INTERNATIONAL STANDARD

ISO 12686

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Metallic and other inorganic coatings — Automated controlled shot-peening of metallic articles prior to nickel, autocatalytic nickel or chromium plating, or as a final finish

Revêtements métalliques et autres revêtements inorganiques — Grenaillage automatique de pièces métalliques avant dépôt électrolytique de nickel, dépôt autocatalytique de nickel, ou dépôt électrolytique de chrome, ou en tant que finition de surface

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 12686 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 3, *Electrodeposited coatings and related finishes*.

Annexes A to F form a normative part of this International Standard. Annex G is for information only.

Introduction

Shot-peening is a process for cold-working surfaces by bombarding the product with shot of a solid and spherical nature propelled at a relatively high velocity. In general, shot peening will increase fatigue life of a product that is subject to bending or torsional stress. It will improve resistance to stress-corrosion cracking. It can be used to form parts or correct their shapes. See annex G for additional information.

It is essential that the shot-peening process parameters be rigidly controlled to ensure repeatability from part to part and lot to lot.

This International Standard describes techniques and methods necessary for proper control of the shot peening process.

Metallic and other inorganic coatings — Automated controlled shot-peening of metallic articles prior to nickel, autocatalytic nickel or chromium plating, or as a final finish

1 Scope

This International Standard describes the requirements for automated, controlled shot-peening of metallic articles prior to electrolytic or autocatalytic deposition of nickel or chromium, or as a final finish, using shot made of cast steel, conditioned cut wire, ceramic shot or glass beads. The process is applicable to those materials on which test work has shown it to be beneficial within given intensity ranges. It is usually not suitable for brittle materials. Hand-peening and rotary flap-peening are specifically excluded.

Shot-peening induces residual compressive stresses in the surface and near surface layers of metallic articles, and changes the surface microstructure (including phase transformation), thereby controlling or limiting the reduction in fatigue properties that occurs from nickel or chromium plating of the article, or increasing the fatigue properties of unplated articles.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 565:1990, *Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings.*

ISO 2194:1991, *Industrial screens — Woven wire cloth, perforated plate and electroformed sheet — Designation and nominal sizes of openings.*

ISO 3310-1:1990, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth.*

ISO 3453:1984, *Non-destructive testing — Liquid penetrant inspection — Means of verification.*

ISO 6933:1986, *Railway rolling stock material — Magnetic particle acceptance testing.*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
Almen strip
UNS G10700 carbon steel specimens that are used to calibrate the energy of a shot-peening stream (see Figure 1)

3.2
Almen strip holding fixture
fixture for holding Almen strips in suitable locations that represent the position and angular orientation of the surfaces of a part where intensity is to be determined and verified (see Figure 2)

3.3
arc height
flat Almen strips which, when subjected to a stream of shot moving at an adequate velocity, will bend in an arc corresponding to the amount of energy transmitted by the shot stream

NOTE The height of the curved arc measured in millimetres is the arc height, measured by an Almen gauge (see Figure 3).

3.4
automatic equipment
shot-peening equipment in which parts, fixtures, nozzles and peening parameters are preset by hand or by locating fixtures and verified by inspection personnel

NOTE Peening time is monitored automatically and air pressure or wheel speed is set manually.

3.5
residual compressive stresses
layer in compression below the surface created by cold-working or stretching the surface beyond the elastic limit by shot-peening

NOTE The depth of compressive stresses is measured from the crown of the dimple to the depth.

3.6
coverage
extent of obliteration of the original surface by dimples produced by impact from individual shot particles, expressed as a percentage

NOTE 100 % coverage is defined as that leaving 2 % or less of the original surface unpeened because the estimation of coverage of the impressions is difficult when this is about 98 % of the total surface. "100 % coverage" is a theoretical limiting value. Hence, the term "complete coverage" is preferred. Usually, complete coverage requires increasing the base time, i.e. the time of peening to reach 98 % coverage, by 15 % to 20 %. Values of 200 % to 300 %, etc. are obtained by multiplying this run time by 2, 3, etc.

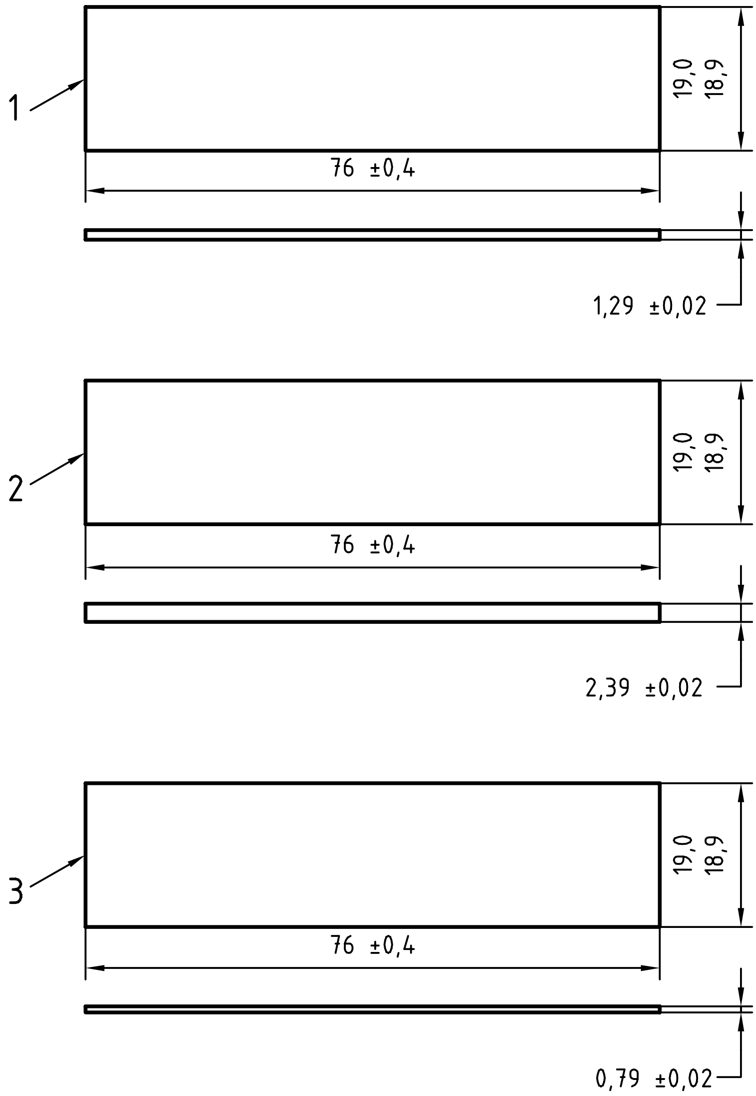
3.7
depth of compressive stresses
where the stress profile passes through zero stress

3.8
shot peening intensity
Almen strip arc height at saturation

NOTE Arc height is not correctly termed intensity unless saturation is achieved.

3.9
liquid tracer system
liquid coating material bearing a pigment that fluoresces under an ultraviolet light and is removed at a rate proportional to peening coverage

Dimensions in millimetres



Key

1 Test strip A

2 Test strip C

3 Test strip N

NOTES

Analysis of stock: UNS G10700

Cold-rolled spring steel

Square edge number one (on 76,2 mm edge)

Finish: blue temper (or bright)

