holder for parallel clamping. The sample is directly put on manual analogue XY-Stage.

RESULT

The microstructure of cutting tool is not homogenous. Thus, the indentation size should large enough to cover both soft and hard phases/structures of sample. In this application we used 0.5 kgf and 1 kgf test forces.



Indendation with 0.5 kgf test force
1699.4HV0.5

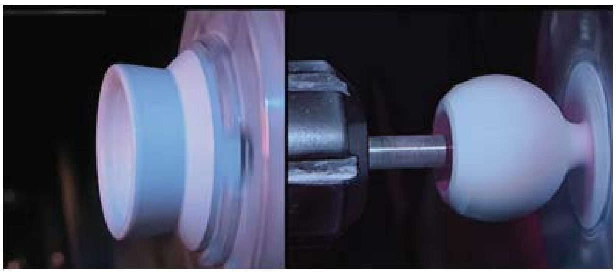


Indendation with 1 kgf test force
1681.2HV1

6. METALLOGRAPHIC PREPARATION OF ALUMINA CERAMIC

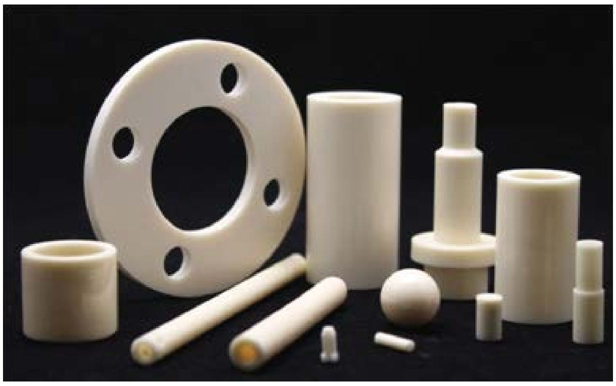
INTRODUCTION

Alumina is the common name given to aluminum oxide (Al_2O_3). Alumina is produced from bauxite, an ore that is mined from topsoil in various tropical and subtropical regions. The Bayer process, discovered in 1887, is the primary process by which alumina is extracted from bauxite. To produce pure aluminum, alumina is smelted using the Hall–Héroult electrolytic process. This process is referred to as primary production.

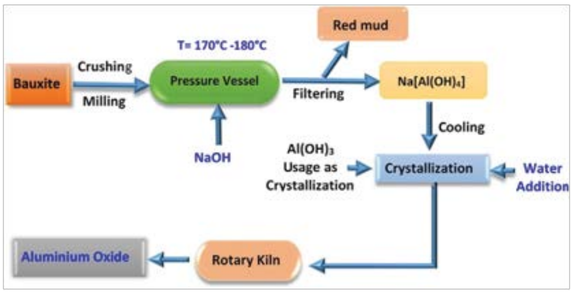


Due to its availability and properties, Al_2O_3 is very often used for the manufacture of ceramic components. Alumina is used in various modifications. The most commonly used for technical ceramics is the trigonal α- Al_2O_3 (corundum). In order to produce aluminum oxide, the natural raw material bauxite is digested in caustic soda using the Bayer process to produce aluminum hydroxide. This is deprived of water by sintering or calcination in rotary kilns, and aluminum oxide is obtained.

Hardness and high wear resistance, alumina is often used as a grinding or polishing agent. As the melting temperature is above 2000 ° C, the material is ideal for use as a refractory material. In electrical engineering Al_2O_3 is used because of the low dielectric loss factor and the high electrical insulation and dielectric strength. The applications range from sealing discs in taps to implants to ballistic protection made of aluminum oxide.



The properties of the material aluminum oxide are strongly influenced by the purity and the manufacturing process. As the proportion of alumina increases, the hardness, corrosion resistance, dielectric strength and thermal conductivity of the material increase. The thermal shock resistance decreases.



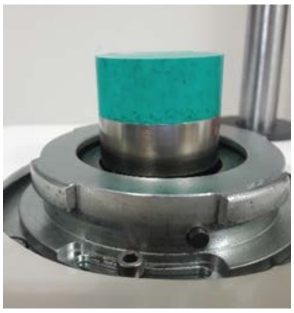
The term sintering of alumina ceramics refers to the solidification and densification of a green body to a dense material by high temperatures (1500 to 2000 ° C). In this case, the ceramic grains should not completely melt, so that the outer shape is maintained. The compaction should lead to the most uniform and reproducible shrinkage of the component.

In this application Alumina (Al_2O_3) samples, which we are using in defense industry will be prepared as Metallographic purpose and hardness determination.

Processes

With the help of GR 0548 Quick Acting Clamping Vise Alumina sample fixed to MICRACUT 202 Automatic High Speed Precision Cutter table.

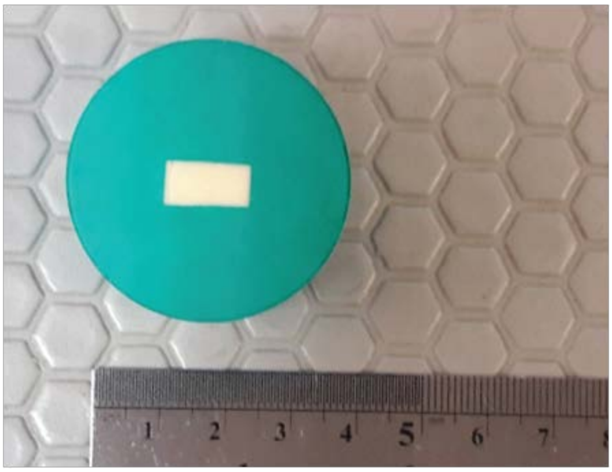
Cutting Parameters	
Feed rate	200 µ/sec.
RPM	2850 r/min.
Travel	25-35 mm.
Force	5.0 A.



