CuMg0,5

UNS:C18665
EN:CW128C

Manufactures list:
Diehl Metall Stiftung & CO.KG (http://www.diehlmetall.de) - SD05
KM Europa Metal AG (http://www.kme.com/) - STOL®78
La Farga (http://www.lfl.es) - CuMg0,5

CuMg0,5 is a high magnesium (Mg) alloyed material with excellent formability at medium strength and good conductivity. Within the CuMg0,5 family, has the highest magnesium content. With this alloy, very high strengths can be achieved, while the electrical conductivity can be maintained at a very good level of approximately 60 % IACS. Therefore CuMg0,5 is especially suitable for lines with long span length and /or high pretension, like suspended cables, connector pins, telecommunications cable, contact wire and catenary cables for high-speed trains.This alloy family is used as a substitution for copper-cadmium which is already prohibited in many countries due to its toxic properties. [Ref: 87, 664]

Basic properties

Basic properties	Value	Comments	Literature
Density [g/cm^3]	8,7-8,9		[Ref: 83, 669]
Specific heat capacity [J/(kg*K)]	320		[Ref: 83]
Temperature coefficient of electrical resistance (0...100°C) [10^{-3}/K]	2,5-2,71		[Ref: 83, 59]
Electrical conductivity [T=20°C, (% IACS)]	41-68	from drawn temper up to annealed temper	[Ref: 83, 87, 115, 94, 95, 669]
Thermal conductivity [W/(m*K)]	270		[Ref: 83]
Thermal expansion coefficient 20...300°C [10^{-6}/K]	17,3		[Ref: 83]

Physical and mechanical properties of copper-magnesium alloys [Ref: 665]

Material		Density, g/cm^3	Tensile strength, MPa		Elongation soft A_{100}, %	Electrical conductivity	
Designation	Alloy		Material state	Value		MS/m	% IACS
SD04/SD05	CuMg0,5	8,9	soft	230-300	>30	37,1	64
			hard	360-460			
			springhard	460-560			
			Superspring hard	560-800			

Applications

Main applications

Typical applications are automotive, electrical and electronic connectors, relays, current carrying spring contact, junction, boxes switches, relays, contacts, connectors, terminals components for the electrical industry, connecting wire, (car) wiring harnesses, stamped parts, semiconductor components, conductive wire, pins, telecommunications cable, catenary cables, contact wire for high-speed trains. Literature: [Ref: 83, 87]

Kinds of semi-finished products/final products

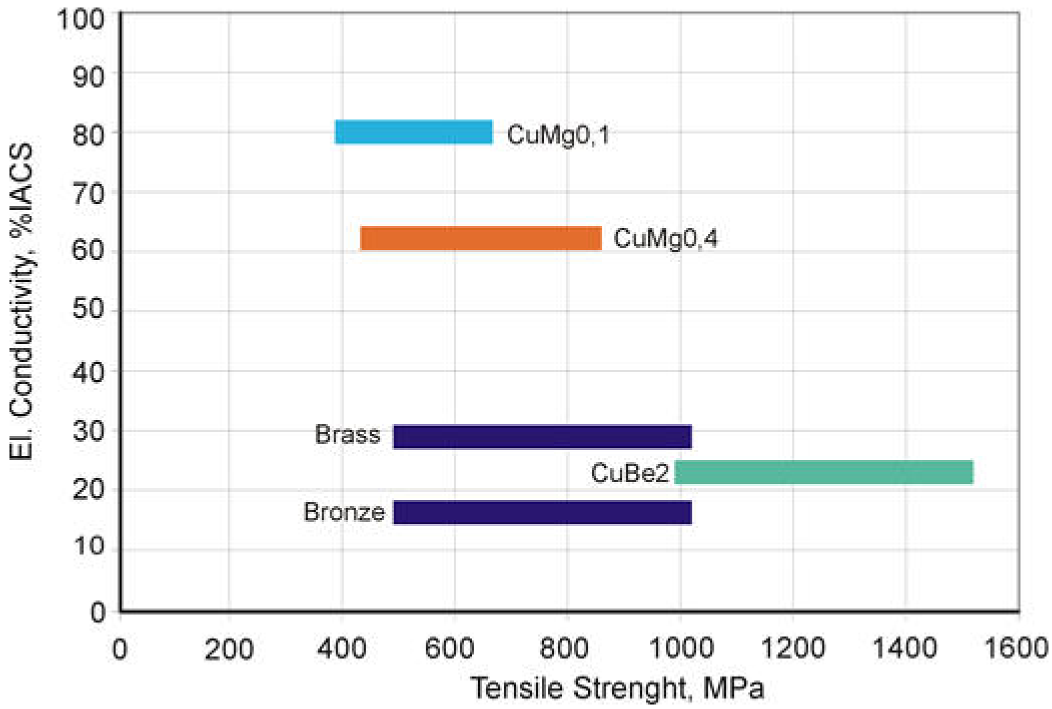
Technical data of CuMg0,5 (VALCOND) [Ref: 85]

