ACTA STEREOL 1987; 6/SUPPL II: 179–184
ISS COMMEMORATIVE-MEMORIAL VOLUME
DISCOURSE

A MODEL STEREOLOGICAL NOMENCLATURE

Hans Eckart Exner

Max-Planck-Institut für Metallforschung, Institut für Werkstoffwissenschaften, Seestrasse 92, 7000 Stuttgart 1, West Germany

One of the major ISS goals in the past was to find a common language and symbolism for stereological terms. Based on the nomenclature adopted in the classical text book by E.E. Underwood (1970) and in the proceedings of a conference held in Gainesville edited by R.T. DeHoff and F.N. Rhines (1968), several proposals were considered by the ISS Committee for Nomenclature formed in 1976, but no final agreement appeared likely until 1980. In order to find a solution, the chairman of the committee (Underwood) and the then President of ISS (myself) decided to launch a nomenclature based essentially on the detailed nomenclature contained in the then recent text books by E. Weibel (1979, 1980). This proposal was intended, after a final revision by all members of the ISS board, to become the official ISS nomenclature. The proposal was sent out in late 1981. Most of the members proposed minor amendments, but two officers *vetoed* the proposal on the basis that the list was inconsistent, and suggested alternatives used in their own text books, which were then in the process of being published (J. Serra, 1982, and H. Elias and D.M. Hyde, 1983). Thus the process had to be curtailed and the President took no further action, since there seemed not the slightest chance of securing agreement on one particular system, or of finding a suitable compromise. In the interim, the recommendation to the members was to use the very detailed and consistent nomenclature suggested by E. Weibel and, if other symbols were to be used, to specify them explicitly.

Subsequently, at least two more text books have been published, one of which follows essentially the proposal below (H.E. Exner and H.P. Hougardy, 1986), while the other one uses a new system following the French School (M. Coster and J.L. Chermant, 1985).

Thus the situation is more complicated than ever. Past experience suggests that attempts to establish a nomenclature system by a committee will probably only lead to frustration. The alternative is an authoritative act by which a specific system is declared as the official one ... It seems impossible to select any system on objective grounds, since suitability depends much on the field of application. In spite of this, it seems opportune to make a first step towards a unified system. It is hoped this will effectively open up the issue, for the first time in many years, to the *general ISS membership.* I believe the following 'model' proposal well represents the systems of Underwood, DeHoff & Rhines, Weibel, Exner & Hougardy and Elias & Hyde; any of which would be suitable for most practical purposes. It is hoped that all scientists, and particularly ISS members, will adopt this system. In more mathematical work with detailed theory, a more extensive symbolism will be needed, but is is suggested that, whenever possible, the standard nomenclature system be used for expressing the final results. Of course, what is yet needed is a similarly compact system relating to the more elementary and important elements of image analysis.

Model Stereological Nomenclature
(Tentative Proposal 1987)

INTRODUCTION

The following rules and symbols are strongly recommended to be used in scientific and technical publications, lecture notes and any other written material in the fields of stereology and image analysis. This nomenclature is based upon earlier systems worked out originally by F.N. Rhines and R.T. DeHoff and by S.A. Saltykov and amended by E.E. Underwood and by E.R. Weibel (see references). The aim of standardizing this nomenclature is to facilitate writing and reading by means of a simple common language in the large variety of fields in which stereology and image analysis are applied.