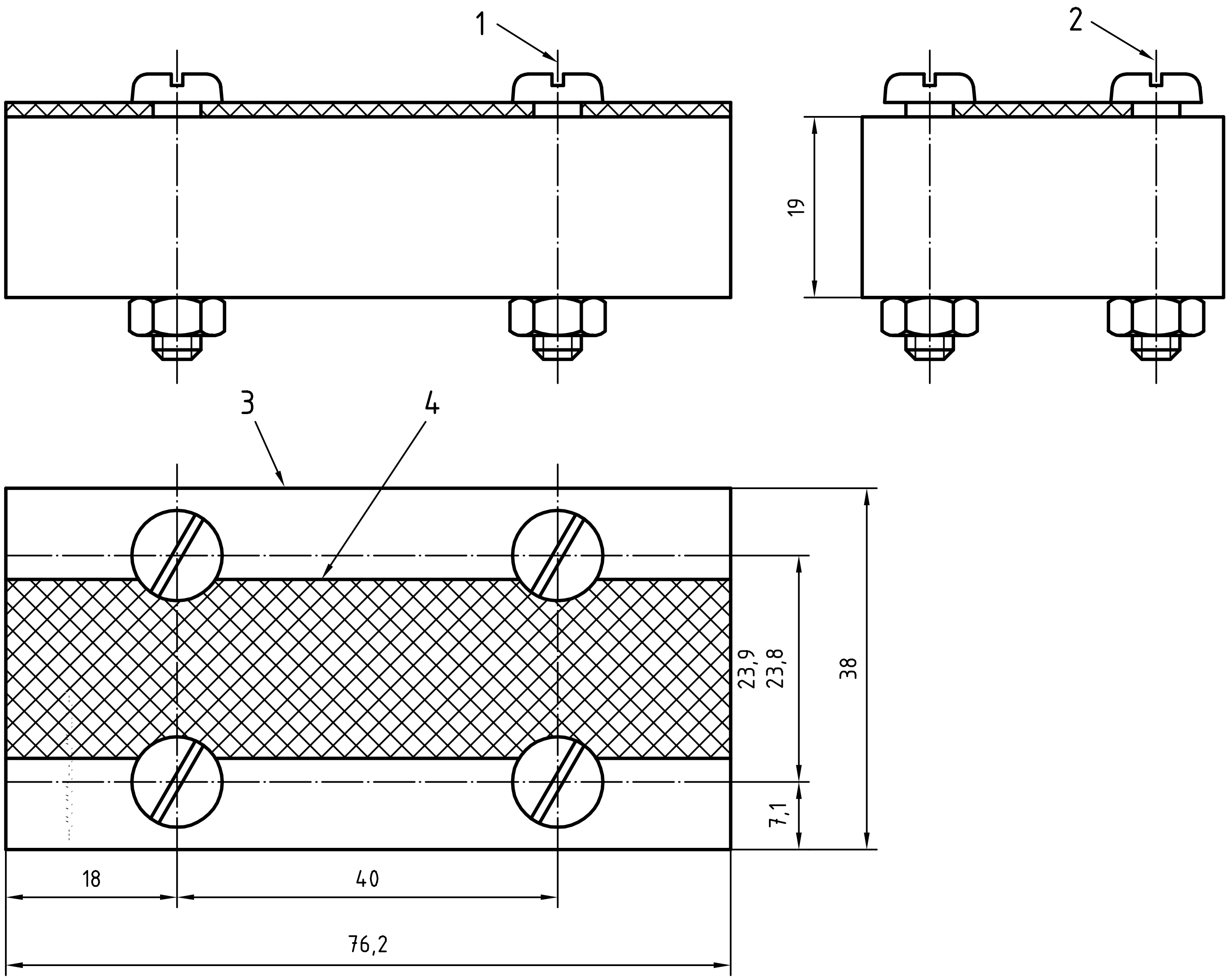
Uniformly hardened and tempered to 44 HRC to 50 HRC

Flatness C ± 0,038 mm arc height

Flatness N and A ± 0,025 mm arc height

Figure 1 — Almen test specimen

Dimensions in millimetres



Key

1 Four M5 pan head machine screws with hexagonal nuts

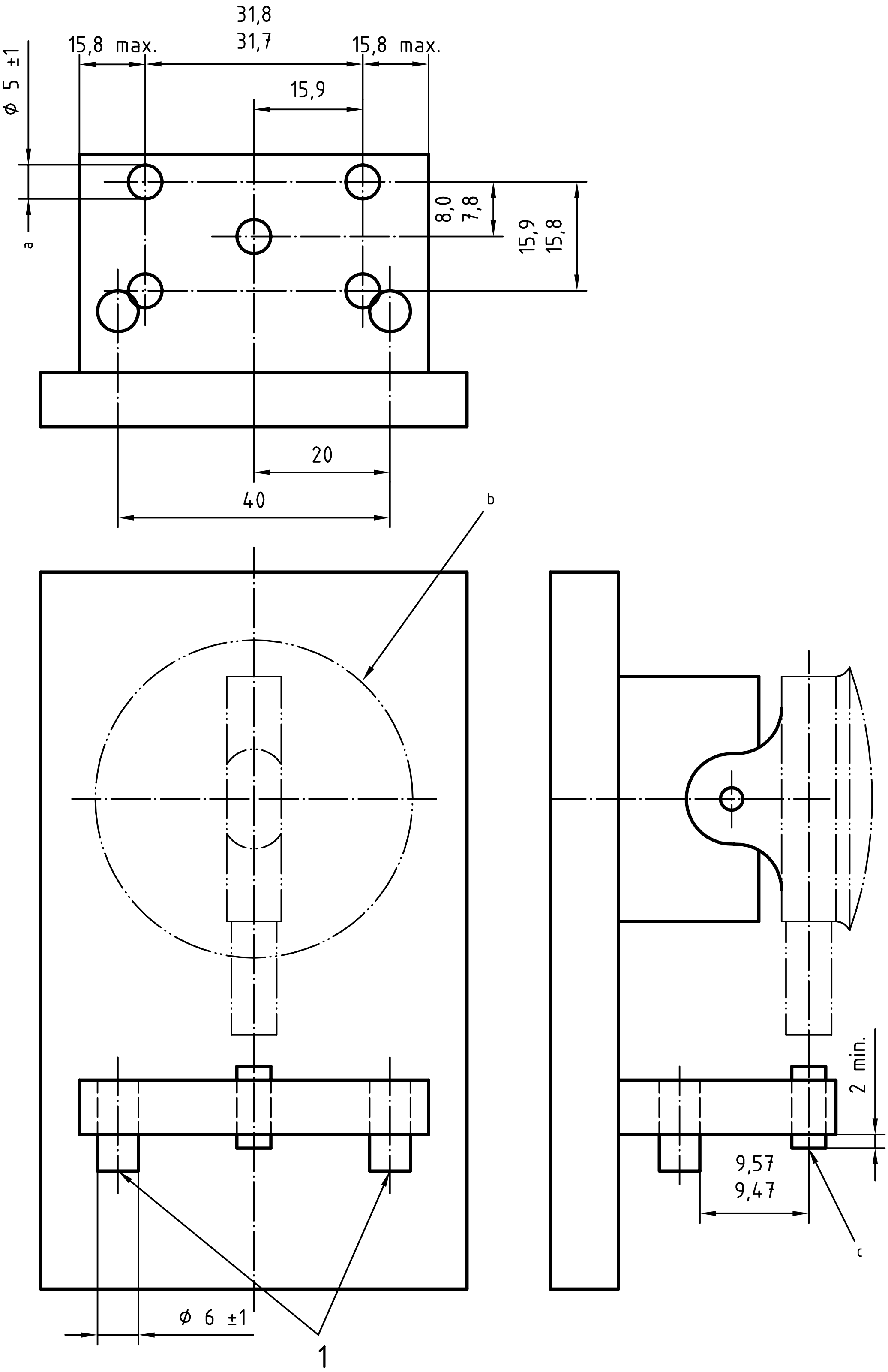
2 Four holes of diameter 5,6 mm

3 Holder

4 Test strip (sectioned)

Figure 2 — Assembled test strip and holder

Dimensions in millimetres



a Four hardened steel balls

b Dial indicator to be graduated in values of 0,025 mm (0,025 4 mm permitted); maximum extension force 25 gf

c Contact surface of all balls to be in one plane ± 0,05 mm

Key

1 Guides

Figure 3 — Almen gauge

3.10
microprocessor-controlled equipment
peening equipment that has nozzle-holding fixtures and is computer-controlled for processing, monitoring and documentation of the peening parameters critical to process certification

3.11
nozzle-holding fixture
fixture that holds the nozzles at the required location, distance and angle in a locked position during the peening operation

3.12
process-interrupt parameters
for critical peening operations, parameters such as shot flow, air pressure, rotational speed of parts (s^{-1}), oscillation rate and cycle time that must be monitored within process requirements

3.13
saturation
minimum duration of peening necessary to achieve the desired Almen intensity which, when doubled, does not increase the Almen strip arc height by more than 10 %

3.14
saturation curve
curve that plots peening time on the Almen strip (abscissa) versus Almen strip arc height (ordinate) achieved for the peening time (see Figure 4)

