

2019 Excellent Product Award of The Japan Society of Mechanical Engineers → P. 19

Small Ball Rebound Tester eNM3A10

(All purpose and high quality hardness tester, portable)

~ At anytime, anywhere, for anything, the precise hardness test available ~

- **Unique:** The sole product in the world to test hardness (coefficient of restitution) using a small ball.
- **Easy:** Switch on, and just start testing! One-push operation to prepare the next test.
- **No need to cut or prepare your specimen:** You can directly test small parts^{*1} and large objects just as they are.^{*2}
- **Minimum damage:** The ball is 3 mm in diameter and weighs only 0.06 g! The left trace is very small.
- **Portable:** The tester weighs about 0.6 kg and is operated by two AA batteries or USB power supply.
- **Any direction:** Test is possible in any direction. (upward, downward, horizontal, etc.)

*1 As a guide, more than 5 mm thickness is required.

*2 It is recommended to polish the surface with #600 emery paper. (With #100, about 2% of coefficient of restitution will be reduced.)



The principle is very simple.

~ Measure hardness by bounce (coefficient of restitution) ~

- The tester hits a sample with a small ball and measures the going and returning velocity. The velocity ratio is called coefficient of restitution, e .

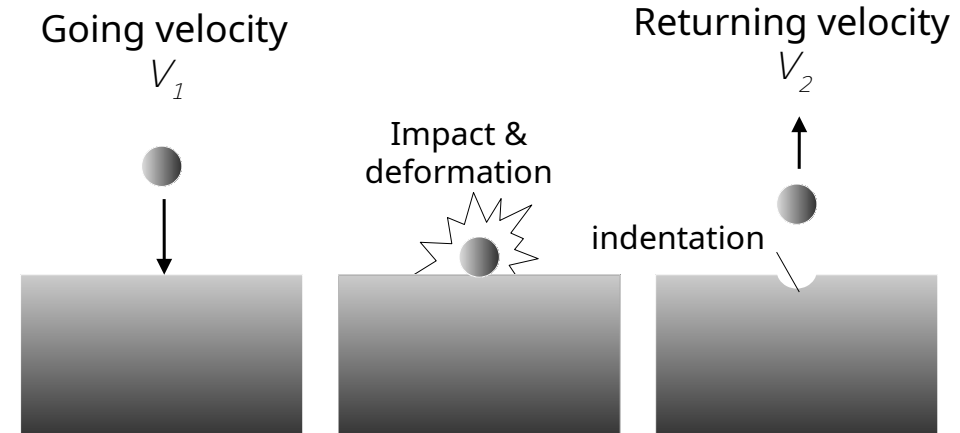
- If deformation is 100 % elastic, the going and returning velocity is equal and thus $e = 1$.

- If plastic deformation occurs, the kinetic energy of the small ball is partially lost by the work to form the indentation and therefore, e will be less than 1.

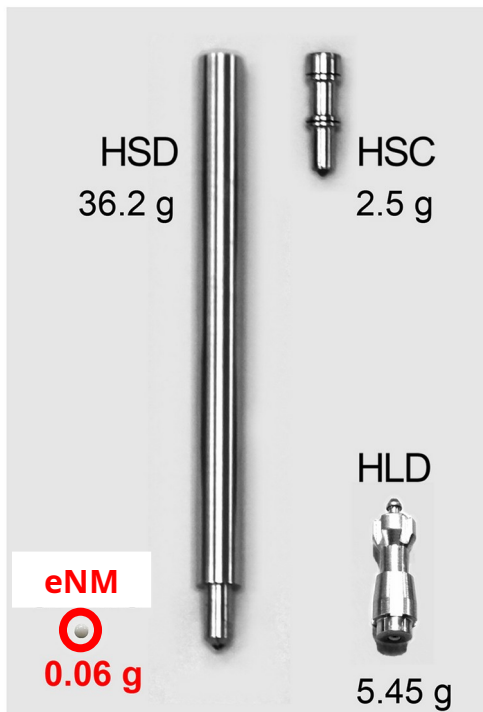
- The more the sample is harder for plastic deformation, the larger e will be and on the other hand, the softer the sample is, the smaller e will be.

- The theory to use a small ball as an impact body is the idea of Prof. M. Nakamura, professor emeritus of Chiba University and Toyohashi University of Technology and Prof. S. Maki, professor emeritus of Mie University. Thus, eNM is the initials of the last names of both professors.

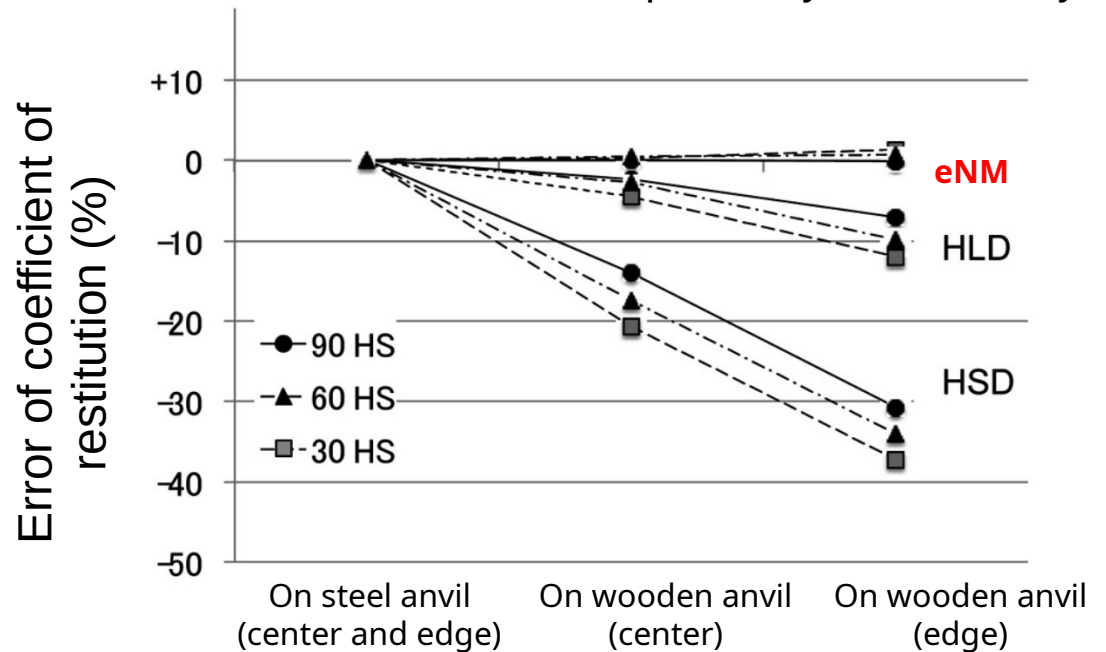
$$\text{coefficient of restitution } e = V_2 / V_1$$



Smaller sample, more freely – with a small ball



~ You can test the smaller sample easily and correctly ~



- The mass (0.06 g) of the small ball of eNM tester is one tenth to one hundreds of the impact bodies for conventional rebound hardness testers.

