Appendix A: Worksheet to model the stress-strain curve of Cu A using the Cabrera-Prado Model and the Avrami DRX model

The predicted stress-strain curve in Chapter 5 was plotted using a commercial worksheet code (Microsoft EXCEL) programmed by Cabrera [1] for HSLA steel. Figure A.1 shows the rows and columns of the worksheet, while table A.1 shows the instructions written to plot the constitutive equation values explained in Chapter 5.

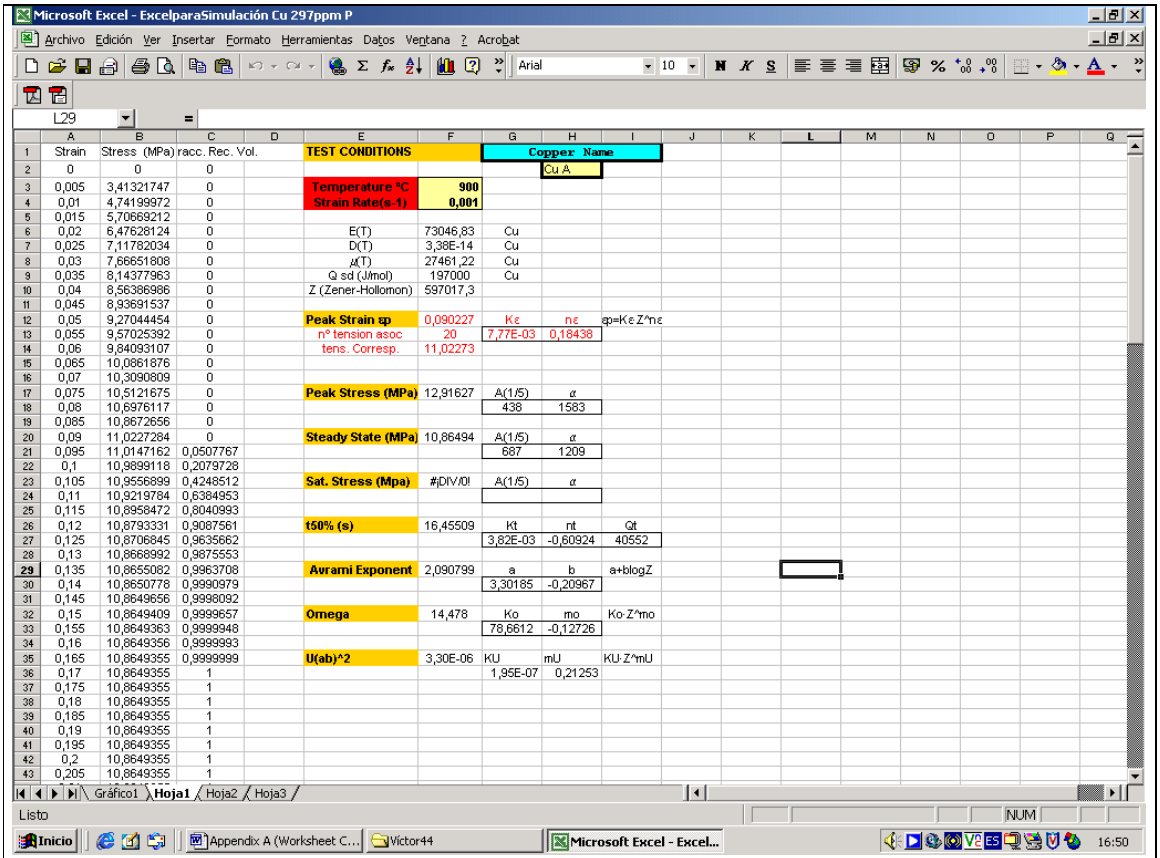


Fig. A.1. The monitor screen image above shows the relevant cells where instructions were written. Columns A and B correspond to the strain and stress values, which were then copied to be plotted elsewhere.

Table A.1. The cell column letter and row number with the corresponding instruction.

CELL	INSTRUCTION
A2	0
A3	=A2+0,005
A4	=A3+0,005
A142	=A141+0,005
B2	=SI(A2<$F$12;$F$17*((1-EXP(-$F$32*A2))^0,5);$F$14-($F$14-$F$20)*C2)
B3	=SI(A3<$F$12;$F$17*((1-EXP(-$F$32*A3))^0,5);$F$14-($F$14-$F$20)*C3)
B4	=SI(A4<$F$12;$F$17*((1-EXP(-$F$32*A4))^0,5);$F$14-($F$14-$F$20)*C4)
B5	=SI(A5<$F$12;$F$17*((1-EXP(-$F$32*A5))^0,5);$F$14-($F$14-$F$20)*C5)
B6	=SI(A6<$F$12;$F$17*((1-EXP(-$F$32*A6))^0,5);$F$14-($F$14-$F$20)*C6)