3.15
surface obliteration
condition of a peened surface in which 100 % of the surface has been dimpled with shot impressions

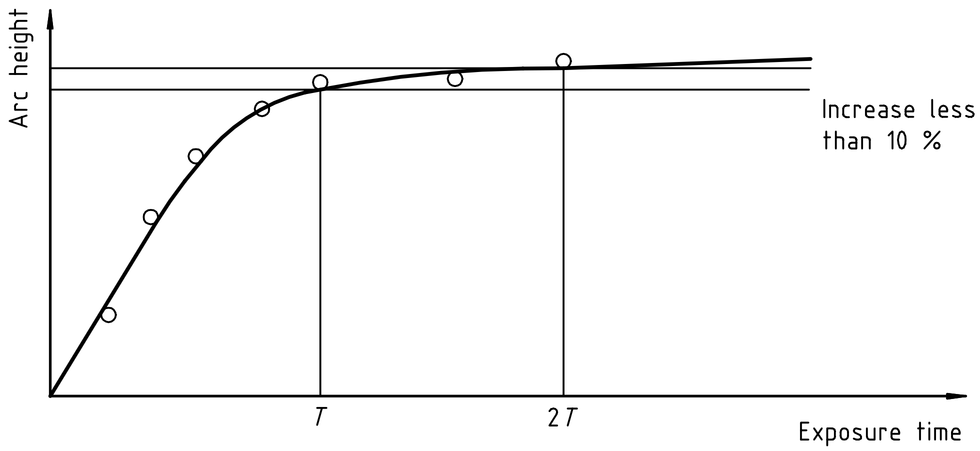


Figure 4 — Saturation curve

4 Materials and equipment

4.1 Shot material composition

4.1.1 Cast steel shot, conforming to the requirements given in annex B.

4.1.2 Cut wire shot, made from cold-finished, round wire, conforming to annex C.

4.1.3 Ceramic shot (beads), conforming to the chemical composition given in Table 1 and in annex D.

4.1.4 Glass beads, free from lead and free silica and maintained dry and free from any surface contamination or dressings. Glass beads shall have a nominal composition of 72,5 % SiO_2, 9,75 % CaO, 13 % Na_2O, 3,3 % MgO, 0,75 % of other minor elements and a specific gravity of 2,5 g/cm^3.

Table 1 — Composition of ceramic shot

ZrO_2 %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	Free iron %	Specific gravity g/cm^3
60 to 70	28 to 33	10 max	0,1 max.	0,1 max.	3,6 to 3,95

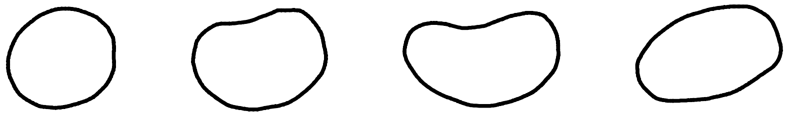
4.2 Shot form and shape

4.2.1 Cast steel

Cast steel shot shall be spherical after pre-conditioning and free from sharp edges, corners and broken pieces. It shall conform to the acceptable shapes given in Figure 5. The number of nonconforming shapes (see Figure 6) shall not exceed the values given in Table 2.

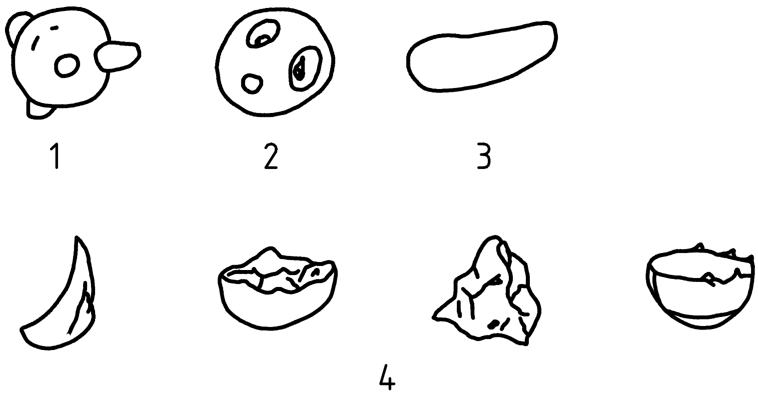
Table 2 — Maximum allowable nonconforming shapes — cast steel, cut wire and ceramic shot (as shown in Figure 6)

Cast steel size	Cut wire size	Ceramic size	Maximum allowable nonconforming shapes per area (1 cm X 1 cm)
930			5
780			5
660	CW62		12
550	CW54		12
460	CW47		15
390	CW41		80
	CW35		80
330	CW32	Z850	80
280	CW28		80
230	CW23	Z600	80
190	CW20		80
170		Z425	80
130			480
110		Z300	640
70		Z210	640



Not necessarily spheres but all corners rounded

Figure 5 — Acceptable shapes



Key

1 Nodulated shot
2 Hollow shot
3 Elongated shot
(1 to 3: see Table 2; diameter to length ratio > 1:2)

4 Broken, sharp-cornered shot (see Tables 4, 6 and 7)

Figure 6 — Unacceptable shapes

4.2.2 Cut wire

Cut wire shot shall be spherical after pre-conditioning. It shall be free from sharp edges, corners and broken pieces. The number of nonconforming shapes shall not exceed the values given in Table 2.

4.2.3 Ceramic shot

Ceramic shot shall be spherical and free from sharp edges, corners and broken pieces. The number of nonconforming shapes shall not exceed the values given in Table 2.

4.3 Hardness

The hardness of the shot shall exceed that of the material to be processed.

4.3.1 Cast steel

Cast steel shot shall have a hardness of HRC 45 to HRC 55. Special hard cast steel shot shall be used on products harder than HRC 50 and shall have a hardness of HRC 55 to HRC 65.

4.3.2 Cut wire

Cut wire shot shall have a hardness equal to or greater than that given in Table 3.

Table 3 — Hardness, cut wire shot

Shot size	Minimum hardness Rockwell C
CW 62	36
CW 54	39
CW 47	41
CW 41	42
CW 35	44
CW 32	45
CW 28	46
CW 23 and finer	48

4.3.3 Ceramic shot

Ceramic shot shall have a minimum hardness of 560 HV 30 (30 kgf).

4.3.4 Glass beads

Glass beads shall have a hardness of 5,5 on the Moh scale.

4.4 Size

The size of the shot shall conform to the following :

a) the size of the shot shall be capable of producing the required intensity in the required time;

b) if a peened surface contains a fillet, the nominal size of the shot shall not exceed one-half of the radius of the fillet;

c) if the shot must pass through an opening, such as a slot, to reach a peened surface, the nominal size of the shot shall not exceed one-fourth of the width of the diameter of the opening.

4.4.1 Cast steel

Cast steel shot charged into a machine shall conform to the screen requirements given in Table 4 for the nominal size selected. Sieves shall be in accordance with ISO 565, ISO 2194 and ISO 3310-1.

Table 4 — Screen size, cast steel shot (as shown in Figure 6)

Size of shot	**All pass screen size** mm	**Maximum 2% on screen** mm	**Maximum 50% on screen** mm	**Cumulative 9% on screen** mm	**Maximum 8% on screen** mm	**Maximum number of deformed shot acceptable per area** (1 cm X 1cm)
930	4,000	3,350	2,800	2,360	2,000	5
780	3,350	2,800	2,360	2,000	1,700	5
660	2,800	2,360	2,000	1,700	1,400	12
550	2,360	2,000	1,700	1,400	1,180	12
460	2,000	1,700	1,400	1,180	1,000	15
390	1,700	1,400	1,180	1,000	0,850	20
330	1,400	1,180	1,000	0,850	0,710	80
280	1,180	1,000	0,850	0,710	0,600	80
230	1,000	0,850	0,710	0,600	0,500	80
190	0,850	0,710	0,600	0,500	0,425	80
170	0,710	0,600	0,500	0,425	0,355	80
130	0,600	0,500	0,425	0,355	0,300	480
110	0,500	0,425	0,355	0,300	0,180	640
70	0,425	0,355	0,300	0,180	0,125	640

When a machine has a completely new charge of cast steel shot, conditioning shall be carried out to remove the oxide layers on the shots, by bombarding on to a hardened steel surface for a minimum of 2 passes. Conditioning may not be required if the addition to the charge already in the machine is less than 25 %. If the addition of more than 25 % is made to the charge, conditioning is required.