- Consequently, you can test much smaller samples. *1

*1 As a guide, more than 5 mm of thickness is required.

- The eNM tester shows the same results on the hard steel anvil (good test condition) and on the wooden anvil (poor test condition).

- Furthermore, the eNM tester works even at the edge of sample on the wooden anvil without problems.

You can test various materials

Coefficient of restitution of various materials (reference value)

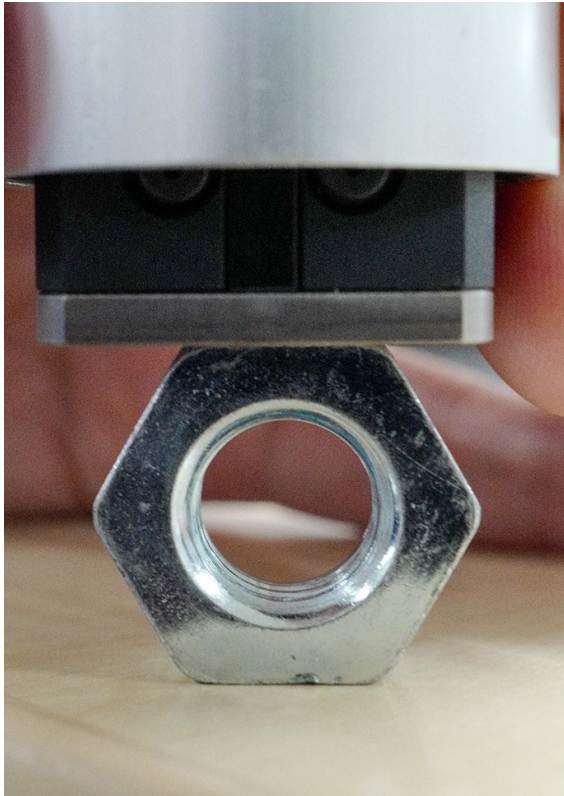
Item	e
40 HV Pure copper hardness standard block (Ø64 x 10 mm, 265 g)	0.19
Boiled egg, shelled (60 g)	0.26
Natural rubber block (50 mm thick)	0.38
100 HV brass hardness standard block (Ø64 x 10 mm, 255 g)	0.44
Wooden bat for juniors (made in 1962, 800 mm long, 560 g)	0.48
200 HV steel hardness standard block (Ø64 x 15 mm, 380 g)	0.55
Polyethylene cooking board (13 mm thick)	0.63
Dried bonito (Katsuobushi) (250 g)	0.70
400 HV steel hardness standard block (Ø64 x 15 mm, 380 g)	0.72
Granite plate (10 mm thick, 2.3 kg)	0.87
800 HV steel hardness standard block (Ø64 x 15 mm, 380 g)	0.90
Crystal glass ashtray (1.9 kg)	0.98



~ Testing a Katsuobushi (dried bonito) ~

- You can test on a flat and smooth surface from which the small ball reflects and returns straight.
- As a guide, the sample requires more than 5 mm thickness.
- A demonstration tester is available. If you like to test your sample, please contact with our agencies.

Practical parts, directly



Steel nut (M12)



Steel cylinder (55mm dia.)



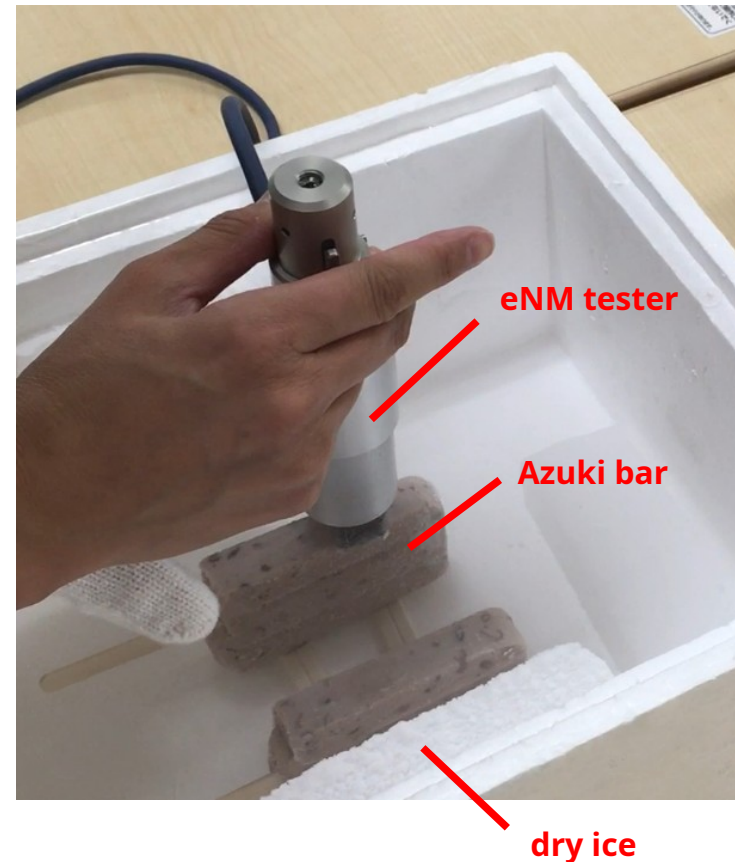
Aluminum wheel for automobile

You can test various shaped practical parts, from small to big, such as nuts, cylinders, aluminum wheels, that are difficult to test with conventional rebound hardness testers.

Testing the hardness of popsicle “Azuki bar” (YouTube video)

～ Hardness tester that can test ice ～

- We tested the popsicle “Azuki bar” by IMURAYA GROUP Co., Ltd., well-known for its high hardness.
- As shown on the photograph, Azuki bar was cooled by dry ice to -25°C and then tested. (Warning: please note that this kind of test at such low temperature may be out of the warranty of your tester.)
- The hardness (coefficient of restitution) is about 0.34 and is harder than ship biscuit (about 0.26) at the room temperature.
- Please watch the video (about 1 minute) from the following link. (in Japanese)