Mounting Parameters	
Heating Temperature	180°C
Pressure	260 bar
Heating Time	3 mins.
Cooling Type	Standart Cooling
Cooling Temperature	35°C

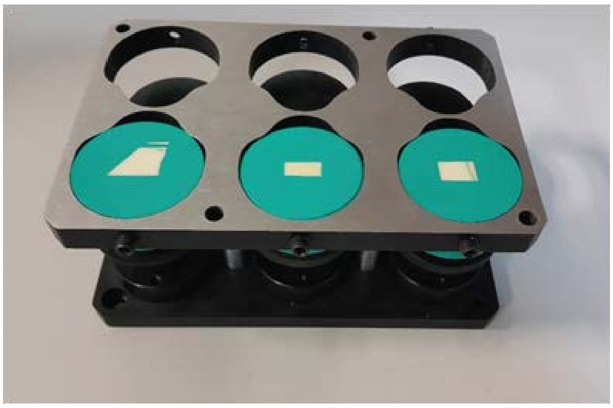
Mounted samples have been grinded & polished with the parametres below;

	Surface	Abrasive	Lubricant	Force Per Sample (N)	Time Min.	Disc Speed Rpm.	Head Speed Rpm.
Grinding Step 1	MAGNETO 38-040-054	54 Mic. Diamond	Water	35 N	1 min.	300 CCW	100 CCW
Final Grinding	MAGNETO 38-040-018	18 Mic. Diamond	Water	35 N	2 min.	150 CCW	100 CCW
Polishing Step 1	METAPO-P 39-013-250	DIAPAT-P 6µ 39-430-P	DIAPAT [39-502]	35 N	10 min.	150 CW	100 CCW
Polishing Step 2	METAPO-B 39-033-250	DIAPAT-P 3µ 39-420-P	DIAPAT [39-502]	25 N	8 min.	150 CW	75 CCW
Final Polishing	FEDO-1M 39-067-250	DIAPAT-P 1µ 39-410-P	DIAPAT [39-502]	25 N	2 min.	150 CW	75 CCW

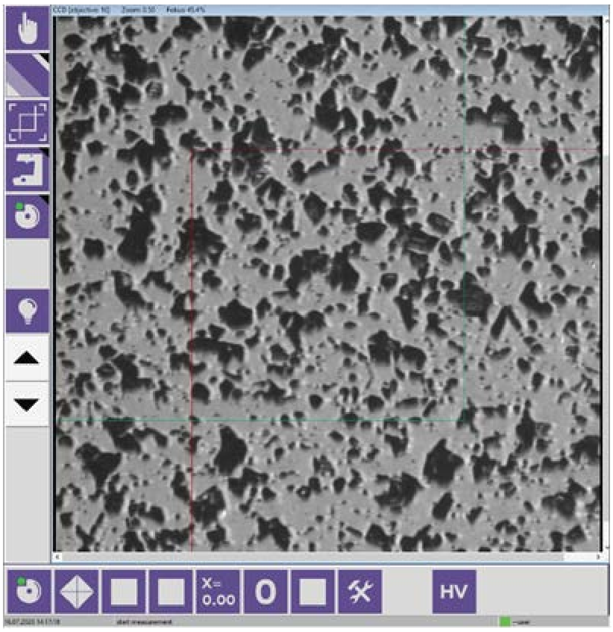


HARDNESS TESTING

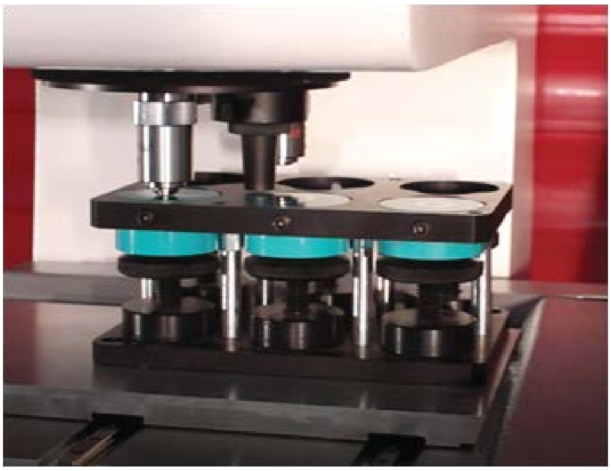
We fixed the samples on GR 2037 Multiple Specimen holder to ensure the surface is perfectly perpendicular to indenter.



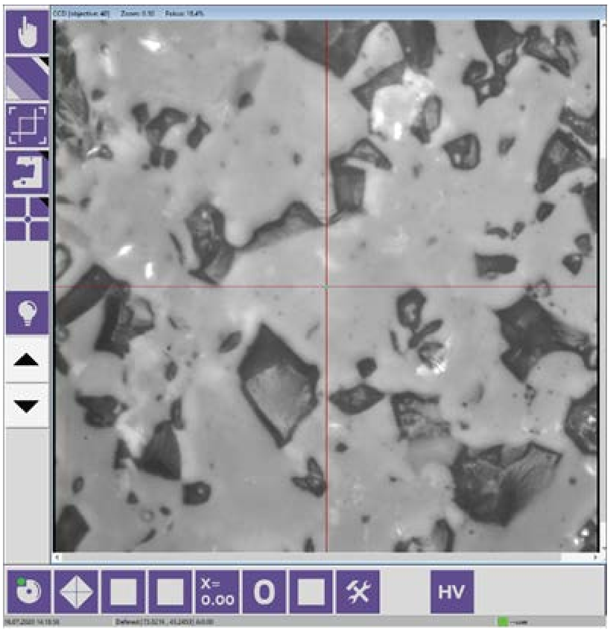
As the alumina is brittle, we used low test force to eliminate cracks on the surface. Also, the indentation size will be smaller with the low forces. In this way, it is possible to measure hardness from very small area. 0.05 kgf test force was suitable for this sample.