4.4.2 Cut wire

The diameter of cut wire shot charged into a machine shall conform to the requirements listed in Table 5. Cut wire shot shall conform to the requirements of length and cumulative weight in Table 5. It is mandatory that only preconditioned cut wire shot be used. As an alternative, cut wire shot may have the same size designations as the cast shot described in Table 4.

4.4.3 Ceramic shot

Ceramic shot charged into the peening machine shall conform to the screen requirements listed in Table 6.

Table 5 — Cut wire shot — Size, length and weight

Shot number	Wire diameter mm	Length of 10 pieces [a] mm	Weight of 50 pieces [b] g
CW-62	1,587 ± 0,051	15,75 ± 1,02	1,09 to 1,33
CW-54	1,372 ± 0,051	13,72 ± 1,02	0,72 to 0,88
CW-47	1,194 ± 0,051	11,94 ± 1,02	0,48 to 0,58
CW-41	1,041± 0,051	10,41 ± 1,02	0,31 to 0,39
CW-35	0,889 ± 0,025	8,89 ± 1,02	0,20 to 0,24
CW-32	0,813 ± 0,025	8,13 ± 1,02	0,14 to 0,18
CW-28	0,711 ± 0,025	7,11 ± 1,02	0,10 to 0,12
CW-23	0,584 ± 0,025	5,84 ± 1,02	0,05 to 0,07
CW-20	0,508 ± 0,025	5,08 ± 1,02	0,04 to 0,05

[a] Shot particles to be checked for length shall be mounted and ground and polished to expose a central longitudinal section. The combined length of 10 random selected particles shall be within the tolerance shown above.

[b] At the discretion of the supplier, the particles may be weighed instead of mounted and measured as stated in a) above. When weighed, the total weight of 50 randomly-selected particles shall be within the limits specified above.

Table 6 — Sizes of fused ceramic beads for peening (as shown in Figure 6)

Designation		**Nominal sizes** mm		**Sieve number and screen opening size in mm**				**Minimum % beads with sphericity > 0,8**	**Maximum No. of beads with sphericity < 0,5**	**Maximum No. of broken or angular beads**
Ceramic size [a]	Shot size	min.	max.	maximum 0,5 % retains	maximum 5% retains	maximum 10 % pass	maximum 3 % pass	(% of true spheres)	acceptable per area 1cm X 1cm	acceptable per area 1 cm X 1 cm
Z 850	330	0,85	1,18	14 (1,400)	16 (1,100)	20 (0,850)	25 (0,710)	65	4	2
Z 600	230	0,60	0,85	18 (1,000)	20 (0,850)	30 (0,600)	40 (0,425)	65	8	4
Z 425	170	0,425	0,600	25 (0,710)	30 (0,600)	40 (0,425)	50 (0,300)	70	14	8
Z 300	110	0,300	0,425	35 (0,500)	40 (0,425)	50 (0,300)	60 (0,250)	70	27	15
Z 210	70	0,212	0,300	45 (0,335)	50 (0,300)	70 (0,212)	80 (0,180)	80	45	20
Z 150	GP60	0,150	0,212	60 (0,250)	70 (0,212)	100 (0,150)	120 (0,125)	80	300	65

[a] Designated number for ceramic is minimum bead diameter (in mm) X 1 000 mm.

4.4.4 Glass beads

Glass beads shall conform to the screening requirements listed in Table 7.

Table 7 — Sizes of glass beads for shot peening

Dimensions in millimetres

Nominal diameter	100 % by weight passing mesh size	Maximum 2 % by weight retained on mesh size	Maximum 8 % by weight passing mesh size	0 % passing mesh size
0,85	1	0,85	0,6	0,5
0,71	0,85	0,71	0,5	0,425
0,6	0,71	0,6	0,425	0,355
0,5	0,6	0,5	0,355	0,3
0,425	0,5	0,425	0,3	0,25
0,355	0,425	0,355	0,25	0,212
0,3	0,355	0,3	0,212	0,18
0,25	0,3	0,25	0,18	0,15
0,212	0,25	0,212	0,15	0,125
0,18	0,212	0,18	0,125	0,106
0,15	0,18	0,15	0,106	0,09
0,125	0,15	0,125	0,090	0,075
0,106	0,125	0,106	0,075	0,063
0,09	0,106	0,09	0,063	0,053
0,075	0,09	0,075	0,053	0,045
0,063	0,075	0,063	0,045	0,036
0,053	—	—	—	—

4.5 Almen strips, blocks and gauges

Almen strips, blocks and gauges used shall follow the details shown in Figures 1 to 3. See annex E for additional information.

4.6 Equipment

Shot-peening shall be done in a machine that is designed for the purpose, that propels shot at high speed against the product, that moves the product through the shot stream in a way that assures complete and uniform peening, and that continuously screens the shot to remove broken or defective shot.

5 Ordering information

When ordering articles to be shot-peened, the purchaser shall state the following:

a) the number of this International Standard, i.e. ISO 12686;

b) the type, size and hardness of shot to be used (see clause 4);

c) the number and frequency of determinations of shot size and uniformity required, if other than those specified in 7.1;

d) the peening intensity to be used at each location (see 7.2);

e) the number, frequency and locations of Almen test specimens to be provided for intensity verification and monitoring of the process if other than those specified in 7.2, 7.2.1 and 7.2.2;

f) the areas on the part that are to be shot-peened and those that are to be protected from the peening (see 6.5);

g) whether magnetic particle or penetrant inspection is required before peening (see 6.2);

h) the percentage coverage required in areas to be peened, complete coverage being the minimum requirement (see 3.6 and 7.3);

i) the method for measuring coverage (see 7.3);

j) the type of equipment to be used — automated or computer monitored microprocessor (see 4.3, G.10, G.11, and G.12);

k) the details of any post treatment such as corrosion protection (see 8.5);

l) the requirements of certification and test records as specified in clause 9.

6 Pre-peening treatment

6.1 Prior operations

Areas of parts to be shot-peened shall be within dimensional requirements before peening. Except as otherwise permitted, all heat treatment, machining and grinding shall be completed before shot-peening. All fillets shall be formed, all burrs shall be removed and all sharp edges and corners that require peening shall be provided with sufficient radii prior to peening in order to ensure complete coverage without any distortion, chipping or roll-over.

6.2 Flaw and crack testing

Magnetic particle, dye penetrant, ultrasonic or other flaw or crack detection processes, when required, shall be completed prior to peening. See ISO 3453 and ISO 6933.

6.3 Corrosion and damage

Parts shall not be peened if they show evidence of invasive corrosion or mechanical damage on the surface.

6.4 Cleaning

Cleaning prior to peening shall be accomplished by vapour degreasing, solvent wiping, warm solvent spray or acceptable water-base nonflammable product as required to remove all soils, scale and coatings from the surface areas to be peened. See [8] to [11].

6.5 Masking

Surfaces designated on the drawing to be free of shot-peening marks shall be masked or otherwise protected from the shot stream or indirect impingement by shot.

Suitable masking materials are adhesive tape, sheet rubber, etc. If adhesive tape is used, it shall be coated with adhesive on one side and when the tape is removed from the surface it shall not show any evidence of corrosion or leave any residue on the surface. Areas not requiring peening and not required to be masked shall be considered optional.

7 Procedure

7.1 Shot

7.1.1 General

Shot charged into the peening machine shall be as specified by the purchaser and meet the requirements given in 4.1 for the particular type, size and material required.

Unless otherwise specified, all shot shall be maintained in the machine so that it conforms to the requirements given in Table 8.

7.1.2 Uniformity determination

At least one determination for shot size and uniformity shall be made, according to data given in Table 8, before and after each production run or after each 8 h stint of production on long runs when using cast or cut wire steel shot. When the process conditions for a particular run differ from those of a previous run, shot size and distributions checks may have to be made more frequently than every 8 h. Ceramic shot size distribution shall be verified at least every 4 h of production and before and after each production run. The size distribution and uniformity of glass beads shall be verified every 2 h.