B20	=SI(A20<$F$12;$F$17*((1-EXP(-$F$32*A20))^0,5);$F$14-($F$14-$F$20)*C20)
B21	=SI(A21<$F$12;$F$17*((1-EXP(-$F$32*A21))^0,5);$F$14-($F$14-$F$20)*C21)
B35	=SI(A35<$F$12;$F$17*((1-EXP(-$F$32*A35))^0,5);$F$14-($F$14-$F$20)*C35)
B36	=SI(A36<$F$12;$F$17*((1-EXP(-$F$32*A36))^0,5);$F$14-($F$14-$F$20)*C36)
F3	900
F4	0,001
F6	=111986*(1-0,54*((F3+273,15-300)/1356))
F7	=0,00002*EXP(-197000/(8,314*(F3+273,15)))
F8	=F6/(2*(1+0,33))
F9	197000
F10	=F4*EXP(F9/(8,31*(F3+273,15)))
F12	=G13*(F10^H13)
F13	=COINCIDIR(F12;A:A)
F14	=INDICE(B:B;F13)
F17	=(F6/H18)*ASENOH((((F4/F7)^(1/5))/G18))
F18	
F20	=(F6/H21)*ASENOH((((F4/F7)^(1/5))/G21))
F23	=(F6/H24)*ASENOH((((F4/F7)^(1/5))/G24))
F26	=G27*(F4^H27)*EXP(I27/(8,31*(F3+273,15)))
F29	=G30+(H30*LOG(F10))
F32	=G33*(F10^H33)
F35	=(G36*(F10^H36))
G12	Ke
G13	0,0077689
G17	A(1/5)
G18	438
G20	A(1/5)
G21	687
G23	A(1/5)
G24	
G26	Kt
G27	0,00382
G29	a
G30	3,30185
G32	Ko
G33	78,6612
G35	KU
G36	0,000000195137169
H12	ne
H13	0,18438
H17	A(1/5)
H18	1583
H20	a
H21	1209

H23	a
H24	
H26	nt
H27	-0,60924
H29	b
H30	-0,20967
H32	mo
H33	-0,12726
H35	mU
H36	0,21253
I12	ep=Ke·Z^ne
I26	Qt
I27	40552
I29	a+blogZ
I32	Ko·Z^mo
I35	KU·Z^mU

References

[1] Cabrera J. M., Co-Director of this thesis work.

Appendix B: Worksheet to model the stress-strain curve of Cu B using the Cabrera-Prado Model and the Avrami DRX model

The predicted stress-strain curve in Chapter 5 was plotted using a commercial worksheet code (Microsoft EXCEL) essentially the same as shown on Appendix A, however some instructions were changed to subtract the back stress, σ_0, from the registered stress, σ. The back stress was calculated using eq. 4.5, whose values can be seen on Appendix D. Figure B.1 shows the new worksheet, while table B.1 shows the new instructions written into the cell blocks of the worksheet in Appendix A.

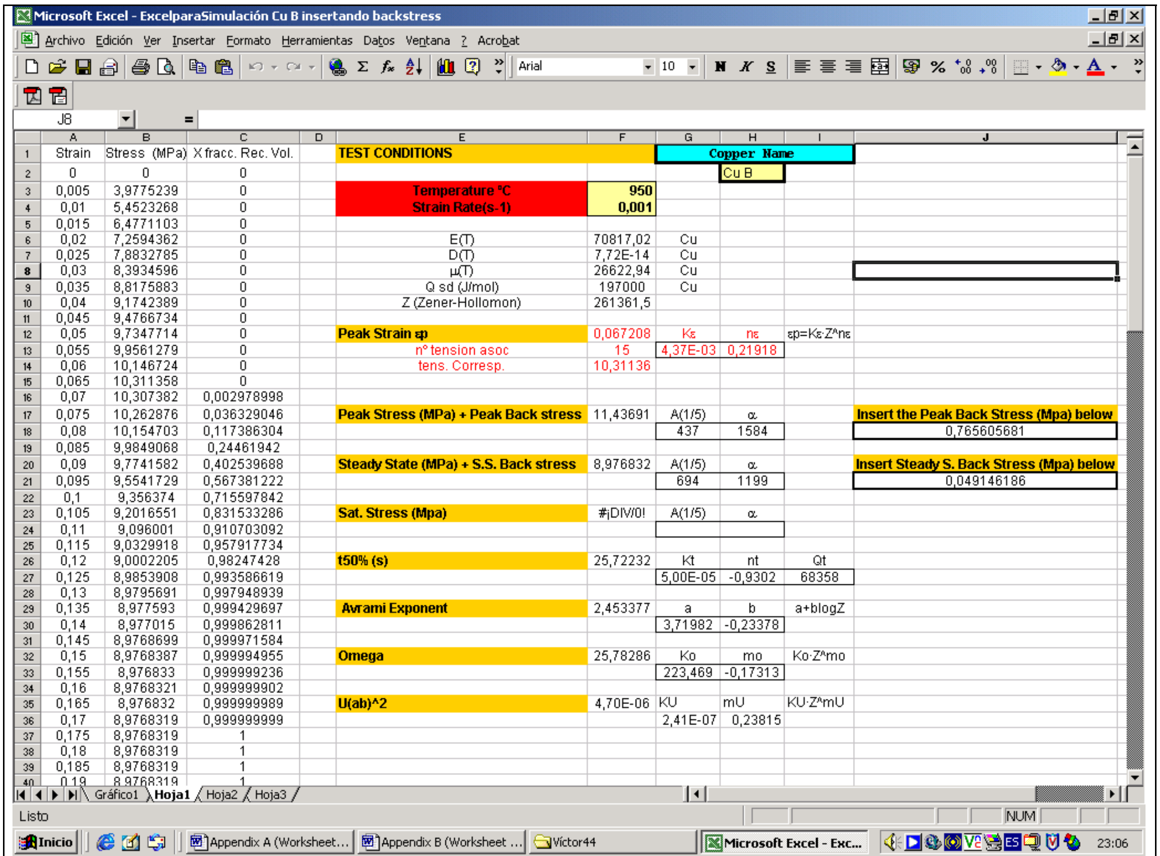


Fig. B.1. The monitor screen image above shows the relevant cells where instructions were written. Columns A and B correspond to the strain and stress values, which were then copied to be plotted elsewhere.

