

Note on orthogonal chip forming (chip breaking)

Citation for published version (APA):

Veenstra, P. C. (1969). *Note on orthogonal chip forming (chip breaking)*. (TH Eindhoven. Afd. Werktuigbouwkunde, Laboratorium voor mechanische technologie en werkplaatstechniek : WT rapporten; Vol. WT0218). Technische Hogeschool Eindhoven.

Document status and date:

Gepubliceerd: 01/01/1969

Document Version:

Uitgevers PDF, ook bekend als Version of Record

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

NOTE ON ORTHOGONAL CHIP FORMING

(Chip Breaking)

P.C. Veenstra

- personal communication to the members of group C (CIRP)
- presented at General Assembly Geneva 1969.

NOTE ON ORTHOGONAL CHIP FORMING

(Chip Breaking)

P.C. Veenstra

1. Chip Former Geometry

The relevant geometric quantities of a chip former have been listed in fig. 1.

On the assumption, that the action of the chip former results in an uniform radius of bending of the chip it holds

$$r_m = (1-l_c) \cot \frac{1}{2} \beta - \frac{1}{2} t \quad (1)$$

This curvature may arise either as a consequence of deformation of the shearplane or it is due to continuous plastic bending of the chip in the plane O_1 where the maximum value of the bending moment prevails (1). It must be kept in mind that this latter case is not identical with the static plastic bending of a bar, where the radius of curvature would range between a minimum value in O_1 and infinite in A corresponding with the decreasing value of the bending moment. Due to the continuity of the chipping process the initial radius r_m generated in O_1 is kept by the chip when neglecting the elastic spring back.

With an eye to mechanical strength the geometry of the chip former sometimes is chosen according to fig. 2 where formula 1 transforms into

$$r_m = (1-l_c - 0.578) 1.73 - \frac{1}{2} t \quad (2)$$

Chip breaking will take place when geometrical conditions allow the chip to hit either the workpiece or the tool, thus forcing a bending back of the chip to a larger radius of curvature accompanied by exceeding the yield strain of the chip's material.

2. Chip material

It can be assumed that in the case of cutting steel the material of the chip behaves in an ideal plastic way {2}.

The very high value of effective strain in cutting results in plastic saturation, which means that in the chip formed the strain hardening exponent is close to zero.

This implies {2.3} that the yield stress is strictly proportional to Vicker's hardness

$$H_V = 3,0 \sigma_y \quad (3)$$

Young's modulus of the chip material is temperature dependent. For the present purpose it is agreed on an average chip temperature of 600°C, which gives {4}

$$E \approx 15,75 \cdot 10^4 \text{ N/mm}^2 \quad (4)$$

This averaging of temperature and hence of Young's modulus in different cutting conditions of course introduces an apparent dependence of the yield strain on cutting conditions. In a more detailed analysis the chip temperature in each cutting condition must be measured and the corresponding value of Young's modulus used.

As it is clear that the cracked inside surface of the chip does not contribute to the mechanical strength of the chip the effective (solid) thickness t_c is defined. This quantity has been measured separately in every sample.

3. Experimental Procedure {5}

The chip formed with the initial radius r_m springs back to a radius R_o .

Using for the case of simplicity an uniaxial stress model it holds

$$R_o = r_m \frac{\frac{2}{3} \frac{p^3}{t_e^2 - p^2} + t_e}{t_e - p}$$

where

(5)

$$p = 2r_m \frac{\sigma_y}{E}$$

According to eqs. 1 and 2 the initial radius can be determined from geometrical conditions, chip thickness and chip contact length. The latter has been measured from the wear pattern on the rake face of the tool.

Hardness measurements on the chip and using eqs. 3, 4, 5 allow for calculation of the radius R_o .

When the chip hits any obstacle and breaks it is locally bend to the radius R_y corresponding to the value of the yield strain.

Neglecting the elastic component and again using an uniaxial model it holds

$$\epsilon_y = \frac{1}{2} t_e \left(\frac{1}{R_o} - \frac{1}{R_y} \right)$$

(6)

In the samples collected from the lathe the broken chips are found with a radius R according to

$$\frac{\sigma_y}{E} = \frac{1}{2} t_e \left(\frac{1}{R} - \frac{1}{R_y} \right)$$

(7)

Using the value of σ_y known by the former step and measuring the value R thus gives the values of the yield radius and finally the yield strain of the chip.

In order to avoid BUE the cutting speed throughout the investigation is chosen 2.08 m/s with a P10 carbide tool. The depth of cut amounts 3.2 mm.