Alumina Sample Surface with 10x Objective



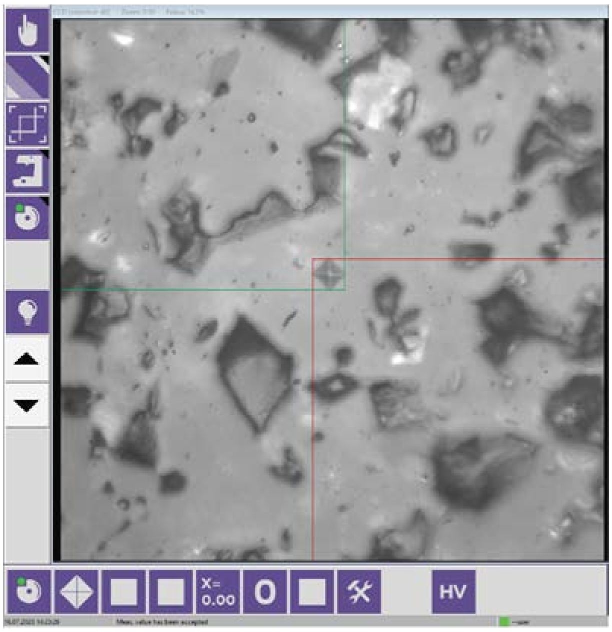
In below application, we easily marked the measurement point on the white area between the black spots. We used the "Place a Measurement Point" function of N-Sure software. The motorized XY-stage of DUROLINE-M4 will make possible to place indentation in this area.



Placing Measurement Point, 40x Objective

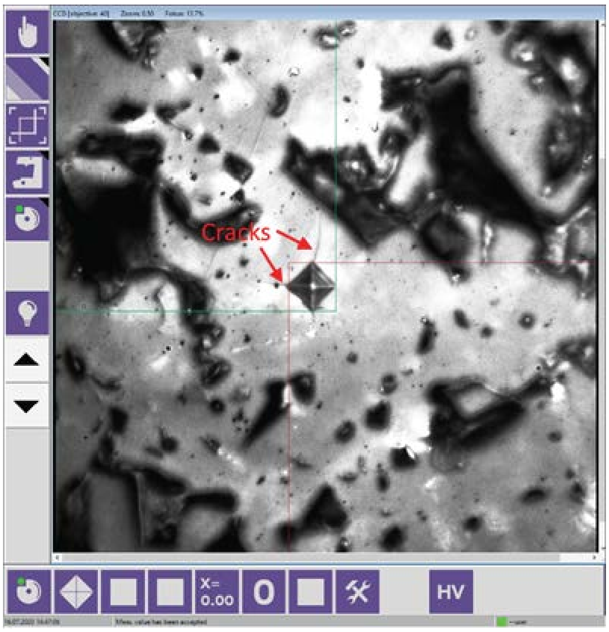
RESULT

The surface of alumina is not reflective as much as a metallic sample, the contrast of indentation is not very high. In addition that, the indentation is very small as alumina has very high hardness.



Indentation with HV0.05

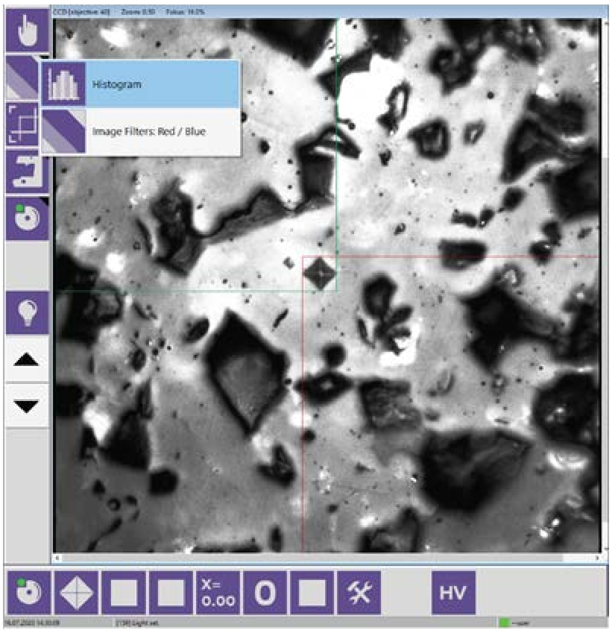
You can see below image of 0.1 kgf test force. There are cracks around the edges of indentation.



Indentation with HV0.1
(Cracks around the edges)

Indentation with HV1
(A lot of cracks and larger indentation size than test area)

To eliminate these difficulties, the N-Sure software has “Histogram” function to increase the contrast of image to make clear edges of indentation. It is also possible to zoom image to see edges larger if necessary.