Table B.1. The cell column letter and row number with the corresponding instruction.

CELL	INSTRUCTION
F17	=J18+(F6/H18)*ASENOH((((F4/F7)^(1/5))/G18))
F20	=J21+(F6/H21)*ASENOH((((F4/F7)^(1/5))/G21))
G13	0,00436586
G18	437
G21	694
G27	0,00005
G30	3,71982
G33	223,46943

G36	0,000000240807495
H2	Cu B
H13	0,21918
H18	1584
H21	1199
H27	-0,9302
H30	-0,23378
H33	-0,17313
H36	0,23815
I27	68358
J17	Insert the Peak Back Stress (Mpa) below
J18	0,765605681
J19	Insert Steady S. Back Stress (Mpa) below
J20	0,0491461856

Appendix C: Worksheet to model the stress-strain curve of Cu C using the Cabrera-Prado Model and the Avrami DRX model

The predicted stress-strain curve in Chapter 5 was plotted using a commercial worksheet code (Microsoft EXCEL) essentially the same as shown on Appendix A, however some instructions were changed to subtract the back stress, σ_0, from the registered stress, σ. The back stress was calculated using eq. 4.6, whose values can be seen on Appendix D. Figure C.1 shows the new worksheet, while table C.1 shows the new instructions written into the cell blocks of the worksheet in Appendix A.

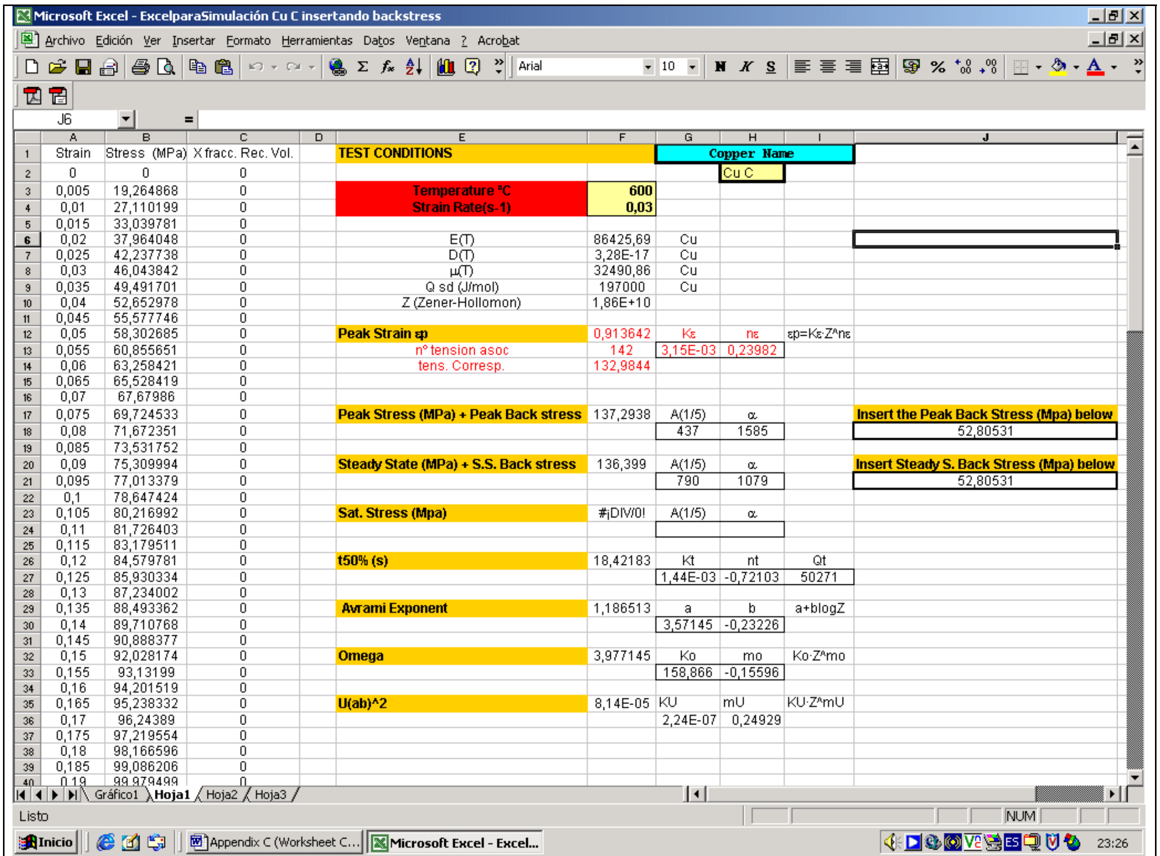


Fig. C.1. The monitor screen image above shows the relevant cells where instructions were written. Columns A and B correspond to the strain and stress values, which were then copied to be plotted elsewhere.

Table C.1. The cell column letter and row number with the corresponding instruction.