Link <https://www.youtube.com/watch?v=3k3iZkVLdRw>

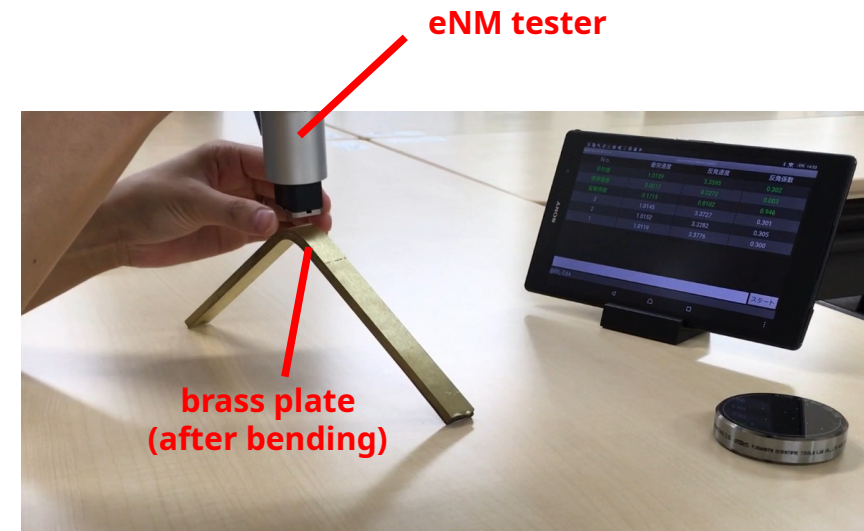
Hardness change before and after bending (YouTube video)

～ Test work hardening by your hand, on a desk ～

- Generally speaking, if you deform metallic material, it hardens (work hardening). This experiment compared the hardness (coefficient of restitution) of brass plate before and after bending.
- The hardness (coefficient of restitution) is 0.30 before bending and 0.42 after bending. It clearly shows hardness increase by work hardening.
- Please watch the uncut video showing the whole experiment, hardness test – bending – retest in just 2 minutes and 20 seconds. (in Japanese)



Link https://www.youtube.com/watch?v=TYS_pBoxlls

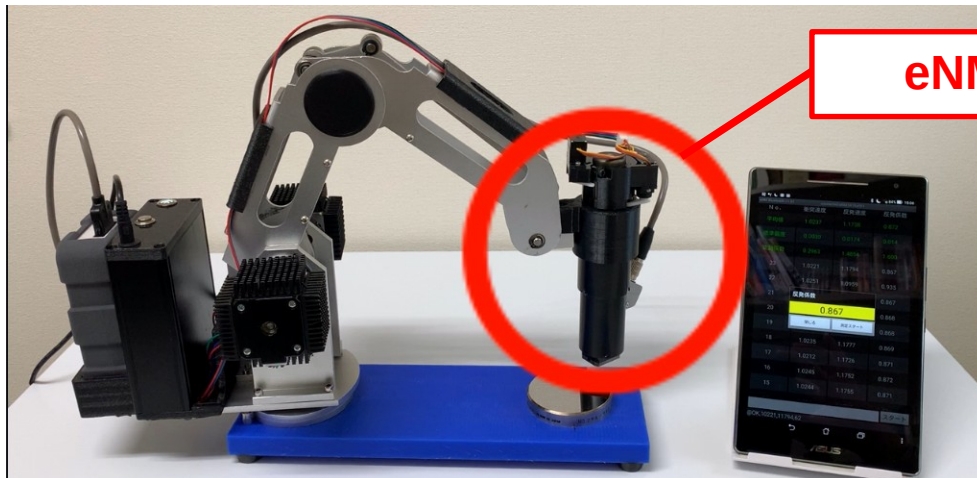


曲げた後の反発硬さ(反発係数)は……

Translation: What will be the rebound hardness (coefficient of restitution) after bending

Automatic hardness testing (YouTube video)

- Our eNM tester can be combined with a robot for automatic hardness testing. The followings are two examples.



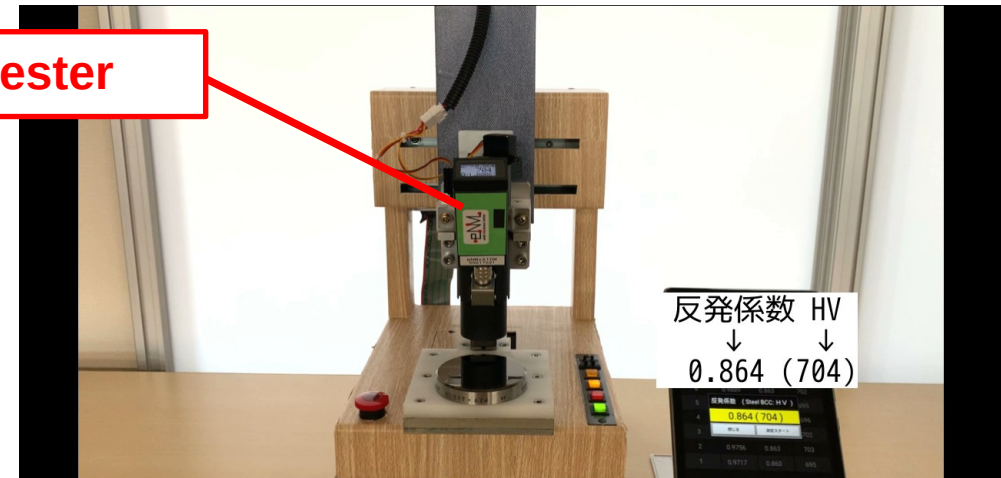
<https://youtu.be/N5NihuaXjK4>

(No.1)

【The First System】

【Basic Operation】

Duration 50s



<https://youtu.be/5imiO5JDTOU>

(No. 2)

【Hi-Speed】

【Vickers Hardness Conversion】

Duration 90s



- Automatic hardness testing system, which has the eNM tester fixed to a robot hand, can obtain hardness distribution of specimens by changing testing positions.
- Automation is easy since the operation of the eNM tester, i.e., shooting and reloading, is simple and straightforward.

Hardness testing of drug tablets

- Commercially available mint tablets were used as drug tablet models and were tested by 2-mm-alumina-ball rebound hardness tester under different humidity conditions.

MINTIA BREEZE

mass ca. 0.76g, diameter ca. 11mm, thickness ca. 7.2mm

e

2 weeks in the dry cabinet (25% humidity) **0.615**

2 weeks by the room window (50% humidity) **0.518**

- The mint tablet kept for two weeks in the dry cabinet (25% humidity) is clearly harder than that placed by the room window (50% humidity). The small ball rebound hardness tester can easily and quantitatively detect hardness difference under various conditions.