In the case of small values of feed a chip former as shown in fig. 1 has been used. To avoid confusion the chipformer distance in this case is represented by the symbol l' .

The results of the measurements are collected in the tables I, II and III.

Table I / observations

run nr.	chipformer 1' mm	distance 1 mm	feed mm/rev.	type of chip
1	1.77	(2.35)	0.079	broken
2	1.86	(2.44)	0.100	jammed
3	1.86	(2.44)	0.125	jammed
4	1.99	(2.57)	0.158	fragmented
5	2.11	(2.69)	0.079	curly
6	2.12	(2.70)	0.100	broken
7	2.05	(2.63)	0.125	broken
8	2.34	(2.92)	0.158	broken
9	2.41	(2.99)	0.200	fragmented
10		3.13	0.100	curly
11		3.13	0.125	curly + broken
12		3.23	0.158	broken
13		3.33	0.200	broken
14		3.18	0.250	fragmented
15		3.48	0.125	curly
16		3.42	0.158	curly + broken
17		3.63	0.200	broken
18		3.59	0.250	broken
19		3.51	0.315	fragmented
20		3.77	0.158	curly
21		3.71	0.200	broken
22		3.83	0.250	broken
23		3.72	0.315	fragmented

Table II / measurements

run.nr.	chip thickness mm	effective chip thickness mm	chip contact length mm	Vickers hardness N/mm ²	final chip radius mm
1	0.350	0.322	0.47	2570	5.2
4	0.514	0.485	0.59	2600	-
6	0.417	0.384	0.53	2650	6.3
7	0.466	0.431	0.56	2570	5.6
8	0.529	0.494	0.67	2590	5.6
9	0.592	0.555	0.68	2560	4.7
11	0.450	0.407	0.56	2500	6.9
12	0.510	0.447	0.66	2490	8.2
13	0.578	0.516	0.73	2430	6.3
16	0.501	0.444	0.68	2590	7.7
17	0.583	0.531	0.76	2590	6.7
18	0.662	0.604	0.81	2530	6.6
21	0.586	0.527	0.79	2470	7.7
22	0.676	0.612	0.87	2400	6.5

Table III / calculations

run.nr.	σ_y N/mm ²	r_m mm	R_o mm	R_y mm	ϵ_y %
1	860	2.09	2.24	6.3	4.6
6	880	2.56	2.77	7.7	4.4
7	860	2.36	2.52	6.6	5.3
8	860	2.64	2.86	6.4	4.8
9	850	2.71	2.86	5.2	4.4
11	830	3.24	3.53	8.4	3.3
12	830	3.22	3.48	10.3	4.3
13	810	3.24	3.45	7.2	3.9
16	860	3.52	3.85	9.5	3.4
17	860	3.69	4.01	7.8	3.2
18	840	3.51	3.74	7.5	4.0
21	820	3.79	4.11	9.1	3.5
22	800	3.81	4.06	7.3	3.3

As shown in graph fig. 3 the yield strain proves to be practically independent on the feed but shows a tendency to increase at smaller values of the chip former distance. As remarked earlier this effect is probably due to differences in chip temperature.

4. Optimal conditions

The observations listed in table I do not refer to optimal conditions in the region between forming of continuous chips and broken chips. As the lathe available is not equipped with continuous feed control in the present experiments the chip former distance is changed at constant feed rate up to the transition point where both types of chips are cut. The broken chips have been sampled in order to determine their values R, t and t_e . An example is shown in table IV.

Table IV
 feed 0,158 mm/rev.
 optimal conditions $l = 3.56$ mm

R mm	t mm	$t - t_e$ mm
8.5	0.49	0.055
11.25	0.50	0.068
10.0	0.50	0.070
10.75	0.49	0.052
10.25	0.49	0.060
10.1	0.50	0.061

The yield stress is averaged from table III at $\sigma_y = 840 \text{ N/mm}^2$
 Applying eq. 7 renders

$$R_{opt} = 13.4 \text{ mm}$$

Averaging the value of the yield strain in the region investigated at $\epsilon_y = 3.5\%$ formula 6 gives $R_0 = 4.31 \text{ mm}$.

From eq. 5 it follows $r_m = 3.90$ mm and hence formula 2 renders $l = 3.68$ mm.

The results obtained this way have been listed in Table V.

Table V
optimal chip former distance

feed mm/rev.	chip former distance mm
0.079	2.55
0.1	2.97
0.125	3.32
0.158	3.68
0.2	4.08

The graph fig. 4 presents this curve of critical or optimal conditions compared with experimental observation.