RULES AND CONVENTIONS

1. The basic symbols shown in the list below are designed to clearly differentiate between (1) real elements of the three-dimensional structure, (2) elements of planar images either real or created by sampling three-dimensional structures by sectioning or by projection, (3) elements created by sampling using a test line and (4) points created in a point counting procedure. While in the proposed system each element has a special symbol, the alternative system also presented *uses only five letters* and differentiates three-dimensional, two-dimensional and linear features by the subscripts 3, 2 and 1, respectively. (Note: The subscript can be omitted if there is no ambiguity.)
2. Reference and test quantities are designated by a subscript zero. (Example: P_0 = Total number of test points, V_0 = Total sample volume.) Whenever possible without ambiguity, the subscript is omitted.
3. Upper case letters (Roman capitals) are used for field quantities, i.e. those relating to the entity of objects or features in one or several samples, fields, or lines. Roman lower case letters are used for feature quantities, i.e. those describing single elements of the structure or of a picture. (Example: A = total area of a component in a section; a = area of a single intersect.)
4. Projected quantities are distinguished from those created by sectioning by means of an apostrophe. (Example: A' = total projected area.)
5. Averages (arithmetic means) of field as well as feature quantities are designated by a bar. (Example: $\overline{\mathrm{L}}$ = mean linear intercept of objects sampled by a test line = L/J, $\bar{\mathrm{l}}$ = mean linear intercept of a single feature, e.g. a sphere.)
6. Whenever possible, ratios of quantities defined by basic symbols are written as a combined figure with the denumerator as subscript. The subscript zero for test quantities is omitted. (Examples: $\mathrm{N_V}$ = number of objects in sample volume = $\mathrm{N/V_0}$, $\mathrm{A'_A}$ = relative projected area of a component = $\mathrm{A'/A_0}$.)

7. Additional symbols may be used according to the foregoing rules. Recommended symbols are collected in the list shown below.
8. Alternative and further symbols can be used. Standard text books (see below) should be consulted. In any case, such symbols must be clearly specified. Greek and other letters should not be mixed with Roman symbols except according to rule 9 and for angles.
9. For annotating symbols to different components (phases) of a structure, a lower case Roman letter should be put in brackets behind the respective symbol. (Examples: $V_V(b)$ = volume fraction of component b , L(a) = length of test line in component a .) Interfaces are characterized by the two adjacent components (example: S(a,b) = interface between components a and b). Alternatively, Greek subscripts may be used (examples: L_α = length of the test line in the α-phase, $S_{\alpha\beta}$ = interface area between phase α and phase β, $S_{\alpha\alpha}$ = grain boundary area in the α-phase).

FINAL COMMENTS

Though ISS does not strictly enforce the above nomenclature its use is highly recommended. If a different set of symbols and rules is used, ISS symbols should be given for comparison, whenever applicable, in all ISS related publications and in papers presented at ISS sponsored events (congresses, symposia, courses etc.).

REFERENCES

Coster M, Chermant J-L. Précis d'analyse d'images, Paris: Editions du CNRS, 1985.

DeHoff RT, Rhines FN (Eds). Quantitative microscopy. New York: McGraw-Hill, 1968.

Elias H, Hyde DM. A Guide to Practical Stereology, Basel: Karger Publ., 1983.

Exner HE, Hougardy HP. Einführung in die quantitative Gefügeanalyse (Introduction to Quantitative Analysis of Microstructures) Oberursel: DGM Informationsges., 1986.

Saltykov SA. Stereometric metallography. Russian original: Metallurgisdat Moscow. First edition 1958, third edition 1970. German edition: H.J. Eckstein, Ed. Leipzig: VEB Deutscher Verlag für Grundstoffindustrie, 1974. English translation of the second edition: Report MCL-905/1+2, MCLTD, Wright Patterson Air Force Base, Ohio, USA, 1961.

Serra J. Image Analysis and Mathematical Morphology, London: Academic Press, 1982.

Underwood EE. Quantitative stereology. Massachusetts, USA: Addison-Wesley, 1970.

Weibel ER. Stereological methods, Vol.1: Practical methods for biological morphometry. London, New York, Toronto, San Francisco: Academic Press, 1979.

Weibel ER. Stereological methods, Vol.2: Theoretical foundations. London, New York, Toronto, San Francisco: Academic Press, 1980.