Histogram Function to Increase Contrast

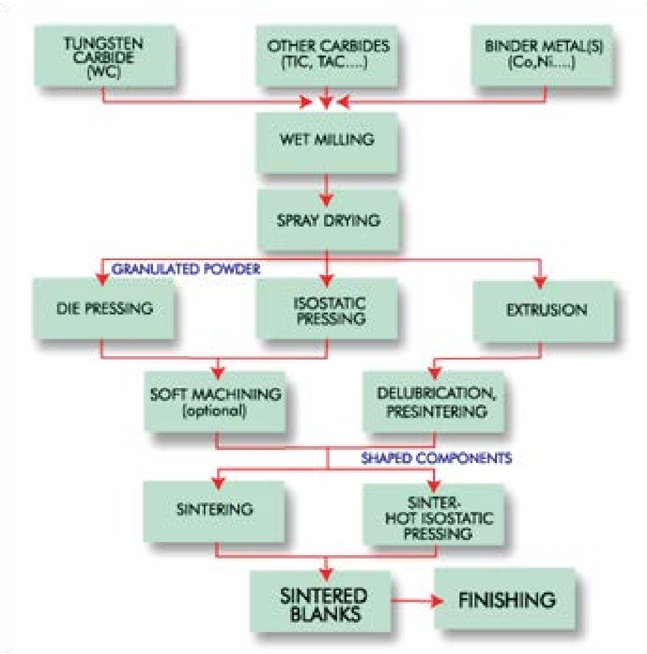
Another test with 1 kgf test force. You can see from the below image, there are a lot of cracks. Also, the indentation size is larger than white area.

7. METALLOGRAPHIC PREPARATION OF WC-Co DRILLS

INTRODUCTION

Tungsten can be found in many different ores but it is accepted that the story of tungsten can be traced all the way back to 1781 with Carl Willhelm Scheele at the heart of it all. Scheel was responsible for discovering a new style of acid that could be created from tungstenite, an ore which would later be referred to as Scheelite. Two years, later, Fausto and Jose Elhuyar were able to isolate the tungsten and this allowed them to extract it from the ore. While this was an important breakthrough, one which laid the foundations for the future use of tungsten, the real benefits of tungsten and its capabilities didn't come to the fore until the initial period of the twentieth century. This was when the use of the material increased greatly, being used in many different products, including drill bits, x-ray tubes and th e filaments of light bulbs.

The tungsten carbide + cobalt powder mixture can be characterised by 2 main parameters: the quantity of cobalt and the grain size. These parameters will highly influence the mechanical properties of the tool. A large tungsten carbide grain size and a high percentage of cobalt will favorise a high shock resistance (impact strength) of the part. A fine tungsten carbide grain size and a low percentage of cobalt will enhance the hardness and the wear resistance of the part. Each application shall be analysed in order to choose the optimum tungsten carbide grade that offers the best wear resistant while showing enough shock resistance.



Once the powder is pressed to shape, the part is consolidated by sinterisation. The part is heated to a temperature between 1'300°C and 1'600°C (depending on the tungsten carbide grade). The cobalt melts and diffuses between the tungsten carbide particles. It will act as a binder between the tungsten carbide grains (these are not affected by the heat). During this process, the compact shrinks and reduces by about 50 % in volume (approximately 20 % in length). All porosities are then eliminated. Sintering was initially made in vacuum conditions. Today, the high-pressure sintering process (Sinter-HIP) combines conventional vacuum sintering with hot isostatic pressing. Heat is applied on the compact whilst high pressure is applied evenly from all directions via an inert gas.

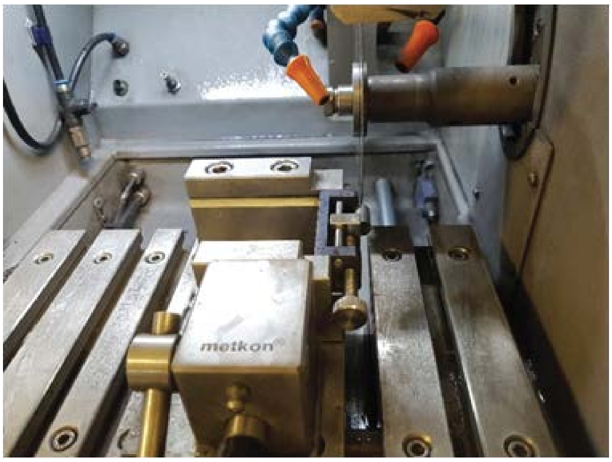
For maximum wear resistance and based on the resulting carbide grade, different quantities of cobalt are added to the tungsten carbide in the nano-crystalline range (<0.2 µm). The manufacturing process of tungsten carbide starts with the mining of the tungsten ore. In the first separation and processing steps a very pure crystallised product, ammonium paratungstate (APT) is produced. Annealing in vacuum then results in the blue tungsten oxide W_2O_5, annealing in air produces the greenish yellow tungsten oxide WO_3. At temperatures ranging between 800 and 1000°C the tungsten oxide is reduced into pure tungsten powder. For this purpose the tungsten powder is mixed with soot or graphite, heating the mixture up to a temperature between 1500 and 2000°C. The powder to be used further on consists of various carbide powders, binder metals and pressing accessories as well as other additives which can be wet milled to the requested grain size in different periods of time; subsequently they are granulated through spray-drying.