7.2 Peening intensity

7.2.1 General

The peening intensity shall be that specified by the purchaser as the arc height produced by the peening process at saturation as measured on Almen strips placed in the required locations. Unless otherwise specified on the drawing or in the contract, the intensity of peening shall be as specified in Table 9 for the thickness involved.

7.2.2 Saturation curve

For initial process development, a saturation curve shall be generated for each location where intensity is to be varied.

7.2.3 Intensity determination

At least one intensity determination for all required locations shall be made immediately before and after each production run and at least every 8 h of continuous running. The intensity determination is also required after any replacement of shot, a new setting of the machine or any other change of setting of the machine, or any event that may affect the shot-peening operations.

7.3 Peening coverage

7.3.1 General

Peened surfaces shall be uniform in appearance and shall be completely dented so that the original surface is entirely obliterated. With the smallest sizes of steel shot, 70 and 110, and with all sizes of ceramic and glass beads, complete obliteration of the original surface may not be achieved despite 100 % coverage. The extent (as a percentage) of coverage shall be specified by the purchaser.

7.3.2 Coverage determination

Unless otherwise specified, at least one coverage determination for all areas requiring peening shall be made for every 8 h of continuous running. Coverage shall be determined by either of the following methods, as specified by the purchaser:

a) visual examination using a ten-power magnifying glass;

NOTE This procedure is not recommended for large areas.

b) visual examination using an approved impact sensitive liquid fluorescent tracer system in accordance with the manufacturer's recommendations. Alternatively, use of a dye, e.g., engineer’s blue, on a selected portion of one batch processed every 8 h may be used to determine coverage. Peening coverage is verified by complete removal of the dye.

7.4 Computer-monitored equipment

When auxiliary computer-monitored equipment is used for shot peening, calibration of the monitored systems shall be in accordance with annex F. Intensity verification, as given in 7.2, shall be done prior to initial operation and after calibration.

Table 8 — Shot maintenance and form maximum allowable nonconforming (as shown in Figure 6)

Size of shot	Maximum 2 % on screen mm	Maximum 80 % on screen mm	Maximum allowable nonconforming shapes per area 1 cm X 1 cm
930	3,353	2,38	5
780	2,819	1,999	5
660	2,38	1,679	12
550	1,999	1,41	12
460	1,679	1,191	15
390	1,41	1	80
330	1,191	0,841	80
280	1	0,711	80
230	0,841	0,589	80
190	0,711	0,5	80
170	0,589	0,419	80
130	0,5	0,351	480
110	0,419	0,297	640
70	0,351	0,178	640

Table 9 — Intensity versus thickness and ultimate tensile strength

Dimensions in millimetres

Material [a]	Steel under 1 380 MPa	Steel over 1 380 MPa	Aluminum alloys (stainless steel shot)
thickness $< 2,5$	—		
$2,5 \leqslant$ thickness $\leqslant 10$	0,2 to 0,3 A [b]	0,15 to 0,25 A	0,15 to 0,25 A
thickness > 10	0,3 to 0,4 A [c]	0,15 to 0,25 A	0,25 to 0,35 A

[a] Magnesium alloys' response to shot-peening is different from the response of other materials. It is essential to avoid broken or deformed peening material. Peening must be done with materials and under conditions that do not cause cracks.

[b] The suffix letter A, indicates that the values have been determined by the use of test strip A.

[c] Test strip A is used for arc heights up to 0,6 mm A. For greater peening intensity test strip C should be used. Test strip N is used if the intensity is less than 0,1 mm A.

8 Post-peening treatment

8.1 Residual shot removal

After shot-peening and removal of protecting masks, all shot and shot fragments shall be removed from surfaces of articles by methods that will not erode, scratch or degrade the surface in any way.

8.2 Surface finish improvement

It is permissible to improve the surface finish of a component after shot-peening by polishing, lapping, or honing provided that the surface temperature is not sufficiently raised to relax the compressive stresses and the amount of material removed is less than 10 % of the depth of the compressive layer induced by peening.

8.3 Nonferrous metals

Nonferrous metals and their alloys that have been shot-peened shall be cleaned by an approved chemical cleaning solution to remove all iron contaminants. Cleaning operations shall not degrade the surface or alter the dimensions of the part. Cleaned surfaces shall be chemically tested for freedom from residual iron by the method given in annex A. Shot used for peening ferrous materials shall not be re-used for treating nonferrous metals and alloys.

8.4 Thermal and mechanical treatment limits

No manufacturing operations that relieve compressive stresses or that develop detrimental residual stresses shall be permitted after shot-peening. When parts are heated after shot-peening, such as for baking of paint or protective coatings, embrittlement relief after electroplating or other thermal treatment, the temperatures employed shall be limited as shown in Table 10.

8.5 Protection from corrosion

Shot-peened parts shall be protected from corrosion during processing and until final preservation and packaging are complete. All shot-peened parts shall be preserved, wrapped or packaged, as specified by the purchaser, in order to ensure protection from corrosion and damage during handling, transportation and storage.

Table 10 — Thermal treatment limits

Material	Maximum temperature °C
Steel parts	230
Aluminium alloy parts	93
Magnesium alloy parts	93
Titanium alloy parts	315
Nickel alloy parts	538
Corrosion- resistant steel parts	315

9 Certification and test records

When specified in the purchase order or contract, the manufacturer's or supplier's certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished. When specified in the purchase order or contract, test strip specimens and test records shall accompany peened parts, and shall be inspected along with the appropriate lot. The following information shall be recorded for each specimen:

a) lot number and other production control numbers;

b) part number;

c) number of parts in lot;

d) date peened;

e) shot-peening machine used and machine setting;

f) specified peening intensity and actual peening intensity by test strip identification numbers if test fixture requires use of more than one strip;

g) shot size, type, hardness, standoff (distance), length of time of exposure to shot stream, and shot flow rate;

h) percent coverage;

i) shot velocity or air pressure.

Annex A
(normative)

Freedom from iron contamination test

A.1 Purpose

The purpose of this test is to detect contamination by iron residues on the surfaces of aluminium and its alloys, corrosion resistant and heat resistant alloys, etc.

A.2 Materials

A.2.1 Hydrochloric acid, 5 % (*V*/*V*) aqueous solution.

A.2.2 Potassium hexacyanoferrate(III) (potassium ferricyanide), 10 % (*m*/*m*) aqueous solution.

A.2.3 Degreasing agent, e.g. propanol-2 (iso-propyl alcohol).

A.2.4 Filter paper.

A.3 Procedure

Degrease the area to be tested by wiping with an appropriate solvent (A.2.3). Place a drop of the hydrochloric acid solution (A.2.1) on the degreased surface and leave for approximately 2 min. Wet a filter paper (A.2.4) with a drop of potassium hexacyanoferrate(III) solution (A.2.2) and place it on the area of the part wetted with the hydrochloric acid solution. Rinse the area with water.

A.4 Result

A deep blue colour on the filter paper indicates the presence of iron. On some alloys, a pale blue colour may be observed in the absence of iron residues. For comparison purposes, it is advisable to prepare a sample that is known to be free from iron contamination.

Annex B
(normative)

Cast steel shot

B.1 Description

Cast steel shot is the product obtained by atomizing molten steel into random sizes and quenching, with subsequent screening and heat treating, to the hardness desired. See standard SAE J 287 [12].

B.2 Identification

Cast steel shot shall be identified by prefix letters CS followed by the appropriate shot number.

EXAMPLE

CS 330 indicates cast steel shot identified by a nominal screen aperture of 0,033 1 in.

B.3 Chemical composition

In general the chemical composition shall conform to the following:

- Carbon: 0,85 % to 1,20 %
- Manganese: 0,60 % to 1,20 %
- Phosphorus: 0,050 % max.
- Sulfur: 0,050 % max.
- Silicon: 0,40 % min.

B.4 Microstructure

The microstructure of cast steel shot shall be uniformly tempered martensite with fine, well-distributed carbides, if any. Carbide networks, transformation products, decarburized surfaces, inclusions, porosity and quench cracks are undesirable.

B.5 Density

Cast steel shot shall not be more than 7 g/cm^3 and shall not contain more than 10 % hollows. The method of determining density may be a displacement method or an actual count of the hollows in a mounted, polished specimen.