5. Conclusion

This note elucidates the principal possibility of determining on the basis of a simple mechanical model the relation between feedrate and chip former distance in order to obtain long broken chips in cutting particularly in the important region of low feed rates. Decreasing of the chip former distance promotes the creation of short-broken and fragmented chips and on the contrary increasing of the optimal distance causes forming of curly continuous chips. To enable the necessary calculations several fundamental quantities must be known like hardness and yield strain of the chip material, chip contact length and effective chip thickness.

It is obvious that some of these depend on cutting conditions and toolgeometry which greatly complicates the problem.

References

- {1} Pekelharing, A.J. CIRP Pittsburgh 1963
- {2} Nakayama, K. Int. Res. Prod. Eng. 1963
- {3} Tabor, D. The Hardness of Metals, Londen 1951
- {4} Roberts, M.H.
Nortcliffe, J. Journ. Iron Steel Inst., nov. 1947
- {5} Hogenboom, J.M. graduate work 1967, Eindhoven

Symbols

l, l'	chip former distance	mm
l_c	chip contact length	mm
β	chip former angle	rad
t	chip thickness	mm
t_e	effective chip thickness	mm
r_m	initial chip radius	mm
R_o	chip radius after spring back	mm
R_y	yield radius	mm
R	final chip radius	mm
ϵ_y	yield strain	-
σ_y	yield stress	N/mm ²
H_v	vickers hardness	N/mm ²
E	Young's modulus	N/mm ²