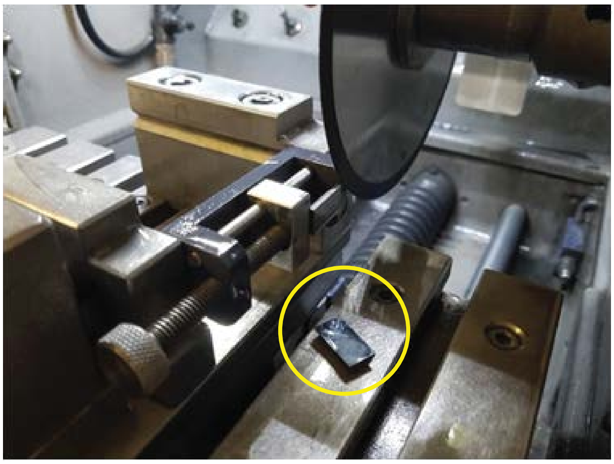
In this application WC-Co drill samples, which we are using in machining industries will be prepared as Metallographic purpose and hardness determination.

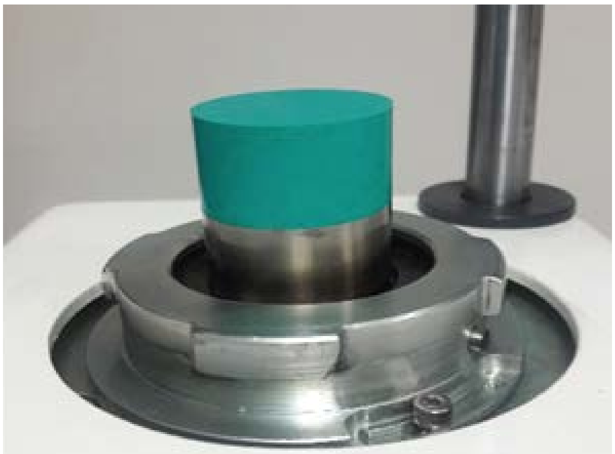
SAMPLE PREPARATION PROCESES

By the help of GR 0548 Quick acting clamping device, drill samples were fixed to MICRACUT 202 table. Small pieces have been holded with GR 0453 before the fixing step.

After cutting operation, samples mounted with Diallyptalat powder in ECOPRESS 102 102 Programmable Automatic Hot Mounting Press







Cutting Parameters	
Feed rate	30 μ/sec.
RPM	2600 r/min.
Travel	media 8 mm. trifoil 16 mm. BSN4 25 mm. BSA3 32 mm. BSA5 41 mm. rod 23mm.
Time (min.)	4:50 9:20 13:30 18:00 23:00 13:10
Force	4.5 A

Mounting Parameters	
Heating Temperature	180°C
Pressure	260 bar
Heating Time	3 mins.
Cooling Type	Standart Cooling
Cooling Temperature	35°C

Mounted samples have been grinded & polished with the parameters below;

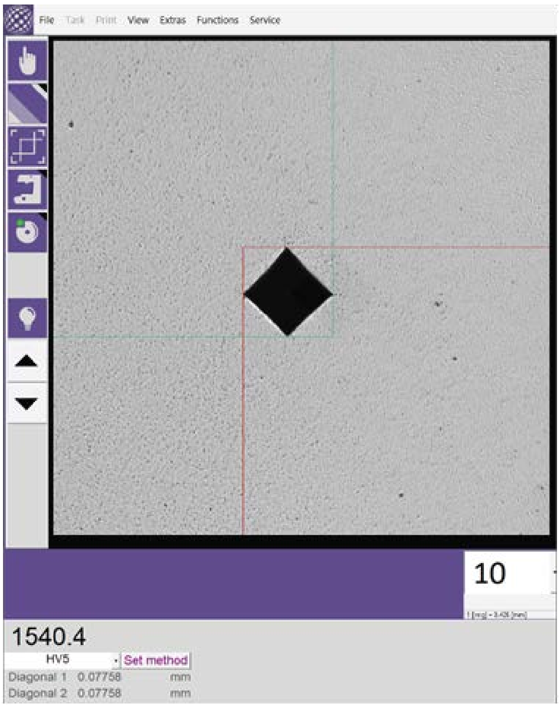
	Surface	Abrasive	Lubricant	Force Per Sample (N)	Time Min.	Disc Speed Rpm.	Head Speed Rpm.
Grinding Step 1	MAGNETO 54 38-040-054	54 Mic. Diamond	Water	20 N	Until Plane	250 CW	100 CW
Final Grinding	MAGNETO 18 38-040-018	18 Mic. Diamond	Water	20 N	4 min.	250 CW	100 CW
Polishing Step 1	METAPO-B 39-033-250	DIAPAT-P 3μ 39-420-P	DIAPAT (39-502)	20 N	4 min.	150 CCW	75 CW
Final Polishing	FEDO-1M 39-067-250	DIAPAT-P 1μ 39-410-P	DIAPAT (39-502)	15 N	2 min.	150 CCW	50 CW

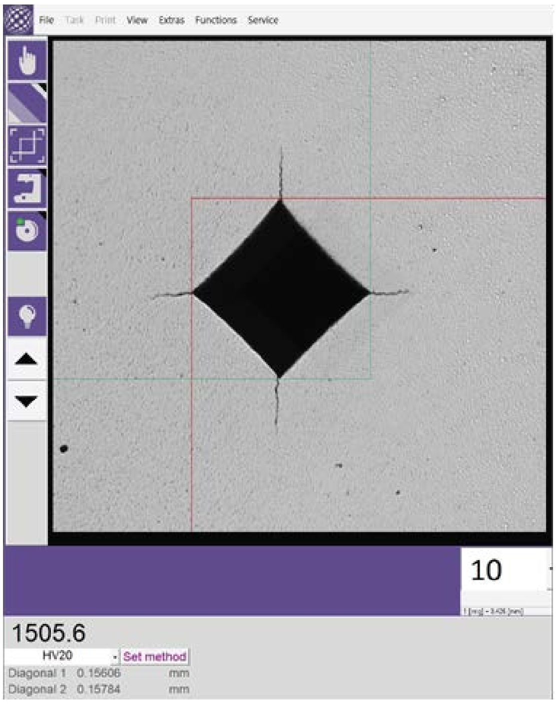
HARDNESS TESTING

WC-Co drill sample is put on the GR 2023 table for measurement purpose of Vickers hardness value. As mounted sample is parallel enough, no special sample fixture was required.