B.6 Mechanical tests

Several designs of shot testing machine are available commercially for application to routine acceptance procedures. The standard SAE J 445a [14] may be consulted for methods of checking uniformity of shipments of shot or to determine the relative fatigue life of different types of shot.

B.7 Inspection procedure

Samples for chemical analysis, hardness, microstructure and density (if checked by a displacement method) shall be at least 100 g each as obtained from a representative sample of each shipment.

Shot particles to be checked for hardness and microstructure shall be mounted in plastic and ground and polished to the centreline, care being taken to prevent work hardening of the polished surface. At least 10 hardness readings shall be taken at random.

A count of hollows may be taken from a representative portion or from all of a polished specimen prior to etching for examining microstructure.

A simple method for determining density by displacement is as follows.

Using a 100 ml burette, fill burette with water to 50 ml mark. Add 100 g of shot. Note rise in water level. Divide volume of shot as shown by water displaced, into the weight of shot. This will give the apparent density of the shot.

For critical density measurements, a pycnometer method for determining true density is recommended.

Annex C
(normative)

Wire shot

C.1 Description

Cut wire shot shall be the product of carbon steel wire or stainless steel wire type 302, 304, condition B, spring temper, cut into the form of cylinders with lengths approximately equal to the wire diameter. See standard SAE J 441 [13]. Conditioned cut wire shot with cut edges pre-rounded may be specified when required for special applications.

C.2 Classification and identification

All cut wire shot shall be classified according to the wire size from which it is obtained. It shall be identified by the prefix letters CW meaning cut steel wire or SCW meaning stainless cut wire. This designation shall be followed by a suffix number equivalent to the mean diameter of the wire from which the shot is produced.

C.3 Chemical composition

The chemical composition shall conform, in general, to the following specification:

a) Steel

carbon:	0,45% to 0,75%
manganese:	0,60% to 1,20%
phosphorous:	0,045% max.
sulfur:	0,050 % max.
silicon:	0,10 % to 0,30%

b) Stainless steel

carbon:	0,15 % max.
manganese:	2,00 % max.
phosphorous:	0,045 % max.
sulfur:	0,030 % max.
silicon:	1,0 % max.
chromium:	17,00 % to 20,00%
nickel:	8,00 % to 11,00 %

C.4 Tensile properties

Shot shall be made from wire conforming to the tensile strengths given in Table C.1.

C.5 Size classification

Cut wire shot shall be made from wire of the diameters given in Table C.1. Shot sizes varying from those shown are available and may be obtained by arrangement between the shot manufacturer and user.

C.6 Soundness

Shot particles shall be free of shear cracks and laps and shall not contain excessive seams or burrs.

Table C.1 — Tensile properties of cut steel wire shot

Shot size	Mean wire diameter		Tensile strength – Steel wire		Tensile strength – Stainless wire	
	mm	in	MPa	klbf/in^2	MPa	klbf/in^2
CW.62	1,6	0,062	1 630 to 1 880	237 to 272	1 758 to 1 965	255 to 285
CW.54	1,4	0,054	1 680 to 1 920	243 to 279	1 793 to 1 999	260 to 290
CW.47	1,2	0,047	1 710 to 1 970	248 to 286	1 806 to 2 013	262 to 292
CW.41	1	0,041	1 760 to 2 020	255 to 293	1 855 to 2 062	269 to 299
CW.35	0,9	0,035	1 800 to 2 080	261 to 301	1 882 to 2 089	273 to 303
CW.32	0,8	0,032	1 830 to 2 110	266 to 306	1 910 to 2 117	277 to 307
CW.28	0,7	0,028	1 870 to 2 140	271 to 311	1 972 to 2 179	286 to 316
CW.23	0,6	0,023	1 920 to 2 200	279 to 319	2 013 to 2 220	292 to 322
CW.20	0,5	0,02	1 950 to 2 230	283 to 323	2 068 to 2 275	300 to 330

Annex D
(normative)

Characteristics of ceramic shot

D.1 Scope

This annex covers characteristics for chemistry, microstructure, density, shape and appearance of zirconium oxide based ceramic shot, suitable for peening surfaces of parts by impingement. See Standard SAE J 1830 [15].

D.2 Chemical composition

The details of the composition of ceramic shot are given in Table 1.

The free iron content of the ceramic shot sample shall not exceed 0,10 % (*m*/*m*). It is determined by slowly sprinkling 500 g of the sample ceramic bead shot on to an inclined aluminum tray that is 1,6 mm (0,062 in) deep X 152 mm (6 in) wide X 305 mm (12 in) long. The tray is supported by a nonmagnetic frame so that it is inclined with a 152 mm (6 in) rise from end to end (30^{o} from horizontal). Four 25 mm X 25 mm X 152 mm (1 in X 1 in X 6 in) bar magnets shall be positioned against the under surface and crosswise to the inclined tray at about the middle of its length. Magnets shall be not less than 10 000 Gs magnetic field each and arranged so that the magnetic north and south poles alternate. The magnetic particles (iron) that accumulate on the tray, as the beads roll down, shall be carefully brushed into a pre-weighed dish. The procedure shall be repeated with the same 500 g sample until all visible magnetic particles are collected. The dish shall then be reweighed and the magnetic particle content calculated as a percentage of the total original sample.

D.3 Microstructure

Ceramic shot shall be manufactured by electric fusion of oxides to form a closely-bonded internal structure of a crystalline zirconia phase within an amorphous silica phase.

D.4 Density

This characteristic is closely related to chemical analysis. It shall range between 3,60 g/cm^3 and 3,95 g/cm^3 (see Table 1).

Density shall be measured at 31 ^{o}C by a pycnometric method.

D.5 Shape

D.5.1 General

Sphericity and roundness shall be measured by an actual counting of a one-layer field of a minimum of 200 ceramic beads at a magnification of X 20.

D.5.2 Sphericity

This refers to the ratio of short to long axes of the hypothetical ellipse that would contain the actual image of the ceramic bead as seen through a microscope.

D.5.3 Roundness

This refers to the relative angularity of grain corners, the ceramic shot having round and smooth surfaces. Scored, broken or angular particles are those that would present sharp or angular surfaces when impacted, causing metal removal or unsatisfactory or irregular finishes. An actual count shall be made of a field of 1 cm^2 at a X 20 magnification. Maximum number of permissible broken or angular beads is shown in Table 6. This number shall never exceed 3 %.

D.6 Appearance

Ceramic shot shall be constant in colour, free flowing, free of defects and free of foreign matter.

D.7 Quality assurance

Ceramic shot quality is checked by lots of 1 000 kg maximum. A representative sample of the shipped lot shall be tested for conformance to all requirements of this specification. Lot number and this specification number shall be marked on each container unit. All control data shall be available from the manufacturer upon request for 2 years after shipment.

Annex E
(normative)

Almen strip, holder and gauge

E.1 Outline of method of control

The control of a peening machine operation is primarily a matter of the control of the properties of a blast of shot in its relation to the work being peened. The basis of measurement of these properties is as follows: if a flat piece of steel is clamped to a solid block and exposed to a blast of shot, it will be curved upon removal from the block. The curvature will be convex on the peened side. The extent of this curvature on a standard sample serves as a means of measurement of the blast. The degree of curvature depends upon the properties of the blast, the properties of the test strip and the nature of exposure to the blast, as described below.

Properties of the blast are the velocity, size, shape, density, kind of material and hardness of the shot. The properties of exposure to the blast are the length of time, angle of impact and shot flow rate. The properties of the test strip depend upon the physical dimensions and mechanical properties of the strip.

E.2 Specification of intensity measuring equipment — Test strips and holding fixtures

Standard test strips A, C and N are shown in Figure 1, and a test strip holder is shown in Figure 2. The relationship between test strips A, C and N are shown in Figure E.1. This curve shows A, C and N strip readings for conditions of identical blast and exposure.

E.3 Gauge

E.3.1 General

The gauge for determining the curvature of the test strip is shown in Figure 3. The curvature of the strip is determined by a measurement of the height of the combined longitudinal and transverse arcs across standard chords. This arc height is obtained by measuring the displacement of a central point on the nonpeened surface from the plane of four balls forming the corners of a particular rectangle. To use this gauge, the test strip is located so that the indicator stem is in direct contact against the non-peened surface.

E.3.2 Designation standard of intensity measurement

The standard designation of intensity measurement includes the gauge reading and the test strip used.