List of Standard Symbols

1. Quantities describing real three-dimensional structures

Symbol	Definition	Dimension	Alternative system
v:	Volume of single object	m^3	v
V:	Total volume of three-dimensional objects of one component (phase) in sample or sub-sample	m^3	V
s:	Surface area of single object	m^2	a_3
S:	Total surface of three-dimensional objects or total area of interfaces of one kind	m^2	A_3
w:	Length of single linear feature	m	l_3
W:	Total length of linear features of one kind	m	L_3
N:	Number of objects of one component	m°	N_3
Z:	Number of points in real structure	m°	P_3
V_0:	Test or sample volume	m^3	V_0

2. Quantities describing planar images (test sections, test projections or real images)

Symbol	Definition	Dimension	Alternative system
a:	Area of isolated feature (profile)	m^2	a_2
A:	Total area of features of one kind in field(s)	m^2	A_2
b:	Boundary length (perimeter) of single feature	m	l_2
B:	Total boundary length of one component or length of boundary length between two particular components	m	L_2
Q:	Number of isolated features	m°	N_2
Y:	Number of points in plane	m°	P_2
A_0:	Test area (field, fields or image)	m^2	A_0

3. Quantities relating to test lines

Symbol	Definition	Dimension	Alternative system
l:	Intercept length (distance between two intersection points between the test line and the surface of a spatial object or the boundary of a planar feature	m	l_1
L:	Total length of test line in a particular component	m	L_1
I:	Number of intercepts on test line	m°	N_1
J:	Number of points on test line (intersection points of test line with surfaces, interfaces or boundaries)	m°	P_1
L_0:	Total length of test line(s)	m	L_0

4. Quantities relating to point sets

Symbol	Definition	Dimension	Alternative system
P:	Number of points inside a		

	particular component		P
P_0:	Total number of test points		P_0

List of Recommended Symbols
(in alphabetical order, subject to revision)

		Dimension	Alternative system
c:	Local curvature of lines and of boundaries	m^{-1}	c_2
C:	Integral curvature		
	...of lines in a volume	m°	C_3
	...of lines in a field		C_2
d:	Distance between two points (centroids)	m^1	
	...of two spatial objects		d_3
	...of two planar features		d_2
D:	Open		
e:	Edge length of	m^1	
	...polyhedra		e_3
	...polygons		e_2
E:	Expected value (estimate)		
f:	Shape parameter	m°	
	...of spatial objects		f_3
	...of planar features		f_2
g:	Connectivity (genus) for individual object	m°	g
G:	Connectivity (contiguity or genus) for a component	m°	G
h:	Caliper diameter	m^1	
	...of a single spatial object		h_3
	...of a single planar feature (dependent on the orientation of tangent planes or of tangent lines; $\overline{h}$: averaged for single object or feature over all orientations)		h_2
$\overline{H}$:	Mean caliper diameter averaged over all orientations	m	
	...for all objects in a volume		$\overline{H}_3$
	...for all features in a plane		$\overline{H}_2$
i:	Moment of inertia	m^4	
	...for spatial object		i_3
	...for planar features		i_2
j:	Index for individual size class		
k:	Local gaussian curvature of surface	m^{-1}	k
K:	Integral gaussian curvature of surfaces	m°	K
m:	Index for arbitrary component (phase)		
M:	Moment of size distributions		

		Dimension	Alternative system
n:	Exponent		
o,O:	Not to be used in order to avoid confusion with zero		
q:	Orientation parameter (ratio of orientated and total surface) for a single object	m°	
Q:	Orientation parameter for a component	m°	
r:	Radius	m	
	...of individual sphere or principal radius of spatial curvature		r_3
	...of individual circle or of planar curvature		r_2
R:	Open		
t:	Thickness of foil or thin section	m	
T:	Number of tangent points (convex and concave, may be differentiated by superscribed (+) and (−) respectively)	m°	
	...of planes to spatial objects		T_3
	...of lines to planar features		T_2
u,U:	Open		
x,y,z:	Coordinates in Cartesian space	m	
X,Y,Z:	Arbitrary variables		