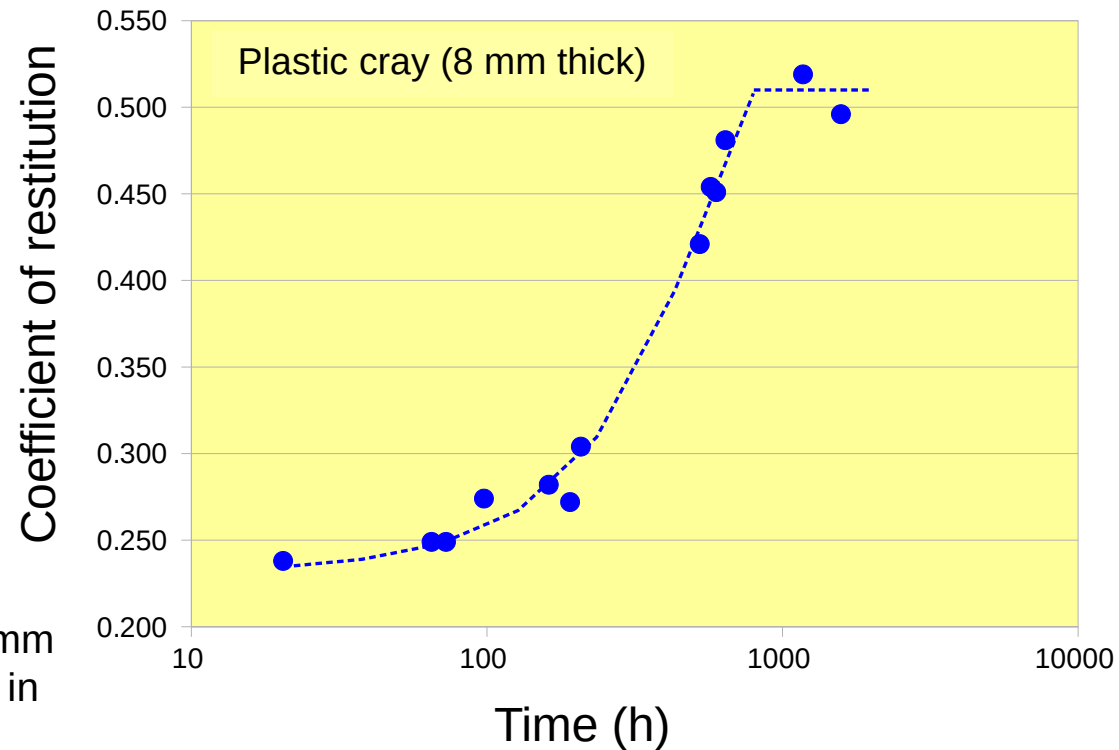
Mint tablet
(ca. 11 mm diameter)



Testing (horizontally)

Monitoring hardness over long term

~ detect change of material by its hardness ~

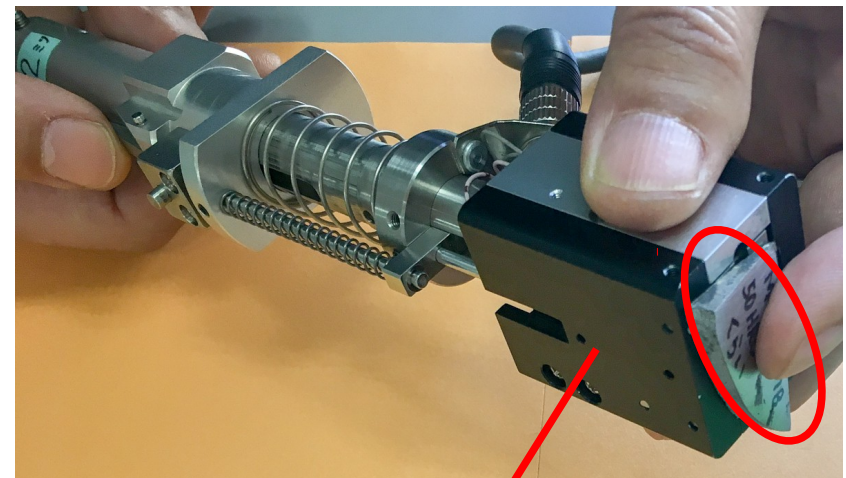


Time dependence of hardness
(coefficient of restitution)

- The plastic cray (vinyl acetate emulsion) of about 8 mm thick that is available at a dollar shop has been kept in a room for about 2 months and the coefficient of restitution has been measured.
- As shown in the chart, you can evaluate its hardening process easily and quantitatively.
- By monitoring hardness, you can diagnose material degradation.

Figuring out the cause of the broken pinch bar – one day, at working site

- One day the pinch bar tip was suddenly broken at working site.
- Small pieces of the broken pinch bar were collected and tested by eNM tester. It was found that the hardness (coefficient of restitution) was 0.78, which was harder than ordinary material of 0.65. It is presumed that the material was not properly treated by tempering after quenching.
- Our eNM tester helps you test the small materials at working site when needed, which is quite efficient for manufacturing.