CELL	INSTRUCTION
F17	=J18+(F6/H18)*ASENOH((((F4/F7)^(1/5))/G18))
F20	=J21+(F6/H21)*ASENOH((((F4/F7)^(1/5))/G21))
G13	0,003149270753
G18	437
G21	790
G27	0,00144
G30	3,57145
G33	158,8656485

G36	0,0000002242538976
H2	Cu C
H13	0,23982
H18	1585
H21	1079
H27	-0,72103
H30	-0,23226
H33	-0,15596
H36	0,24929
I27	50271
J17	Insert the Peak Back Stress (Mpa) below
J18	52,80531
J19	Insert Steady S. Back Stress (Mpa) below
J20	52,80531

Appendix D: Values of the Peak Back Stress, $\sigma_{0\,p}$, and Steady State Back Stress, σ_{0ss}, Calculated Using Equations 4.5 for Cu B and 4.6 for Cu C

KELVIN	$\dot{\varepsilon}$	CELSIUS	σ_P for Cu B (MPa)	σ_{SS} for Cu B (MPa)	$\sigma_{0\,P}$ for Cu B, (MPa)	$\sigma_{0\,SS}$ for Cu B, (MPa)
873,15	0,03	600	129,20	129,20	44,40	46,83
873,15	0,01	600	111,55	110,24	38,12	39,37
873,15	0,003	600	92,70	89,11	31,73	32,13
873,15	1E-3	600	81,80	74,93	26,52	26,42
923,15	0,1	650	116,59	116,59	36,09	39,25
923,15	0,03	650	96,27	93,74	31,29	31,77
923,15	0,01	650	87,38	84,39	27,11	25,94
923,15	0,003	650	74,36	64,96	22,82	20,62
923,15	1E-3	650	59,18	49,50	19,24	16,64
973,15	0,03	700	73,01	67,47	18,65	16,72
973,15	0,01	700	59,65	54,42	15,05	12,95
973,15	0,003	700	50,11	43,72	11,80	9,85
973,15	1E-3	700	44,65	35,12	9,42	7,74
1023,15	0,1	750	65,71	58,89	12,71	10,95
1023,15	0,03	750	58,42	51,75	11,53	8,99
1023,15	0,01	750	47,00	39,47	10,31	7,42
1023,15	0,003	750	39,08	32,02	8,90	5,96
1023,15	1E-3	750	31,88	25,11	7,61	4,85
1073,15	0,1	800	50,52	44,70	6,21	5,21
1073,15	0,03	800	41,80	36,31	4,89	3,82
1073,15	0,01	800	33,93	29,41	3,92	2,92
1073,15	0,003	800	27,11	22,44	3,07	2,20
1073,15	1E-3	800	22,13	17,90	2,45	1,72
1123,15	0,1	850	40,28	35,28	3,73	3,15
1123,15	0,03	850	33,75	28,89	3,34	2,38
1123,15	0,01	850	26,73	22,16	2,93	1,85
1123,15	0,003	850	23,33	18,16	2,46	1,43
1173,15	0,1	900	33,13	29,18	2,45	1,50
1173,15	0,03	900	26,04	21,97	1,64	1,03
1173,15	0,01	900	21,29	17,27	1,17	0,75
1173,15	0,003	900	17,13	13,12	0,83	0,55
1173,15	1E-3	900	13,41	10,44	0,62	0,42
1223,15	0,1	950	26,03	22,29	0,39	0,29
1223,15	0,03	950	20,99	17,75	0,75	0,17
1223,15	0,01	950	17,81	13,94	0,86	0,11
1223,15	0,003	950	14,36	11,34	0,84	0,07

KELVIN	$\dot{\varepsilon}$	CELSIUS	σ_P for Cu C	σ_{SS} for Cu C	$\sigma_{0\ P}$ for Cu C	$\sigma_{0\ SS}$ for Cu C
873,15	0,3	600	157,10	--	52,83	
873,15	0,1	600	153,27	--	52,95	
873,15	0,03	600	140,55	--	52,81	
873,15	0,01	600	125,77	--	52,31	
873,15	0,003	600	115,47	--	51,22	
873,15	1E-3	600	94,310	89,27	49,60	
923,15	0,3	650	140,99	--	51,05	58,46
923,15	0,1	650	129,67	--	47,84	52,57
923,15	0,03	650	110,42	--	44,12	46,06
923,15	0,01	650	97,20	94,54	40,50	40,17
923,15	0,003	650	83,29	75,99	36,28	33,95
923,15	1E-3	650	79,21	66,21	32,26	28,66
973,15	0,3	700	127,13	--	51,01	57,67
973,15	0,1	700	107,78	--	43,14	44,67
973,15	0,03	700	90,25	86,61	35,37	33,84
973,15	0,01	700	76,12	67,96	29,15	26,40
973,15	0,003	700	61,71	52,82	23,35	20,26
973,15	1E-3	700	52,18	40,24	18,94	16,00
1023,15	0,3	750	101,89	--	38,68	31,07
1023,15	0,1	750	81,79	75,49	28,34	23,20
1023,15	0,03	750	64,45	55,32	20,21	17,08
1023,15	0,01	750	54,43	45,39	14,98	13,11
1023,15	0,003	750	41,69	33,45	10,96	9,94
1023,15	1E-3	750	31,27	27,24	8,36	7,80
1073,15	0,3	800	70,33	63,67	18,11	14,25
1073,15	0,1	800	57,68	48,63	14,23	10,85
1073,15	0,03	800	50,74	41,50	10,87	8,13
1073,15	0,01	800	38,24	32,41	8,51	6,32
1073,15	0,003	800	29,12	24,25	6,53	4,84
1073,15	1E-3	800	23,96	19,47	5,15	3,83
1123,15	0,3	850	53,39	46,61	8,73	6,53
1123,15	0,1	850	42,68	36,11	7,43	5,61
1123,15	0,03	850	34,86	30,06	6,13	4,65
1123,15	0,01	850	29,60	25,43	5,08	3,86
1123,15	0,003	850	26,56	21,80	4,09	3,11
1123,15	1E-3	850	18,96	15,26	3,33	2,53
1173,15	0,3	900	39,64	33,86	2,81	1,64
1173,15	0,1	900	33,27	28,18	2,36	1,41
1173,15	0,03	900	26,29	23,25	1,93	1,16
1173,15	0,01	900	21,26	17,99	1,59	0,96
1173,15	0,003	900	17,62	13,70	1,27	0,77
1173,15	1E-3	900	14,20	10,69	1,03	0,63
1223,15	0,3	950	33,81	28,72	2,39	1,47
1223,15	0,1	950	26,55	23,25	1,62	0,97