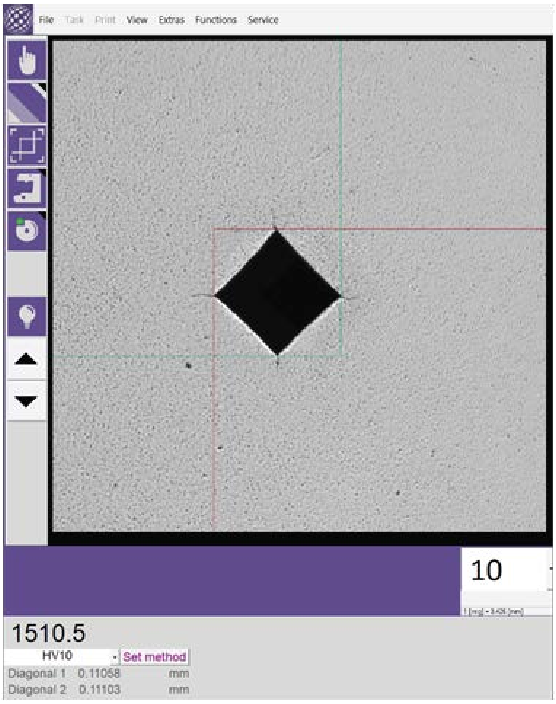
RESULT

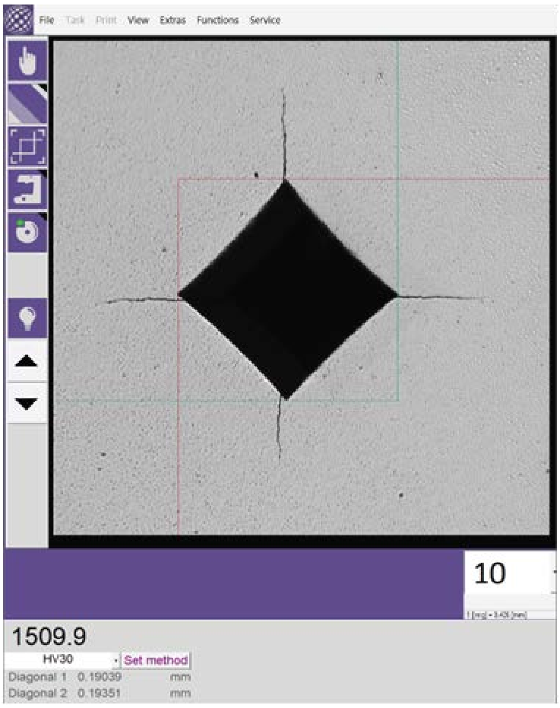
Sample hardness test is performed under four different forces on the same sample: 5kgf, 10kgf, 20kgf, 30kgf.





5 kgf test force is the most suitable force for this sample. As the sample is too hard and brittle, higher forces caused cracks on the edges of indent. However there is no significant effect on hardness value.



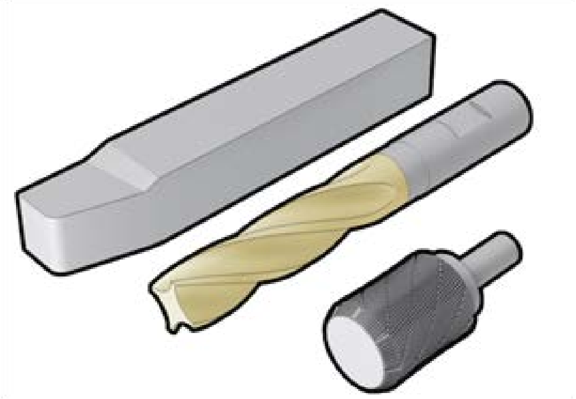


8. METALLOGRAPHIC PREPARATION OF HIGH SPEED STEEL 1.343 (HSS)

INTRODUCTION

In 1868 the English metallurgist Robert Forester Mushet developed Mushet steel, considered to be the forerunner of modern high speed steels. It consisted of 2% carbon (C), 2.5% manganese (Mn), and 7% tungsten (W). The major advantage of this steel was that it hardened when air cooled from a temperature at which most steels had to be quenched for hardening. Over the next 30 years the most significant change was the replacement of manganese (Mn) with chromium (Cr). Their experiments were characterised by a scientific empiricism in that many different combinations were made and tested, with no regard for conventional wisdom or alchemic recipes, and with detailed records kept of each batch.