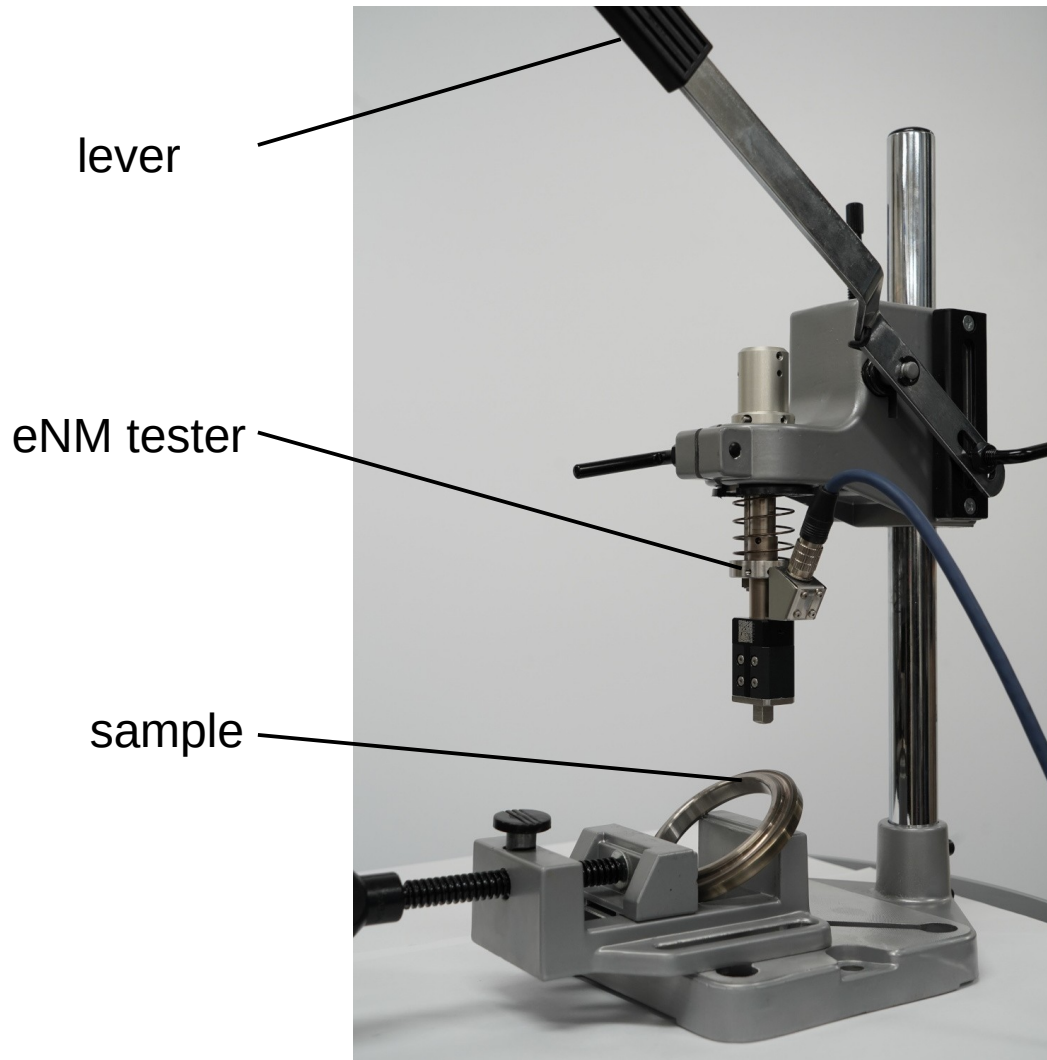


eNM tester
(prototype)

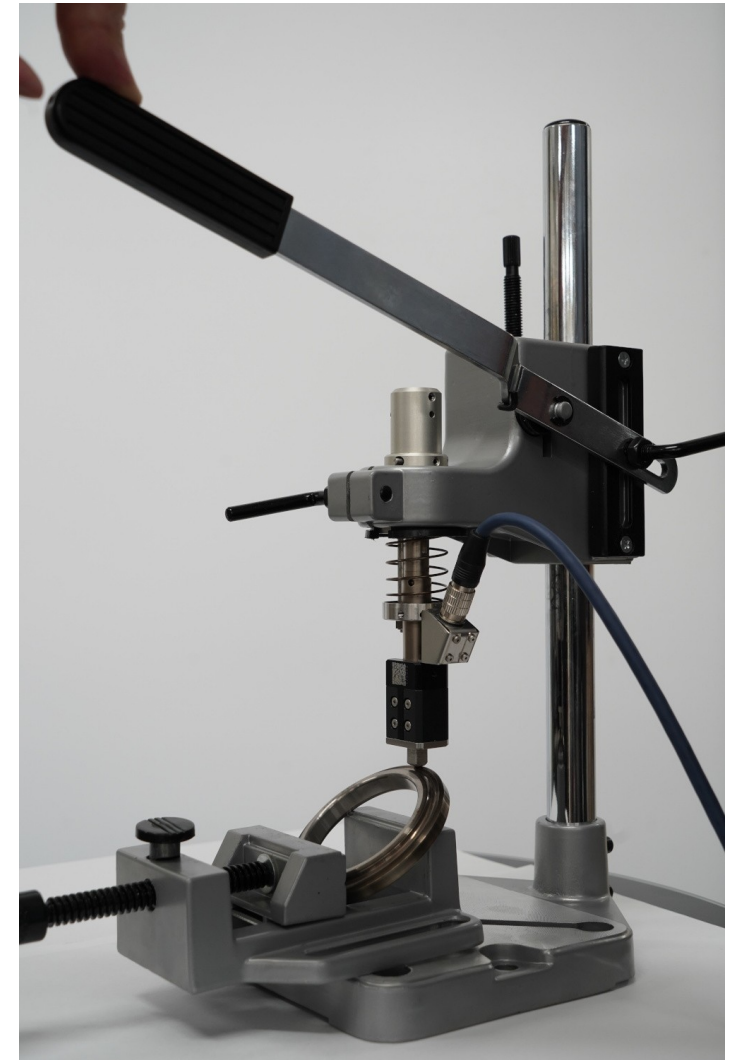
broken pinch bar

Combination with a universal stand

~ The surface of complicated parts can be easily tested. ~



1. Set eNM tester and sample in position

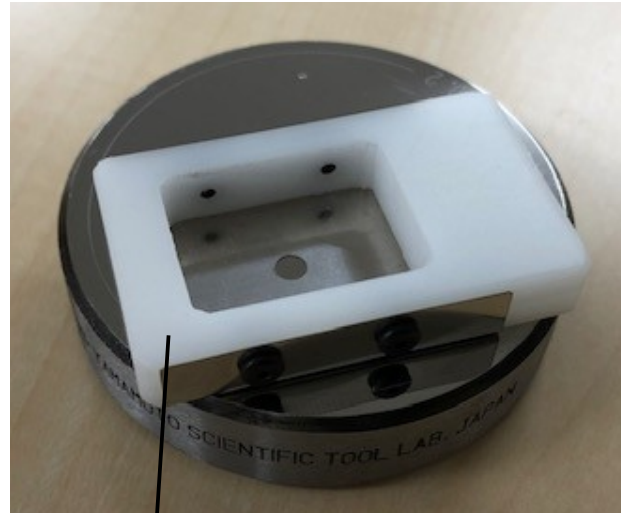


2. Push the lever down and test sample

Customizing parts available for various needs



“Adapter for narrow space”

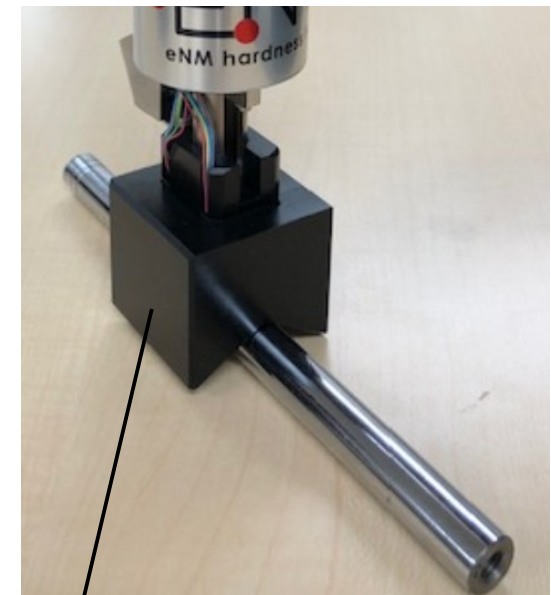


“Targeting scope”

These are in the stage of development and if you are interested in customizing, please contact our development team through our agencies.