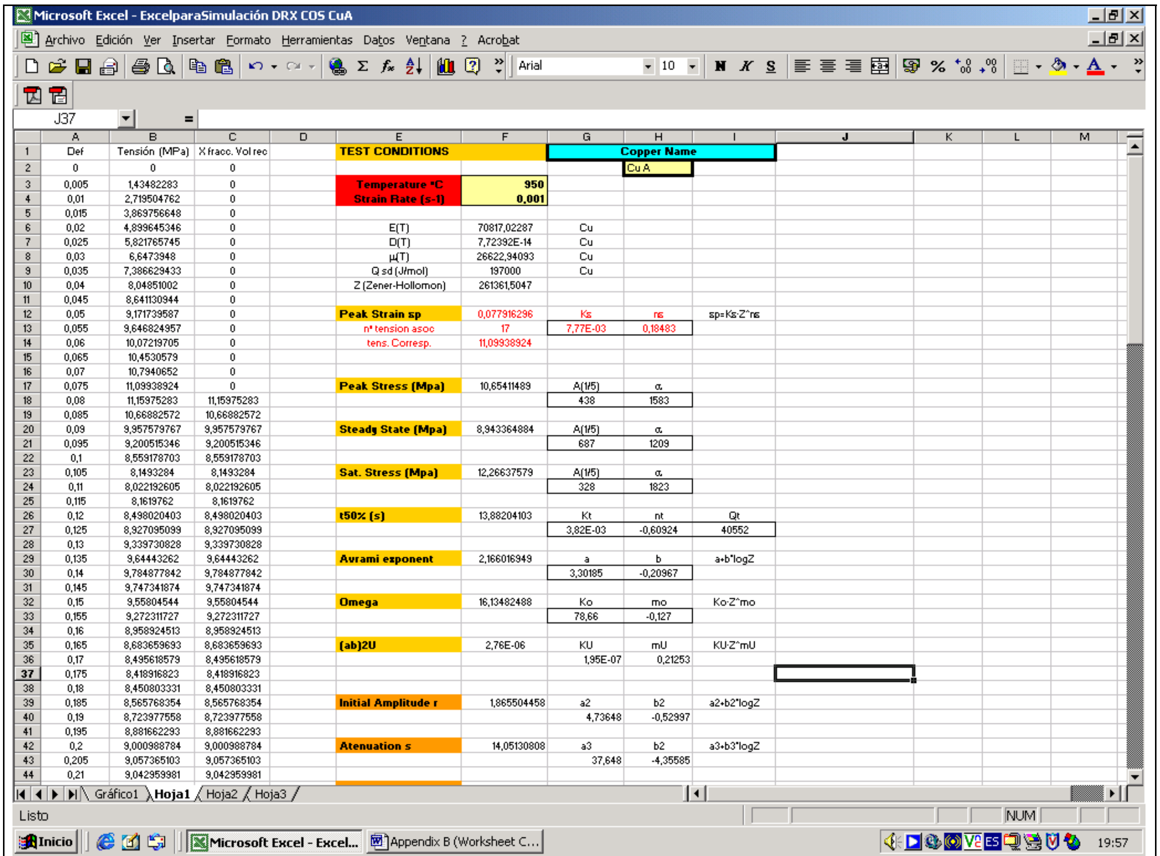
KELVIN	$\dot{\varepsilon}$	CELSIUS	σ_P for Cu C	σ_{SS} for Cu C	$\sigma_{0\,P}$ for Cu C	$\sigma_{0\,SS}$ for Cu C
1223,15	0,03	950	21,49	18,02	1,08	0,64
1223,15	0,01	950	17,17	14,34	0,76	0,46
1223,15	0,003	950	14,02	10,88	0,54	0,33
1223,15	1E-3	950	11,91	9,04	0,40	0,25

KELVIN	$\dot{\varepsilon}$	CELSIUS	σ_P for Cu A	σ_{SS} for Cu A
873,16	0,3	600	101,33	101,33
873,16	0,1	600	97,91	97,91
873,16	0,03	600	93,26	93,22
873,16	0,01	600	80,17	80,13
873,16	0,003	600	72,30	70,67
873,16	1E-3	600	44,33	43,07
923,16	0,3	650	88,99	88,99
923,16	0,1	650	75,90	75,76
923,16	0,03	650	69,20	63,15
923,16	0,01	650	57,84	50,64
923,16	0,003	650	46,63	40,54
923,16	1E-3	650	36,42	35,09
973,16	0,3	700	74,43	72,90
973,16	0,1	700	63,76	58,07
973,16	0,03	700	53,85	48,24
973,16	0,01	700	44,41	38,24
973,16	0,003	700	33,06	28,69
973,16	1E-3	700	26,47	24,41
1023,16	0,3	750	66,34	62,36
1023,16	0,1	750	57,89	51,10
1023,16	0,03	750	47,25	40,60
1023,16	0,01	750	37,34	31,50
1023,16	0,003	750	29,64	26,93
1023,16	1E-3	750	19,92	17,64
1073,16	0,3	800	54,16	49,58
1073,16	0,1	800	44,82	39,73
1073,16	0,03	800	37,25	31,59
1073,16	0,01	800	29,71	26,10
1073,16	0,003	800	23,35	20,03
1073,16	1E-3	800	19,16	16,53
1123,16	0,3	850	46,08	40,37
1123,16	0,1	850	37,25	31,92
1123,16	0,03	850	30,10	25,47
1123,16	0,01	850	24,15	21,20
1123,16	0,003	850	18,50	15,87
1123,16	1E-3	850	14,12	12,18
1173,16	0,3	900	34,97	30,96