EXAMPLE 1

13 A This signifies that the gauge reading on the A-size peened test strip is 13. This is a dimensionless number relating to the number of gradations read on the dial indicator to the Almen gauge.

EXAMPLE 2

6-8C This signifies gauge readings on the C-size test strip measured with the same gauge. This example is typical of the method used for specifying a gauge reading tolerance for an application.

As shown in both of the examples, the gauge reading is given first and is followed by the test strip designation.

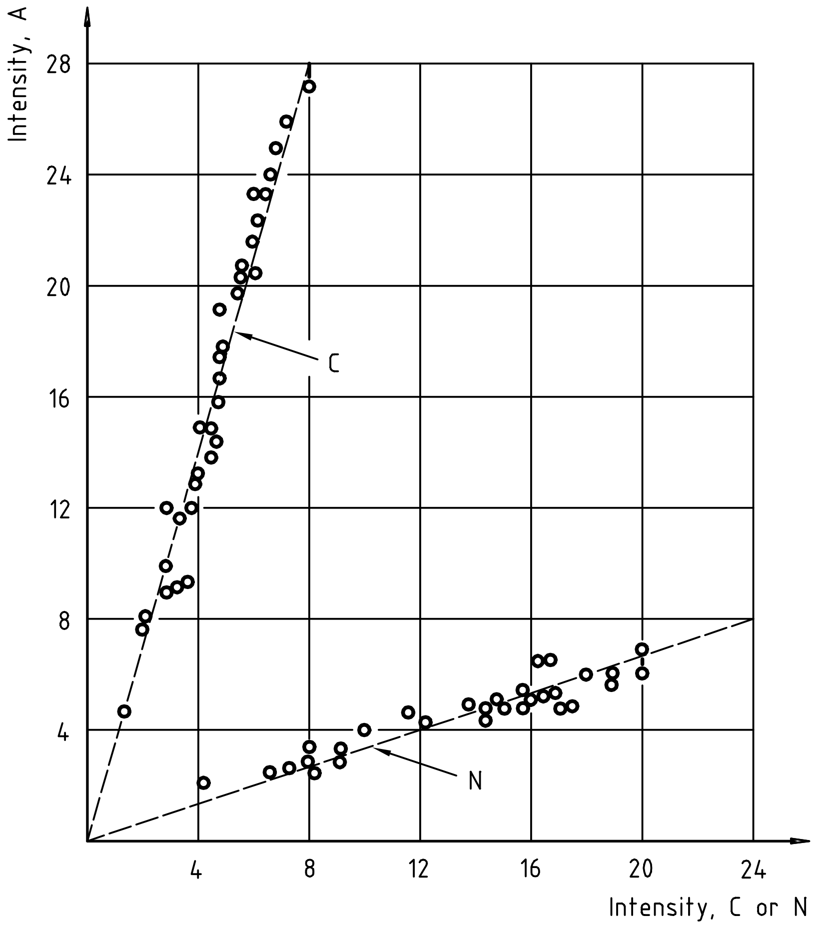


Figure E.1 — Correlation of A, C and N strips as checked on an Almen gauge

Annex F
(normative)

Calibration system requirements

F.1 Scope

This annex provides requirements for the establishment and maintenance of a calibration system to control the accuracy of measuring and test equipment (MTE), and measurement standards used to assure that supplies and services delivered to the purchaser comply with prescribed technical requirements.

F.2 Significance

This annex and any procedure or document executed in implementation thereof shall be in addition to and not weaken or detract from other contract requirements.

F.3 Definitions

For the requirements of this annex the following definitions apply:

F.3.1
calibration
comparison of MTE or measurement standard of unknown accuracy to a measurement standard of known accuracy in order to detect, correlate, report or eliminate by adjustment, any variation in the accuracy of the instrument being compared

F.3.2
measuring and test equipment (MTE)
all devices used to measure, gauge, test, inspect or otherwise determine compliance with prescribed technical requirements

F.3.3
measurement standard
those devices used to calibrate MTE or other measurement standards and provide traceability

F.3.4
traceability
ability to relate individual measurement results through an unbroken chain of calibrations to one or more of the following:

a) national and regional standard reference materials;

b) fundamental or natural physical constants with values assigned or accepted by the national standards authority;

c) ratio type of calibrations;

d) comparison to consensus standards.

F.4 Requirements

F.4.1 General

The supplier shall establish and maintain a system for the calibration of all MTE and measurement standards used in fulfilment of contractual requirements. The calibration system shall be coordinated with the supplier's inspection or quality control system and shall be designed to provide adequate accuracy in use of MTE and measurement standards. All MTE and measurement standards applicable to the contract, whether used in the supplier's plant or at another source, shall be subject to such control as is necessary to assure conformance of supplies and services to contractual requirements. The calibration system shall provide for the prevention of inaccuracy by ready detection of deficiencies and timely positive action for their correction. The supplier shall make objective evidence of accuracy conformance readily available to the purchaser.

F.4.2 Quality assurance provisions

All operations performed by the supplier in compliance with this annex may be subject to purchaser verification that shall include, but not be limited to the following:

a) review of the supplier's documented calibration system description to determine compliance with the detailed requirements of this annex;

b) surveillance of calibration operations for conformance to the supplier's documented calibration system;

c) review of calibration results to verify adequacy of the supplier's calibration process.

The supplier's MTE and measurement standards shall be made available for use by the purchaser, as required. Where conditions warrant, supplier personnel shall be made available for operation of such devices. Results of inspection or audits conducted within the last 12 months may be used by the purchaser in determining the supplier’s compliance with this annex.

F.4.3 Calibration system description

The supplier shall provide and maintain a written description of the calibration system covering MTE and measurement standards to satisfy each requirement of this annex. Requests for deviation from the detailed requirements of this annex, with supporting justification, shall be submitted to the purchaser for approval before commencement of the shot-peening operation.

F.4.4 Adequacy of measurement standards

Measurement standards used by the supplier for calibrating MTE and other measurement standards shall be traceable and shall have the accuracy, stability, range and resolution required for the intended use. Unless otherwise specified in the contract requirements, the collective uncertainty of the measurement standards shall not exceed 25 % of the acceptable tolerance for each characteristic being calibrated. The supplier's calibration system description may include provisions for deviating from the uncertainty requirements, provided the adequacy of the calibration is not degraded. All deviations shall be documented.

F.4.5 Environmental controls

MTE and measurement standards shall be calibrated and utilized in an environment controlled to the extent necessary to assure continued measurements of required accuracy, giving due consideration to temperature, humidity, vibration, cleanliness and other controllable factors. When applicable, compensating corrections shall be applied to calibration results obtained in an environment that departs from acceptable conditions.

F.4.6 Intervals of calibration

MTE and measurement standards shall be calibrated at periodic intervals established and maintained to assure acceptable accuracy and reliability, where reliability is defined as the probability that the MTE and measurement standard will remain in tolerance throughout the established interval. Intervals shall be shortened or may be lengthened, by the supplier, when the results of previous calibrations indicate that such action is appropriate to maintain acceptable reliability. The supplier shall establish a system for the mandatory recall of MTE and measurement standards to assure timely recalibrations, thereby precluding use of an instrument beyond its calibration-due date. The recall system may include provisions for the temporary extension of the calibration-due date for limited periods of time under certain specific conditions such as the completion of a test in progress.

F.4.7 Calibration procedures

Procedures shall be available and utilized for the calibration of all MTE and measurement standards. As a minimum, calibration procedures shall specify the measurement standards and equipment to be used (manufacturer and model of generic description), the required parameter, range and accuracy of the measurement standard, and the acceptable tolerance of each instrument characteristic being calibrated. Calibration procedures shall provide instructions to enable calibration personnel to adequately calibrate each instrument characteristic or measurement parameter of concern. The procedures used may be those available in manufacturer's manuals, or published standard practices, and need not be rewritten by the supplier, provided they meet the content requirements of this annex.

F.4.8 Out-of-tolerance conditions

If any MTE or measurement standard is found to be significantly out-of-tolerance during the calibration process, the supplier of the calibration system shall notify the respective user of the designated supplier quality element in the out-of-tolerance condition and provide associated measurement data so that appropriate action can be taken.