“Mount-type display”



“Adapter for curved surface”

Conversion table between coefficient of restitution and other hardness

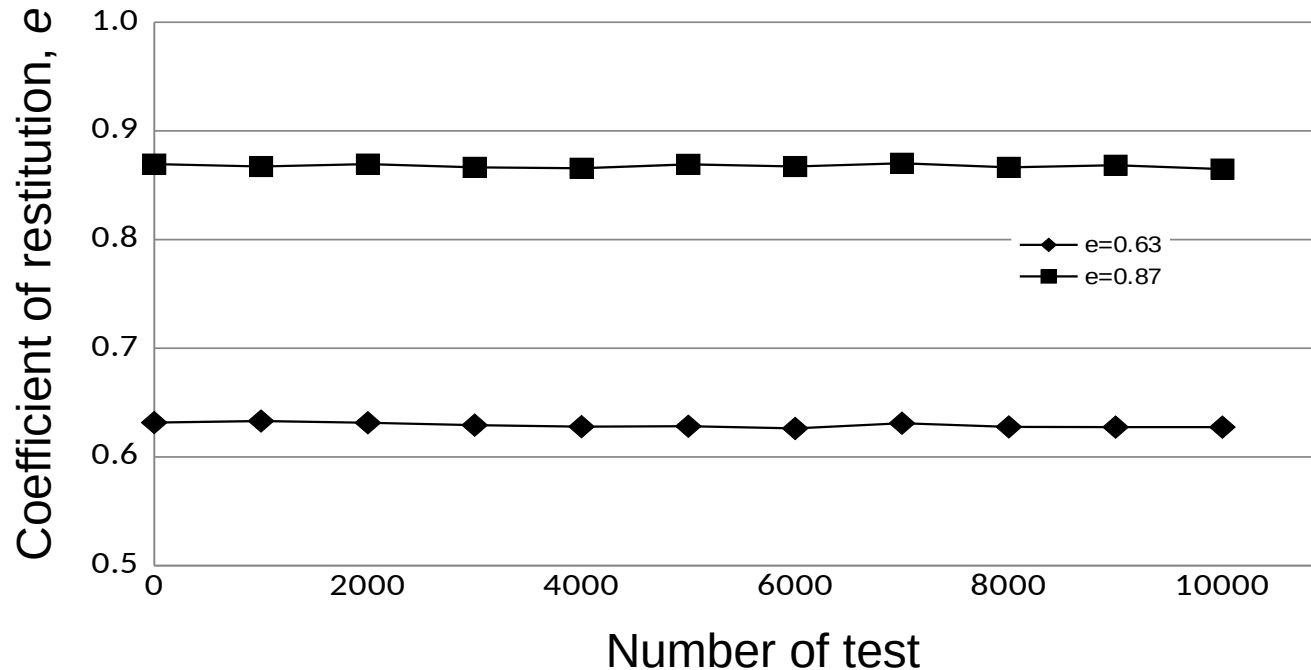
～ A guide to compare the coefficient of restitution e with other hardness ～

- In general, conversion of hardness is not really precise. Please consider it a guide.
- The conversion depends on the material. (The table shown is for steels. Currently preparing: Al-alloy and Cu-alloy)
- The conversion table may be altered without prior notice.
- You can download the full conversion table here.
 - Link Conversion table (in Japanese)
<http://www.ystl.jp/topics/?p=1334>

 - Link Yamamoto Scientific Tool Laboratory
<http://www.ystl.jp/>


ロックウェル	ビッカース	ブリネル HB10/3000		ロックウェル			ロックウェル スーパーフィシャル			ショア	リーブ [®]		引張強さ (近似値) MPa	ロックウェル	微小球反発
		HBS	HBW	HRA	HRB S	HRD	HR15N	HR30N	HR45N		HLD	HLE			
ダイヤモンド		標準球	タングステンカーバイト球	ダイヤモンド	1/16" 球	ダイヤモンド	ダイヤモンド				タングステンカーバイト	ダイヤモンド		ダイヤモンド	アルミナ球
150kgf				60kgf	100kgf	100kgf	15kgf	30kgf	45kgf					150kgf	3mm
68	940	-	-	85.6	-	76.9	93.2	84.4	75.4	98.0	878	846	-	68	0.925
67	900	-	-	85.0	-	76.1	92.9	83.6	74.2	95.6	869	836	-	67	0.920
66	865	-	-	84.5	-	75.4	92.5	82.8	73.3	93.4	860	826	-	66	0.910
65	832	-	(739)	83.9	-	74.5	92.2	81.9	72.0	91.2	850	817	-	65	0.900
64	800	-	(722)	83.4	-	73.8	91.8	81.1	71.0	89.0	840	806	-	64	0.895
63	772	-	(705)	82.8	-	73.0	91.4	80.1	69.9	87.1	830	796	-	63	0.885
62	746	-	(688)	82.3	-	72.2	91.1	79.3	68.8	85.2	820	786	-	62	0.880
61	720	-	(670)	81.8	-	71.5	90.7	78.4	67.7	83.3	810	776	-	61	0.870
60	697	-	(654)	81.2	-	70.7	90.2	77.5	66.6	81.5	800	766	-	60	0.860
59	674	-	(634)	80.7	-	69.9	89.8	76.6	65.5	79.7	790	755	-	59	0.855
58	653	-	615	80.1	-	69.2	89.3	75.7	64.3	78.1	781	746	-	58	0.845
57	633	-	595	79.6	-	68.5	88.9	74.8	63.2	76.4	771	736	-	57	0.835
56	613	-	577	79.0	-	67.7	88.3	73.9	62.0	74.8	762	726	-	56	0.830
55	595	-	560	78.5	-	66.9	87.9	73.0	60.9	73.2	753	717	2075	55	0.820
54	577	-	543	78.0	-	66.1	87.4	72.0	59.8	71.7	744	708	2015	54	0.810
53	560	-	525	77.4	-	65.4	86.9	71.2	58.6	70.2	735	699	1950	53	0.805
52	544	(500)	510	76.8	-	64.6	86.4	70.0	57.4	68.8	707	691	1890	52	0.795