KELVIN	$\dot{\varepsilon}$	CELSIUS	σ_P for Cu A	σ_{SS} for Cu A
1173,16	0,1	900	29,87	26,27
1173,16	0,03	900	24,04	20,44
1173,16	0,01	900	20,08	16,58
1173,16	0,003	900	15,44	13,08
1173,16	1E-3	900	12,31	9,42
1223,16	0,3	950	30,75	27,06
1223,16	0,1	950	25,27	22,22
1223,16	0,03	950	20,24	16,83
1223,16	0,01	950	16,32	13,73
1223,16	0,003	950	13,10	10,19
1223,16	1E-3	950	10,57	7,91

Appendix E: Worksheet to model the stress-strain curve using the modified Voce-Kocks Model and the new Damped Cosine Avrami Model for DRX

The predicted stress-strain curve in Chapter 6 was plotted using a commercial worksheet code (Microsoft EXCEL). Figures E.1 and E.2 show the rows and columns of the worksheet, while table E.1 shows the instructions written to plot the constitutive equation values explained in Chapter 6. On fig. E.1 appears an almost exact replica of fig. A.1 from Appendix A with the exception of columns A, B, C and the rows 23 and 24. However rows 23 and 24 are not necessary but are placed for the record. The rest of the instructions appearing on fig. E.1 are a consequence of building on the worksheet of Appendix A as a base. On fig. E.2 appears a continuation of the worksheet where most new instructions were written.



	A	B	C	D	E	F	G	H	I
1	Def	Tensión (MPa)	X fracc. Vol rec		TEST CONDITIONS		Copper Name		
2	0	0	0					Cu A	
3	0,005	1,43482283	0		Temperature °C	950			
4	0,01	2,719504762	0		Strain Rate (s-1)	0,001			
5	0,015	3,869756648	0						
6	0,02	4,899645346	0		E(T)	70817,02287	Cu		
7	0,025	5,821765745	0		D(T)	7,72392E-14	Cu		
8	0,03	6,6473948	0		µ(T)	26622,94093	Cu		
9	0,035	7,386629433	0		Q sd (J/mol)	197000	Cu		
10	0,04	8,04851002	0		Z (Zener-Hollomon)	261361,5047			
11	0,045	8,641130944	0						
12	0,05	9,171739587	0		Peak Strain εp	0,077916296	Kε	nε	εp=Kε·Z^nε
13	0,055	9,646824957	0		nº tension asoc	17	7,77E-03	0,18483	
14	0,06	10,07219705	0		tens. Corresp.	11,09938924			
15	0,065	10,4530579	0						
16	0,07	10,7940652	0						
17	0,075	11,09938924	0		Peak Stress (Mpa)	10,65411489	A(1/5)	α	
18	0,08	11,15975283	11,15975283				438	1583	
19	0,085	10,66882572	10,66882572						
20	0,09	9,957579767	9,957579767		Steady State (Mpa)	8,943364884	A(1/5)	α	
21	0,095	9,200515346	9,200515346				687	1209	
22	0,1	8,559178703	8,559178703						
23	0,105	8,1493284	8,1493284		Sat. Stress (Mpa)	12,26637579	A(1/5)	α	
24	0,11	8,022192605	8,022192605				328	1823	
25	0,115	8,1619762	8,1619762						
26	0,12	8,498020403	8,498020403		t50% (s)	13,88204103	Kt	nt	Qt
27	0,125	8,927095099	8,927095099				3,82E-03	-0,60924	40552
28	0,13	9,339730828	9,339730828						
29	0,135	9,64443262	9,64443262		Avrami exponent	2,166016949	a	b	a+b*logZ
30	0,14	9,784877842	9,784877842				3,30185	-0,20967	
31	0,145	9,747341874	9,747341874						
32	0,15	9,55804544	9,55804544		Omega	16,13482488	Ko	mo	Ko·Z^mo
33	0,155	9,272311727	9,272311727				78,66	-0,127	
34	0,16	8,958924513	8,958924513						
35	0,165	8,683659693	8,683659693		(ab)2U	2,76E-06	KU	mU	KU·Z^mU
36	0,17	8,495618579	8,495618579				1,95E-07	0,21253	
37	0,175	8,418916823	8,418916823						
38	0,18	8,450803331	8,450803331						
39	0,185	8,565768354	8,565768354		Initial Amplitude r	1,865504458	a2	b2	a2+b2*logZ
40	0,19	8,723977558	8,723977558				4,73648	-0,52997	
41	0,195	8,881662293	8,881662293						
42	0,2	9,000988784	9,000988784		Atenuation s	14,05130808	a3	b2	a3+b3*logZ
43	0,205	9,057365103	9,057365103				37,648	-4,35585	
44	0,21	9,042959981	9,042959981						

Fig. E.1. The monitor screen image above shows part of the worksheet explained on Appendix A, which served as base, but the new instructions to calculate the strain (in column A) and the stress (in column B) start below row 39 as will be seen on fig. 2.