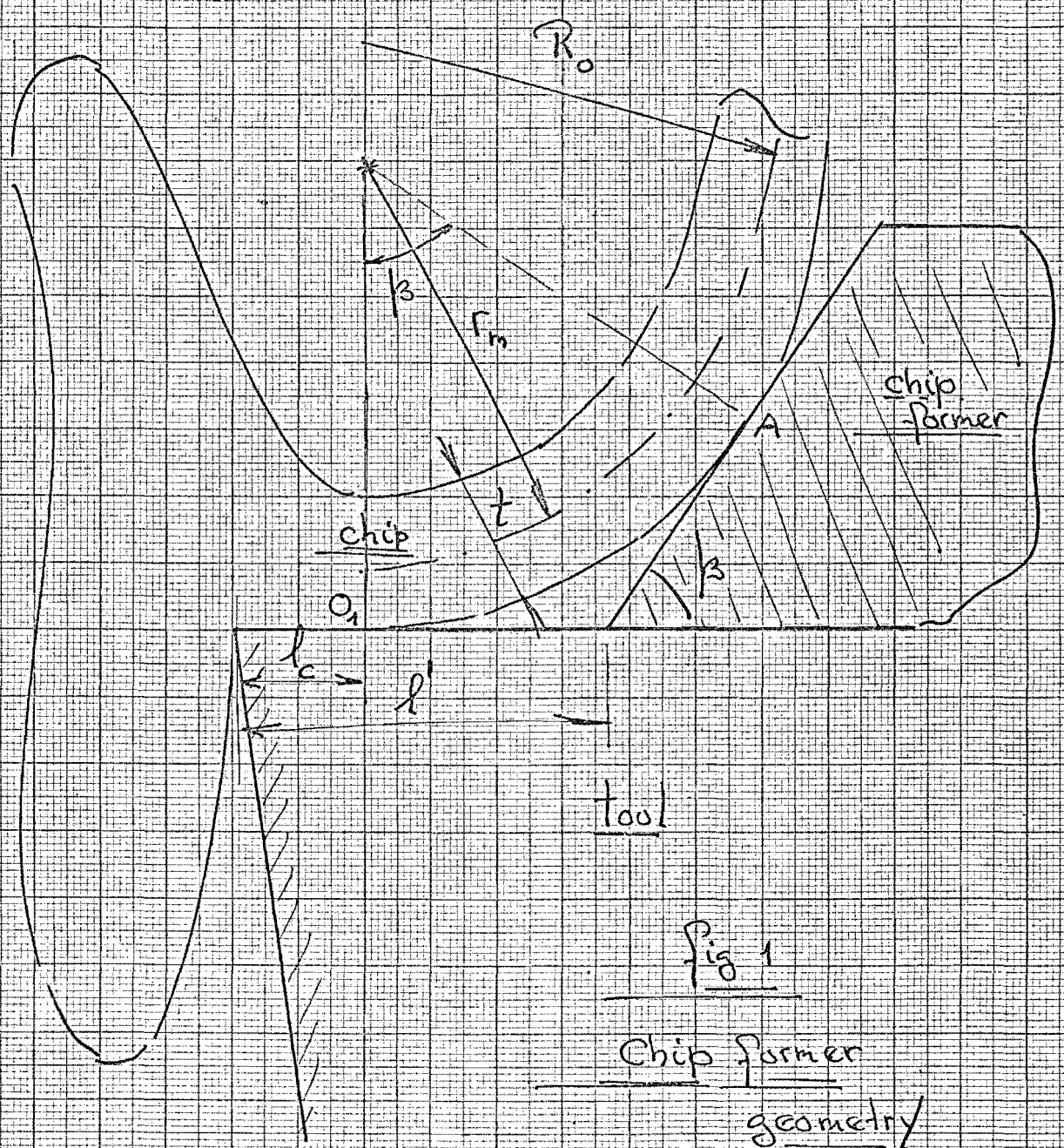


Fig 1
Chip former
geometry
type I

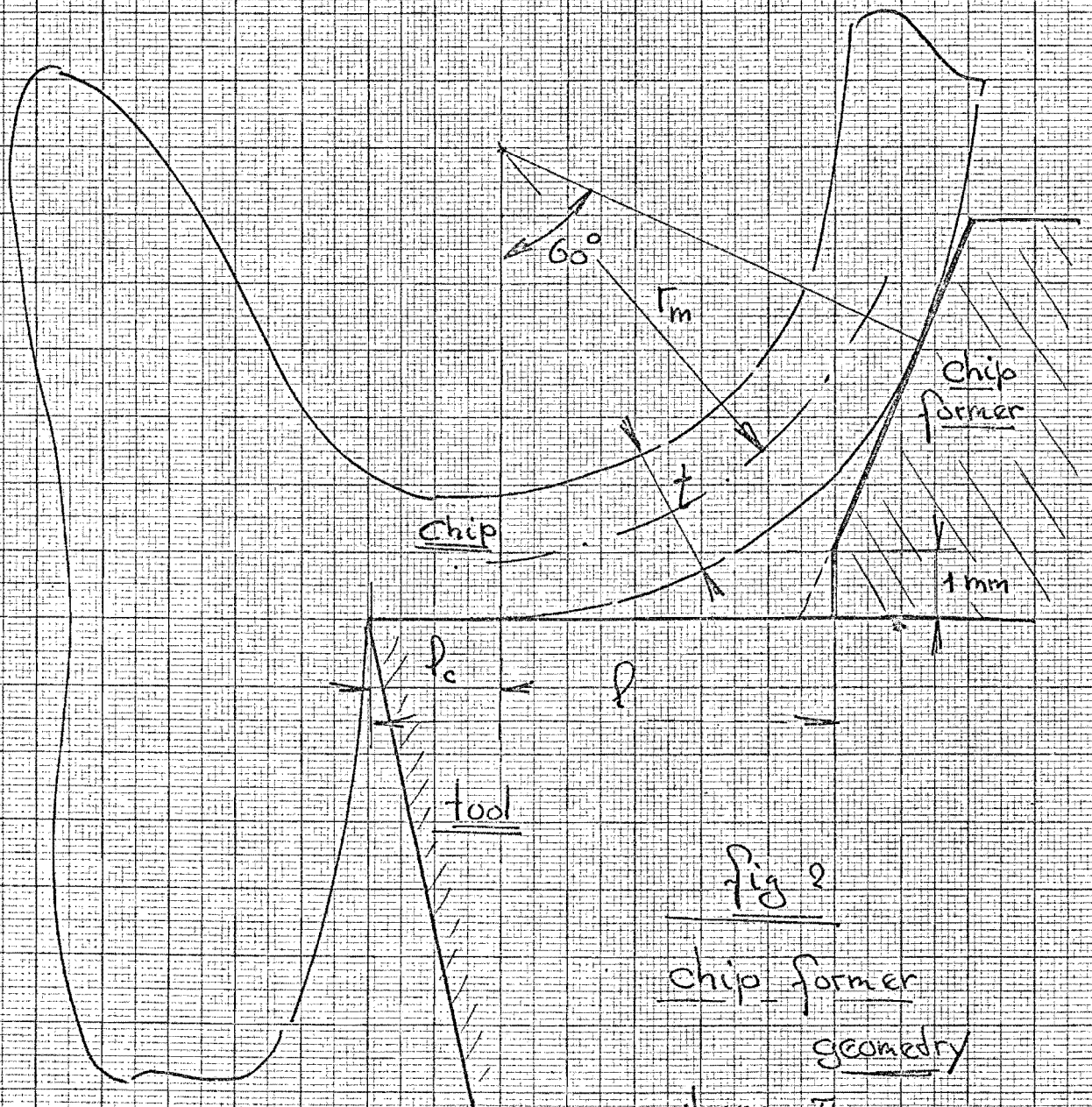


fig 2
chip former
geometry
type II

yield strain
%

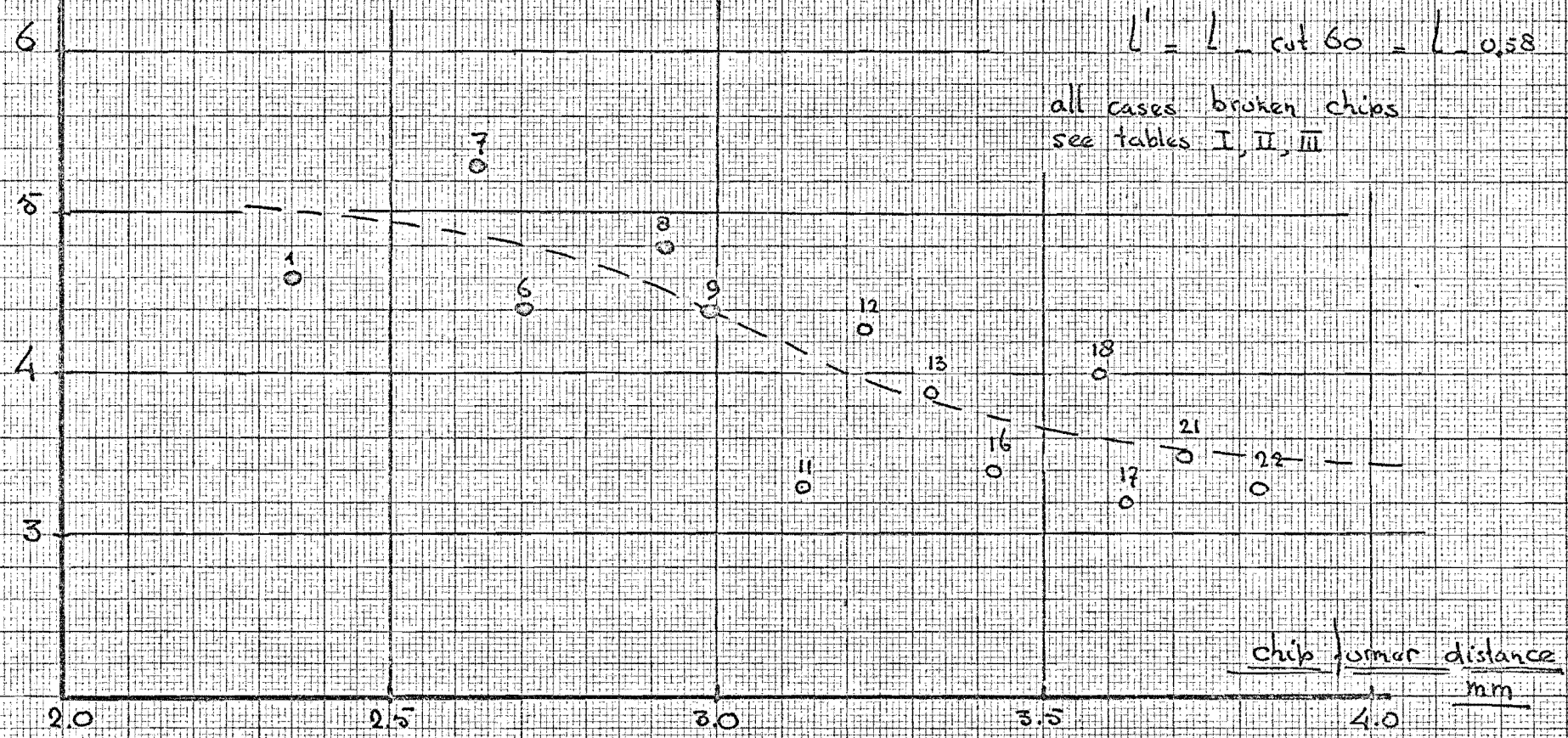
Steel Nogs

- chip former type I
- chip former type II

reduced value of L'

$$L' = L - \text{cut } 60 = L - 0.58$$

all cases broken chips
see tables I, II, III



feed
mm/rev

0.25

0.2

0.168

0.125

0.1

0.079

2.0

2.5

3.0

3.5

4.0

chip former distance
mm

x = broken chips
& fragmented chips
o = continuous curly
chips

o = opt. conditions
table IV, V

transition region