10^4 times endurance test

~ Proved both durability and stability ~

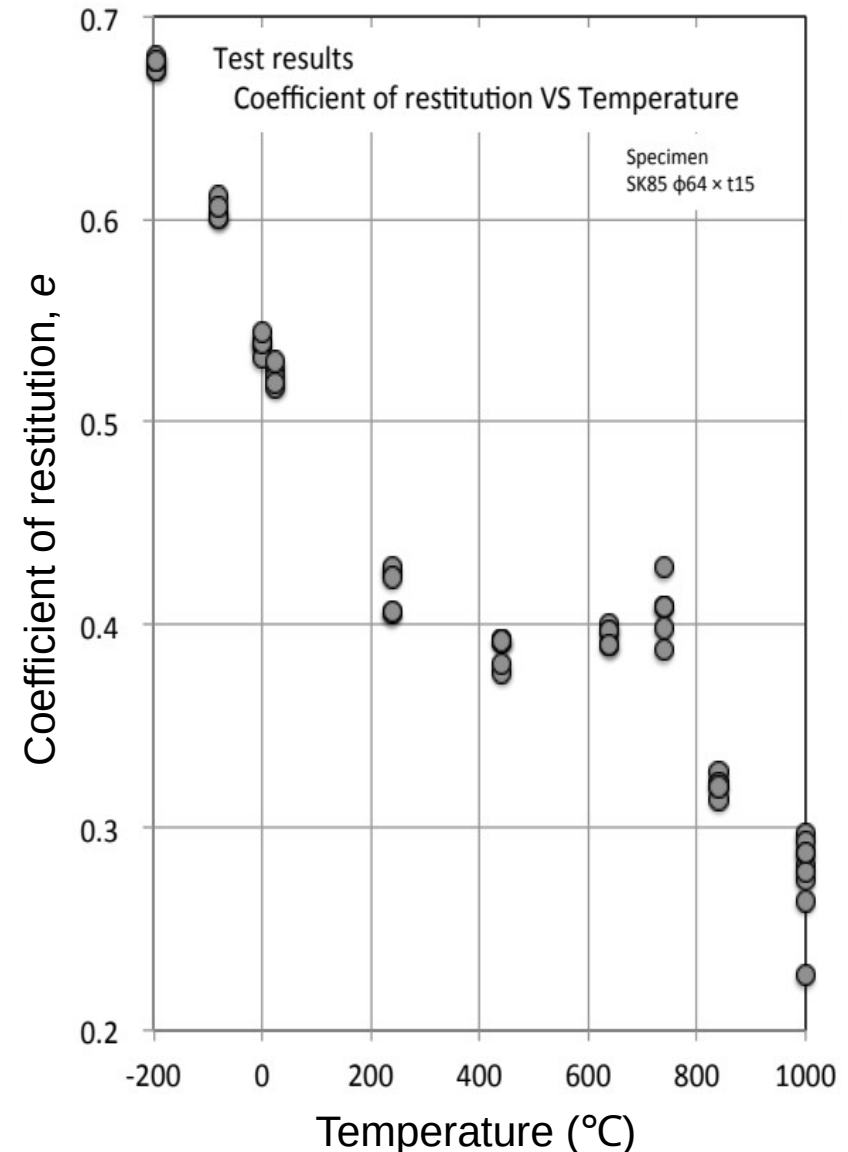


- To prove the durability and stability of the tester, specimen equivalent to 1000 HV was tested for 10,000 times. For every 1,000 tests, the standard blocks of $e = 0.87$ and $e = 0.63$ were also measured.
- The change of coefficient of restitution stayed within roughly 0.5 % and no particular problem was detected for durability and stability.
- Even if the small ball in the tester is damaged, it is easy to replace it. (Not free)

Hardness test at high and low temperature (in the stage of development)

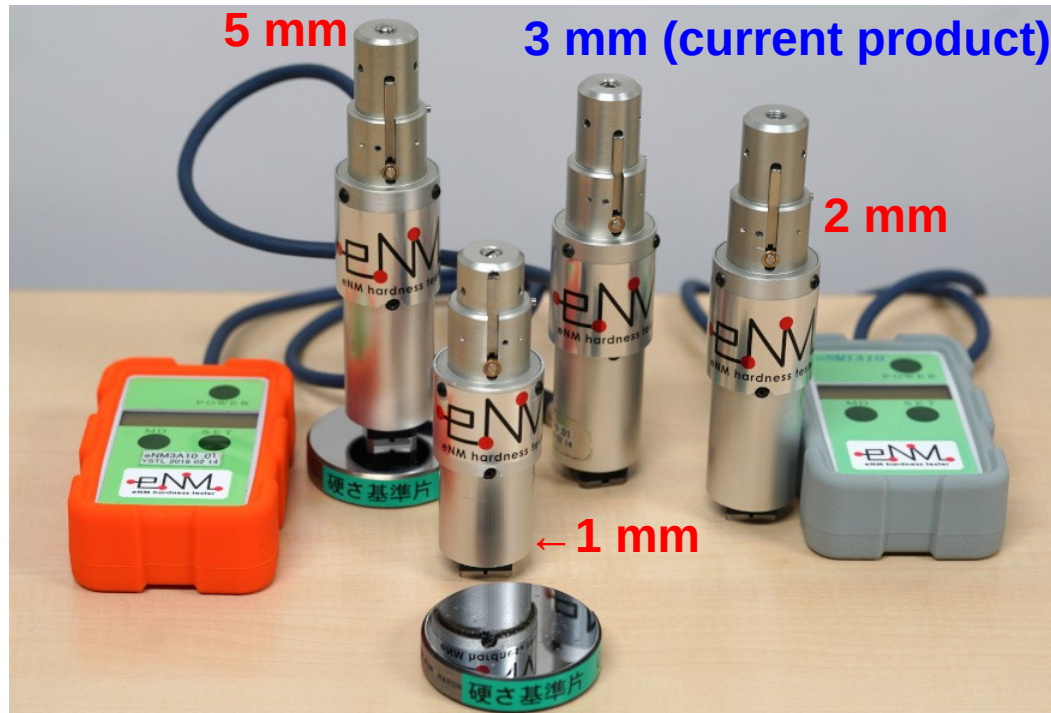
~ Possibility of hardness at various temperature ~

- As the small ball touches the sample only for an instant, it is considered to be suitable for hardness test at high or low temperature.
- The right chart shows the dependence of coefficient of restitution of SK85 carbon tool steel on temperature from -196 to +1000 °C, tested by eNM tester (prototype).
- At present, the development is progressing, and if you are interested, please contact our agencies or distributors.