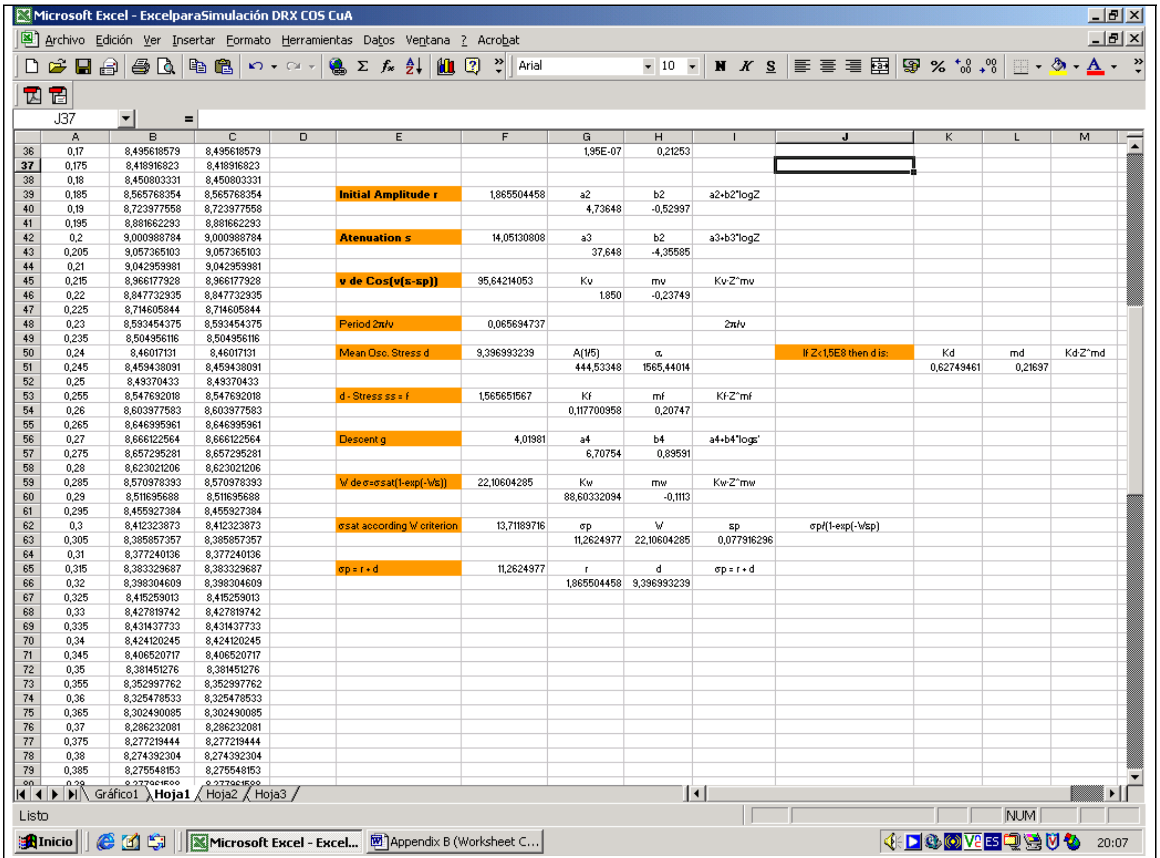


Fig. E.2. The monitor screen image above shows the worksheet cells where instructions for the modified Voce-Kocks Model for strain hardening and dynamic recovery and also for the Damped Cosine Avrami Model for multiple peak DRX. Columns A and B correspond to the strain and stress values, which were then copied to be plotted elsewhere.

Table E.1. The cell column letter and row number with the corresponding instruction.

CELL	INSTRUCTION
A2	0
A3	=A2+0,005
A4	=A3+0,005
A142	=A141+0,005
B2	=SI(A2<$F$12;$F$62*(1-EXP(-$F$59*A2));C2)
B3	=SI(A3<$F$12;$F$62*(1-EXP(-$F$59*A3));C3)
B4	=SI(A4<$F$12;$F$62*(1-EXP(-$F$59*A4));C4)
B142	=SI(A142<$F$12;$F$62*(1-EXP(-$F$59*A142));C142)
C2	=SI(A2<$F$12;0;$F$39*(EXP(-$F$42*(A2-$F$12)))*COS($F$45*(A2-$F$12))+$F$50-$F$53*(1-EXP(-$F$56*(A2-$F$12))))
C3	=SI(A3<$F$12;0;$F$39*(EXP(-$F$42*(A3-$F$12)))*COS($F$45*(A3-$F$12))+$F$50-$F$53*(1-EXP(-$F$56*(A3-$F$12))))
C4	=SI(A4<$F$12;0;$F$39*(EXP(-$F$42*(A4-$F$12)))*COS($F$45*(A4-$F$12))+$F$50-$F$53*(1-EXP(-$F$56*(A4-$F$12))))