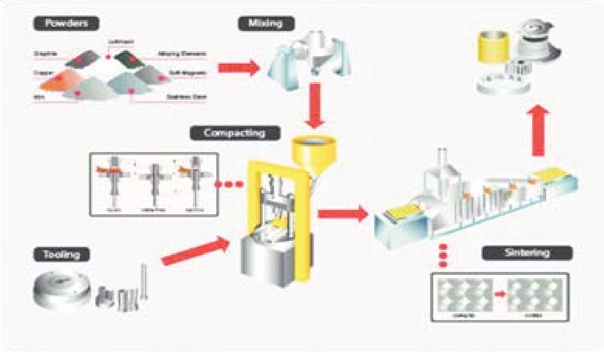
The useful cutting characteristics of high-speed steel have been further extended by applying thin, but extremely hard, titanium carbide coatings which reduce friction and increase wear resistance, thereby increasing cutting speed and tool life. The exceptional high temperature wear properties of molybdenum-containing high-speed steels are ideal for new applications such as automobile valve inserts and cam-rings. The HSS can be divided into four types according to the different preparation technology: traditional casting technology, electroslag remelting technology, powder metallurgy technology and Osprey Process technology.



In the slow solidification process of high-speed steel, a large amount of carbon and alloying elements are formed before crystallization to form intercrystalline carbide network. In order to eliminate the uneven distribution of carbides, the high temperature repeated forging or rolling is used to break and districarbides evenly. This forging process is easy to cause cracking, and the limitation of processing equipment and forging pressure ratio leads to material utilization rate only up to 24-36% from ingot to final product.

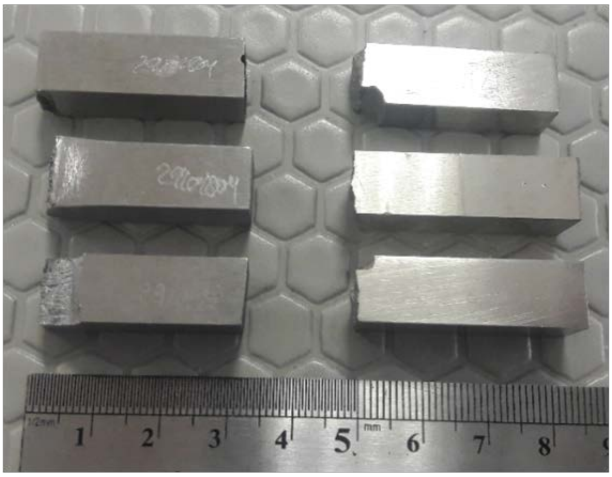
Powder metallurgy to produce produce highly alloyed steels such as high-carbon, high-chromium and high-speed. This process has become increasingly popular in recent years. Take the M2 tool steel for example, the production process is mainly divided into two steps: Powder atomization. The basic principle is to atomize molten high speed steel to a certain scale distribution of powder by high-pressure argon or pure nitrogen at a certain flow rate after limiting the flow through the guide tube at the bottom of crucible.

Powder molding. after sieving and preloading, these powders are solidified and densified under high temperature (1100) ,high pressure (100MPa), then formed the finished blank or steel billet.



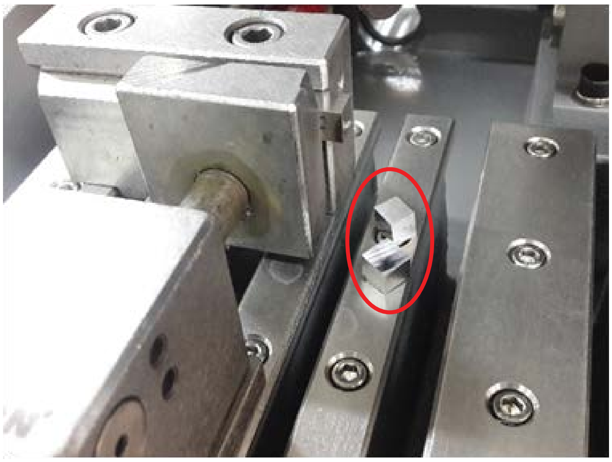
Osprey technique is an advanced technology to prepare high-performance materials by means of rapid solidification. There are four main stages in Osprey Process, including melting and dispersing, gas atomization, deposition and collector manipulation.The molten alloy is poured from an induction furnace through a nozzle and blasted with high-pressure gas atomization jets, causing the formation of small droplets. The droplets are collected and used to form billets, hollows and sheets.

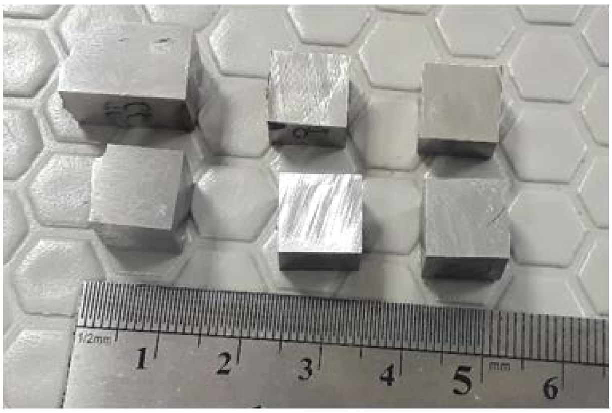
In this application High Steel Samples 1.3343 (HSS), will be prepared as Metallographic purpose and hardness determination.