Future lineup of eNM-series testers

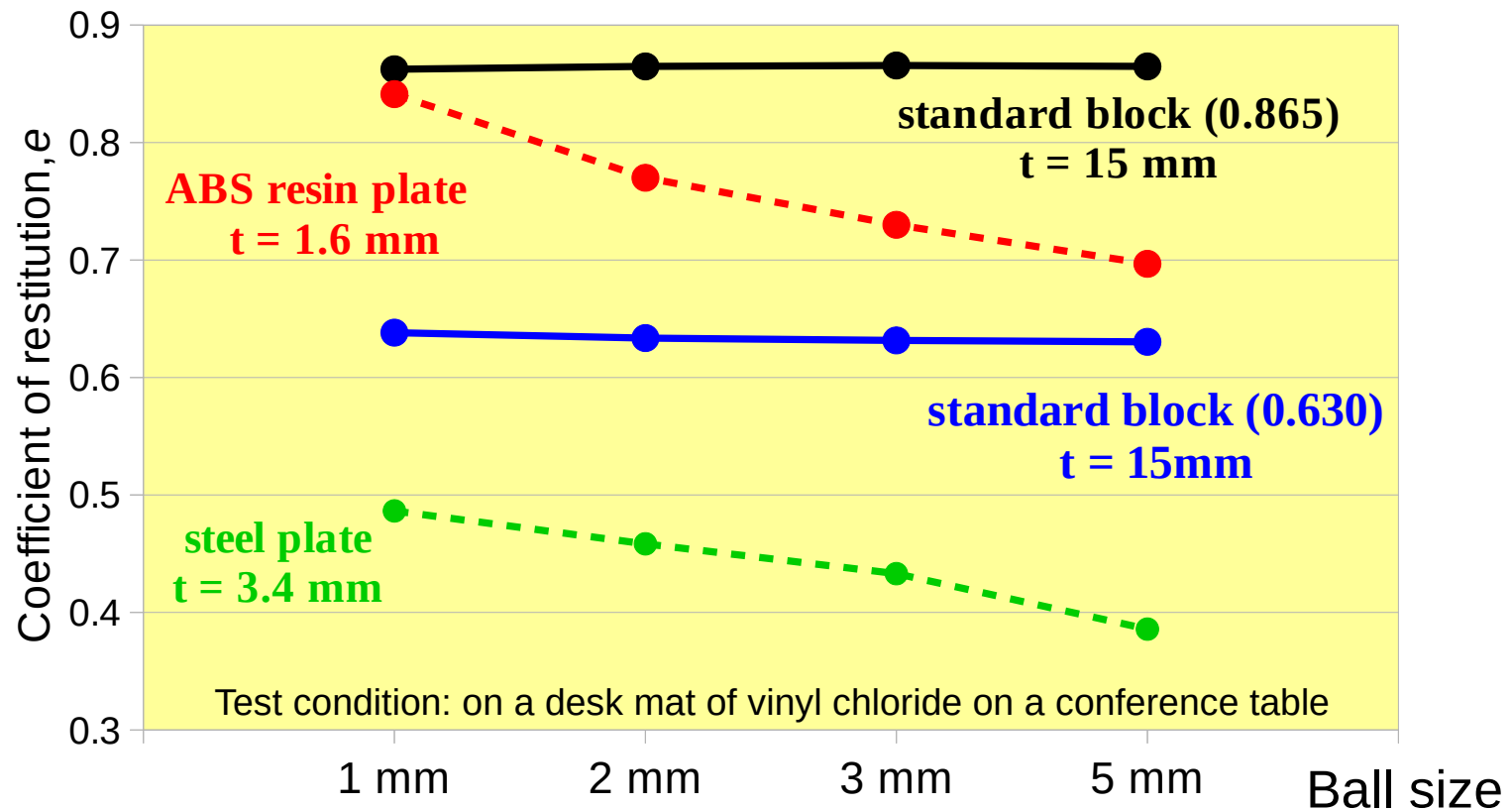
~ Testers with suitable ball size to be available ~



- Currently, eNM testers with ball size of 3 mm (product), and 1 mm, 2 mm, and 5 mm (all prototypes) has been manufactured.
- The smaller the ball, the smaller and thinner sample can be tested. Please refer to the next page.
- With the larger ball, test is less affected by surface roughness or unevenness.
- Coefficient of restitution dose *not* change with different ball sizes in principle. (Similarity law of hardness)

Ball size and coefficient of restitution

~ Tester with a smaller ball is suitable for thinner sample ~

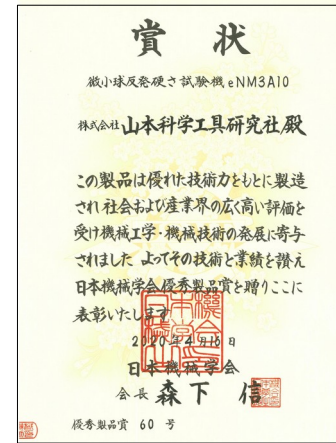


- Coefficient of restitution does *not* change with different ball sizes in principle. (Please refer to the solid lines of standard block data in the chart.)
- If the thickness of sample is sufficient (as a guide, more than 5 mm), you can obtain the correct coefficient of restitution with the 3 mm ball.
- To measure thinner sample correctly, you need smaller balls. (Please refer to the broken lines of thin plate data.)

Awards, applications, etc.

~ Awards and Certificates ~

- **Excellent Product Award of The Japan Society of Mechanical Engineers (2019)**
... Yamamoto Scientific Tool Laboratory
- Certified “Monodukuri” (manufacturing) products by Chiba Prefecture (2020.2.6)
... SHOU EI KOKI
- Certified “Monodukuri” Grand Prix Business by Funabashi City (2017) ... SHOU EI KOKI
- Verification Certificate [JIS B 7727:2000 annex 2 Shore hardness tester] by ClassNK (2018.2.26)
... Nakai Precision Machinery Mfg. Co., Ltd.
- Patent ... JP No.6624564 (2019.12.6) / US 10161839 (2018.12.25) / EP 3165897 (2023.7.19)
- Trademark ... Registered trademark JP 6182900 (2019.9.20)



~ Supported by ~

- Chiba Prefecture: Subsidies for Small and Medium Business (2011-2013) and “Monodukuri” Subsidies (2013) ... Yamamoto Scientific Tool Laboratory



~ Applications (updating) ~

- Polishing process management
- Heat treatment management
- Accident investigation
- Shipping inspection
- Deterioration diagnosis
- Research & Development

Development Team of Small Ball Rebound Tester

Members

- Koji Akatsu (FUTURE-TECH CORP.)
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- Koji Kadogawa (MCL)
- Masaki Koga (Koga PE Office)
- Koji Kojima (ITANI KOKI MFG.CO.,LTD.)
- Tadashi Sato (IMAI TESTING MACHINE)
- Ryoichi Sato (IMAI TESTING MACHINE)
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- Yoshiro Nakai
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- Tomio Minemura (FTS. , LTD)
- Kensuke Miyahara (NIMS)
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(Yamamoto Scientific Tool Laboratory)
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(Yamamoto Scientific Tool Laboratory)

(in Japanese syllabary order)

Contact

Sales Agencies (Development Team Members)

● IMAI TESTING MACHINE

<http://www.imatester.com/>



● Nakai Precision Machinery Mfg. Co., Ltd.

<http://www.nakaiseiki.co.jp/>



● SHOUUEI KOKI

<http://syoueikouki.co.jp/>



● FTS. , LTD

<http://www.fts-web.jp/>



● FUTURE-TECH CORP.

<http://www.ft-hardness.com/>



Distributors

● SANSHO KENMAZAI CO.,LTD.

<http://www.3sho.co.jp/other/enm3a10>



● SHIMADZU SCIENCE EAST CORPORATION. <https://www.sse-shimadzu.co.jp/>



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(Video in Japanese)
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