C17	=SI(A17<$F$12;0;$F$39*(EXP(-$F$42*(A17-$F$12)))*COS($F$45*(A17-$F$12))+$F$50-$F$53*(1-EXP(-$F$56*(A17-$F$12))))
C18	=SI(A18<$F$12;0;$F$39*(EXP(-$F$42*(A18-$F$12)))*COS($F$45*(A18-$F$12))+$F$50-$F$53*(1-EXP(-$F$56*(A18-$F$12))))
C142	=SI(A142<$F$12;0;$F$39*(EXP(-$F$42*(A142-$F$12)))*COS($F$45*(A142-$F$12))+$F$50-$F$53*(1-EXP(-$F$56*(A142-$F$12))))
F23	=(F6/H24)*ASENOH((((F4/F7)^(1/5))/G24))
F39	=(H40)*LOG(F10)+G40
F42	=(H43)*LOG(F10)+G43
F45	=G46*(F10^H46)
F48	=2*(3,141592654)/F45
F50	=SI($F$10<150000000;(K51)*(($F$10)^(L51));(F6/H51)* ASENOH((((F4/F7)^(1/5))/G51)))
F53	=G54*(F10^H54)
F56	=(H57)*LOG(F4)+G57
F59	=G60*($F$10^H60)
F62	=G63/(1-EXP(-H63*I63))
F65	=G66+H66
G23	A(1/5)
G24	328
G39	a2
G40	4,73648
G42	a3
G43	37,648
G45	Kv
G46	1850,077835
G50	A(1/5)
G51	444,53348
G53	Kf
G54	0,117700958
G56	a4
G57	6,70754
G59	Kw
G60	88,60332094
G62	sp
G63	=$F$65
G65	r
G66	=$F$39
H39	b2
H40	-0,52997
H42	b2
H43	-4,35585
H45	mv
H46	-0,23749
H50	a
H51	1565,44014
H53	mf

H54	0,20747
H56	b4
H57	0,89591
H59	mw
H60	-0,1113
H62	W
H63	=$F$59
H65	d
H66	=$F$50
I39	a2+b2*logZ
I42	a3+b3*logZ
I45	Kv·Z^mv
I48	2p/v
I53	Kf·Z^mf
I56	a4+b4*loge'
I59	Kw·Z^mw
I62	ep
I63	=$F$12
I65	sp = r + d
J50	If Z<1,5E8 then d is:
J62	sp/(1-exp(-Wep)
K50	Kd
K51	0,62749461
L50	md
L51	0,21697
M50	Kd·Z^md

Appendix F: Macrographs of Cu B after compressing at 650ºC, 700ºC and 750ºC

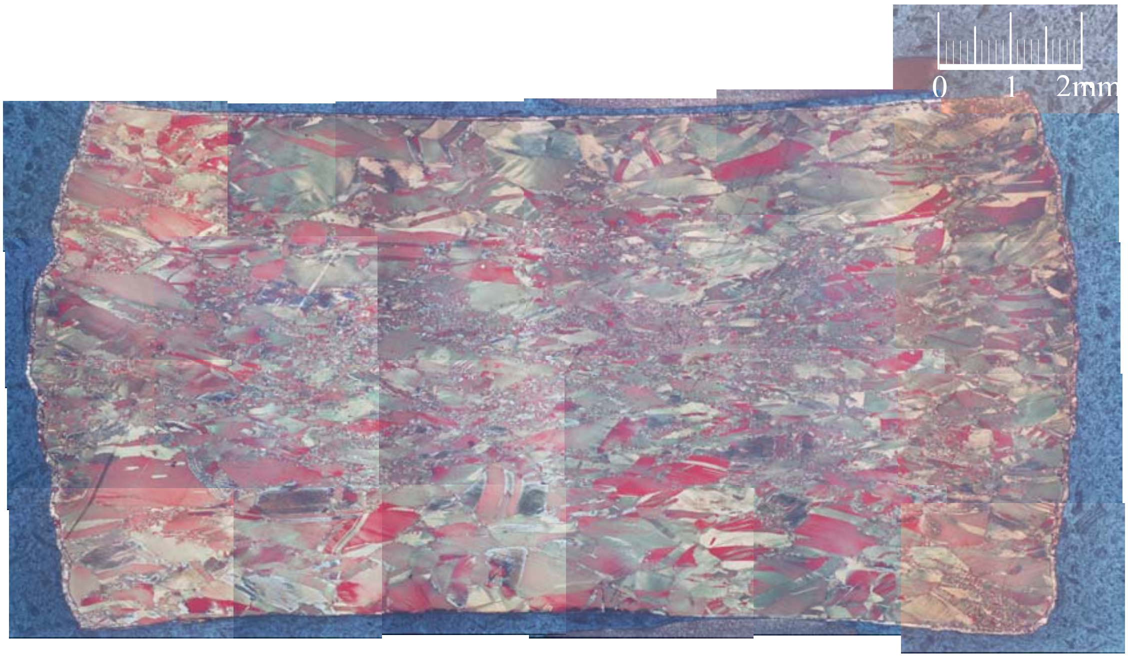


Fig. F.1. Macrograph of compressed Cu B test cylinder after 650ºC, $0.3s^{-1}$ and $\varepsilon = 0.8$.

Fig. F.2. Macrograph of compressed Cu B test cylinder after 700ºC, $0.3s^{-1}$ and $\varepsilon = 0.8$.

Fig. F.3. Macrograph of compressed Cu B test cylinder after 750ºC, 0.3s^{-1} and $\varepsilon = 0.8$.

Temperature and strain rate have and affect not only on stress but, also on the resulting microstructure. A comparison of the macrographs on figures F.1, F.2 and F.3 portraits an visual understanding of how raising the temperature above a critical *Z* value can lead to complete DRX on most of the test sample. On fig. F.1 the initial grains can still be recognized despite being flattened. Annealing twins can also be recognized. On fig. F.1 new dynamically recrystallized grains are only sparsely present on the middle line of the sample. Few new grains nucleate near the compression plates where inevitable friction creates a cone shaped volume of lower strain. On fig. F.2 the temperature has been raised to 700ºC and the tested volume with more accumulated strain dynamically recrystallizes forming an X of finer grains on the macrograph. On fig. F.3 the temperature has been raised 50ºC more and the accumulated strain is sufficient to produce a homogeneously fine structure on most of the test sample. However the two cones of lower accumulated strain are still visible.