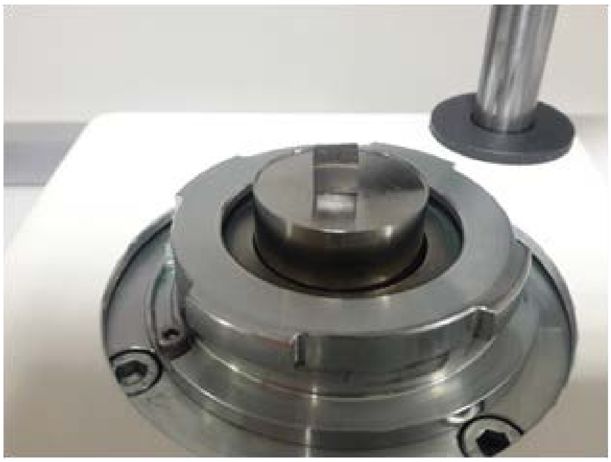
SAMPLE PREPARATION PROCESES

By the help of GR 0013 Quick Acting Clamping Vise, HSS 1.3343 samples fixed to the METACUT 302 abrasive cutting equipment table.





After cutting operation, samples mounted with Epoxy Hard in ECOPRESS 102 Programmable Automatic Hot Mounting Press.



Cutting Parameters	
Heating Temperature	180˚C
Pressure	260 bar
Heating Time	3 mins.
Cooling Type	Standart Cooling
Cooling Temperature	35˚C

We applied grinding&polishing recipe to HSS 1.3343 steel specimens with the parameters below

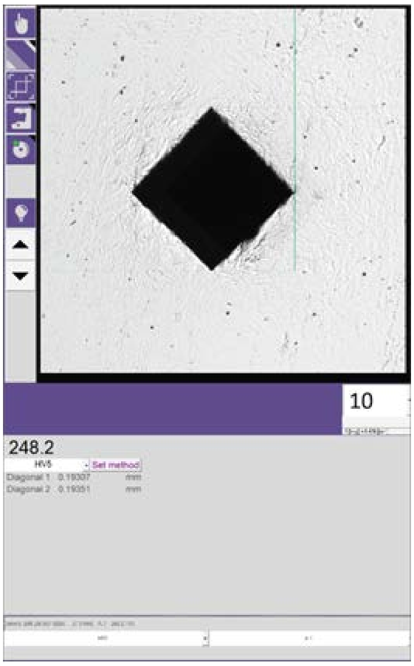
	Surface	Abrasive	Lubricant	Force Per Sample (N)	Time Min.	Disc Speed Rpm.	Head Speed Rpm.
Grinding Step 1	DEMPAX-F 38-040-320F	400 grit SiC	Water	25 N	2 min.	250 CW	100 CW
Grinding Step 2	DEMPAX-F 38-040-600F	800 grit SiC	Water	25 N	2 min.	250 CW	100 CW
Final Grinding	DEMPAX-F 38-040-1200F	1200 grit SiC	Water	25 N	3 min.	250 CW	100 CW
Polishing Step 1	METAPO-B 39-033-250	DIAPAT-P 3µ 39-420-P	DIAPAT [39-502]	20 N	4 min.	150 CCW	75 CW
Final Polishing	FEDO-1S 39-066-250	DIAPAT-P 1µ 39-410-P	DIAPAT [39-502]	15 N	2 min.	150 CCW	75 CW

HARDNESS TESTING

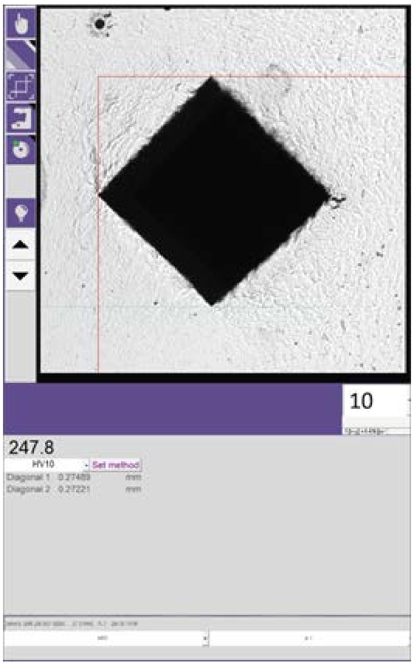
High Speed Steel 1.3343 samples are put on the GR 2023 table for measurement purpose of Vickers hardness value. As mounted sample is parallel enough, no special sample fixture was required.

RESULT

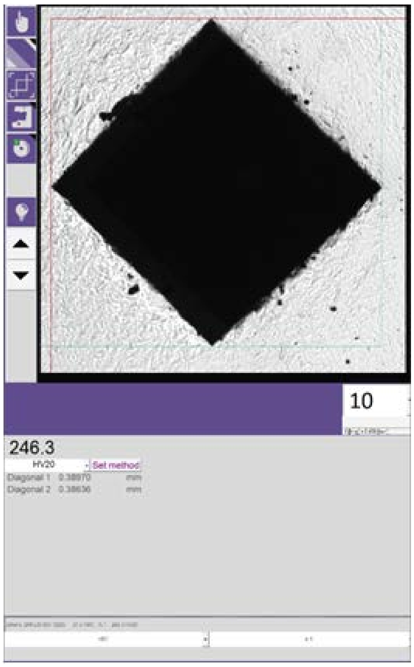
Sample hardness test is performed under three different forces: 5kgf, 10kgf and 20kgf



248.2HV5



247.8HV10



246.3HV20

MICROSCOPY

UPRIGHT

UPM 902

INVERT

IMM 901

IMM 902

POLARIZE

IPP 902

STEREO

PST 901

PST 902

HARDNESS TESTING

MICRO VICKERS

DUROLINE M1/M2/M3/M4

MACRO VICKERS

DUROLINE V

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ADVANCED GRINDIG & POLISHING

ACCURA 102

ELECTROLYTIC PREPARATION

ELOPREP 102

PORTABLE METALLOGRAPHY

MOBIPREP

MOBISCOPE