F.4.9 Adequacy of the calibration system

The supplier shall establish and maintain documented procedures to evaluate the adequacy of the calibration system and to ensure compliance with all requirements of this annex.

F.4.10 Calibration sources

MTE and measurement standards shall be calibrated by the supplier or another calibration facility utilizing measurement standards whose calibration is traceable. All measurement standards used in the calibration system shall be supported by certificates, reports or data sheets attesting to the description or identification of the item, calibration source, date of calibration, calibration assigned value, statement of uncertainty and environmental or other conditions under which the calibration results were obtained. In those cases where such data are not required to use the measurement standard, a suitable annotated calibration label on the item shall be sufficient. Certificates or reports shall attest to the fact that the measurement standards used in obtaining the results are traceable. The supplier shall be responsible for assuring that the sources providing calibration services are capable of performing the required service to the satisfaction of this annex.

F.4.11 Records

The requirements of this annex shall be supported by records documenting that established schedules and procedures are followed to maintain the accuracy of all MTE and measurement standards. The records shall include an individual record of calibration or other means of control for each item of MTE and measurement standard providing a description or identification of the item, calibration interval, date calibrated, identification of the calibration source, calibration procedure used, calibration results and calibration actions taken. In addition, the individual record of any item whose accuracy must be reported via a calibration certification report, shall state the certificate or report number.

F.4.12 Calibration status

MTE and measurement standards shall be labelled to indicate calibration status. The label shall identify, as a minimum, specific date calibrated (day, month and year – Julian date or equivalent) and the specific calibration-due date. Items not calibrated to their full capability or that have other limitations of use, shall be labelled or otherwise identified as to the limitations. When it is impractical to apply a calibration label directly to an item (eg. gauge block) the calibration label may be affixed to the instrument container or some other suitable measures may be used to reflect calibration status. Tamper-resistant seals shall be affixed to operator-accessible controls or adjustments on MTE and measurement standards which, if moved, will affect the calibration. The supplier's calibration system shall provide instructions for use of such seals and disposition on items whose seals are broken.

F.4.13 Control of subcontractor calibration

The supplier is responsible for assuring that the subcontractor's calibration system conforms to this annex to the degree necessary to assure compliance with contractual requirements. Results of purchaser inspections or audits conducted within the last 12 months may be used in determining subcontractor compliance.

F.4.14 Storage and handling

MTE and measurement standards shall be handled, stored and transported in a manner that shall not adversely affect the calibration or condition of the equipment.

Annex G
(informative)

Non-mandatory information

G.1 ISO metallic coating standards

Electrodeposits of nickel or chromium and autocatalytic nickel deposits applied, in accordance with ISO 1458 [1], ISO 4526 [5], ISO 4527 [6] and ISO 6158 [7], to steel products can cause significant reduction in the fatigue strength of the product subjected to cyclical stress loading. Shot peening the steel prior to electroplating helps to control or limit possible reduction of fatigue strength.

G.2 Reduction of crack propagation

Shot peening induces compressive stresses in the surface of the product. Compressive stresses offset high tensile stresses that may be present in electrodeposited metal coatings, thereby impeding the propagation of cracks that cause fatigue failures under cyclical loads.

G.3 Fatigue life improvement

Reductions in fatigue strength are also affected by the hardness and strength of the steel and by the thickness and internal tensile stress of the electrodeposit. Fatigue life may be enhanced by increasing the hardness and strength of the steel and by maintaining the deposit thickness at the minimum value consistent with design requirements. Eliminating or lowering the internal tensile stress of the electrodeposited coating is beneficial. The use of compressively stressed, electrodeposited coatings may prevent significant reduction in fatigue strength.

G.4 Maintenance of fatigue strength

Shot-peening, combined with the proper selection of the steel and control of thickness and internal tensile stress of the electrodeposit, can be used to minimize or avoid reduction of fatigue strength in plated steel.

G.5 Intensity reduction indicator

The Almen strip will quickly indicate a reduction in intensity (lower arc height) caused by a reduction in wheel speed or a drop in air pressure, by excessive breakdown of shot or by other operational faults such as non-removal of undersize shot.

G.6 Efficiency and cost

The smallest shot size capable of producing the desired effect is the most efficient and least costly. Intensity may be considered excessive if, as with very thin parts, it produces a condition in which the tensile stresses of the core material outweigh the beneficial compressive stresses induced at the surface. Table 9 gives a recommended peening intensity relative to cross-sectional thickness and strength of the steel.

G.7 Test strip code

The suffix letter A, C or N indicates that the intensity values have been determined by the use of test strip of that value. Test strip A is used for arc heights between 4 (0,1 mm) A and 24 (0,6 mm) A. If greater peening intensity than 24 (0,6 mm) A is desired, test strip C should be used. Test strip N is used if the intensity is less than 4 (0,1 mm) A.

G.8 Masking alternatives

When it is impractical to mask or otherwise protect areas designated to be free from shot-peening marks, sufficient stock may be provided in these areas for subsequent removal of affected material for compliance with dimensional requirements of the contract provided the temperature of Table 10 is not exceeded. If the beneficial effects of the compressive layer are required, do not remove more than 10 % of the total depth of the compressive layer.

G.9 Saturation curve

A saturation curve is produced by exposing individual test strips for increasing time periods and plotting the results (exposure time vs. arc height). A minimum of four points other than zero should be used to define the curve; one of the four points used to indicate saturation should be at least double the time of the saturation point. Saturation is achieved when, as the exposure time for the test strips is doubled, the arc height does not increase by more than 10 % (see Figure 4). The arc height at saturation for each location must be within the required arc height range for that location. The re-use of test strips is not permitted. The test strip specimens as shown in Figure 1 should be attached as shown in Figure 2, to holders of the form and dimensions also shown in Figure 2, and mounted on a fixture or article and exposed to the shot stream in a manner that simulates conditions used for the articles. The test strips should be run for the saturation time established by the saturation curve. After exposure, the test strips should be removed from the holders and the amount of deflection measured with a micrometer gauge, of the form and dimensions shown in Figure 3. The arc height or amount of deflection measured on the test strips should be within the specified intensity range. If the arc height measured is not within the intensity range specified, the process parameters must be adjusted and new saturation curves must be run. In using the micrometer gauge, the central portion of the unpeened side of the test strip should be placed against the indicator stem of the gauge. A peened test strip should not be repeened after being removed from the test strip holder.

G.10 Automatic equipment

Automatic shot-peening may be accomplished with equipment that propels shot by air pressure or centrifugal force against the product and moves the work through the shot stream in translation, rotation or both. The equipment should be capable of consistent reproduction of the shot-peening intensities required. The equipment should include a separator that continuously removes broken or defective shot during peening. The equipment should be capable of automatically controlling the peening cycle.

G.11 Computer-monitored equipment

Machines equipped with a mechanical means with programmable speed selection for turning the part as closely as possible on its geometric centerline may be used. The machine should be equipped with mechanical means with programmable speed selection for translating the nozzle across the surface part (either horizontally or vertically). When run without nozzle translation, the machine should be capable of programmable shutdown of each nozzle at any time during the peening cycle. The equipment should be computer-controlled for processing, monitoring and documentation of the critical process interrupt parameters such as: air pressure of each nozzle; shot flow of each nozzle; wheel speed of each wheel; shot flow of each wheel; part rotation rate; nozzle reciprocation rate and amount; run time for each part; total cycle time.

This type of equipment is capable of programming maximum and minimum limits for each process interrupt parameter. At intervals of 1 s or less all process interrupt parameters are scanned and evaluated against the preprogrammed maximum and minimum limits. If any deviation from the preprogrammed limits is found, the machine should shut down and the malfunction should be indicated. The problem should be corrected before the machine process cycle is resumed. The process is then restarted and completed from the exact point of shutdown. The machine should be capable of storing in memory, the data evaluated for each process interrupt parameter and providing that data in hard copy form, if required. The machine should be able to document memory or hard copy for the details of any process interruptions. The machine should be capable of continuous separation of shot, both by size and shape, so that the shot being used conforms to the requirements of Table 8.

G.12 Manual or hand peening and rotary flap peening

Manual or hand peening and rotary flap peening should not be permitted except with the express written permission of the purchaser since these processes are not as controllable and results are less predictable than those obtained by automated shot peening.

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