Literature: [Ref: 83]

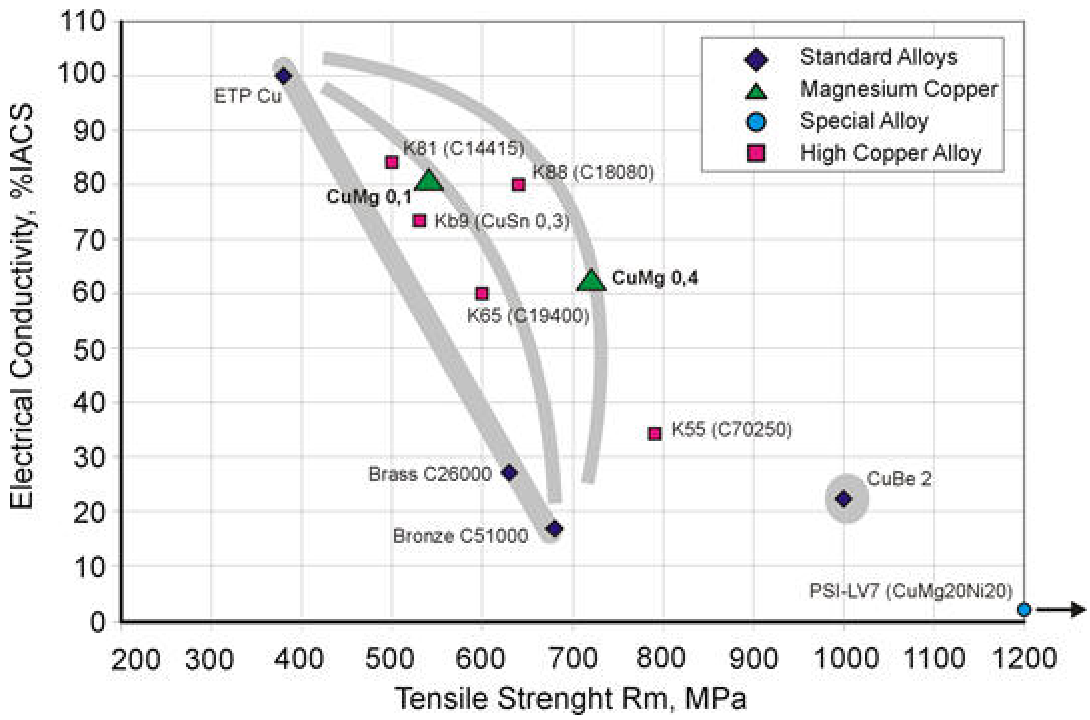
Formats	Dimension		
Coil	Strip thickness (other thicknesses on request) Strip width Outside diameter	≥ 0.1 .. 6.00 ≥ 3 .. 690 ≤ 1.400	mm
Traverse wound strip	Thickness Width	≥ 0.2 .. ≤ 1.50 ≥ 8 .. ≤ 60.0	mn
Multicoil	Thickness Width Inner diameter 300 mm for thickness Inner diameter 400 mm for thickness	0.18 .. 0.80 15 .. 50 0.15 .. 0.80 0.41 .. 0.80	mm
Sheet ≤ 6.35 mm	Thickness Width Length	0.3 .. 6.35 50 . 690 200 .. 6.500	mm
Sheet > 6.35 mm	Thickness Width Length	6.35 .. 9.50 50 .. 690 200 .. 7.500	mm mm m
Plate	Thickness Width Length	9.5 .. 150 ≤ 720 ≤ 15.000	mm
Disc	Thickness Diameter	0.3 .. 150 20 .. 690	mm

Standards for copper and copper alloys

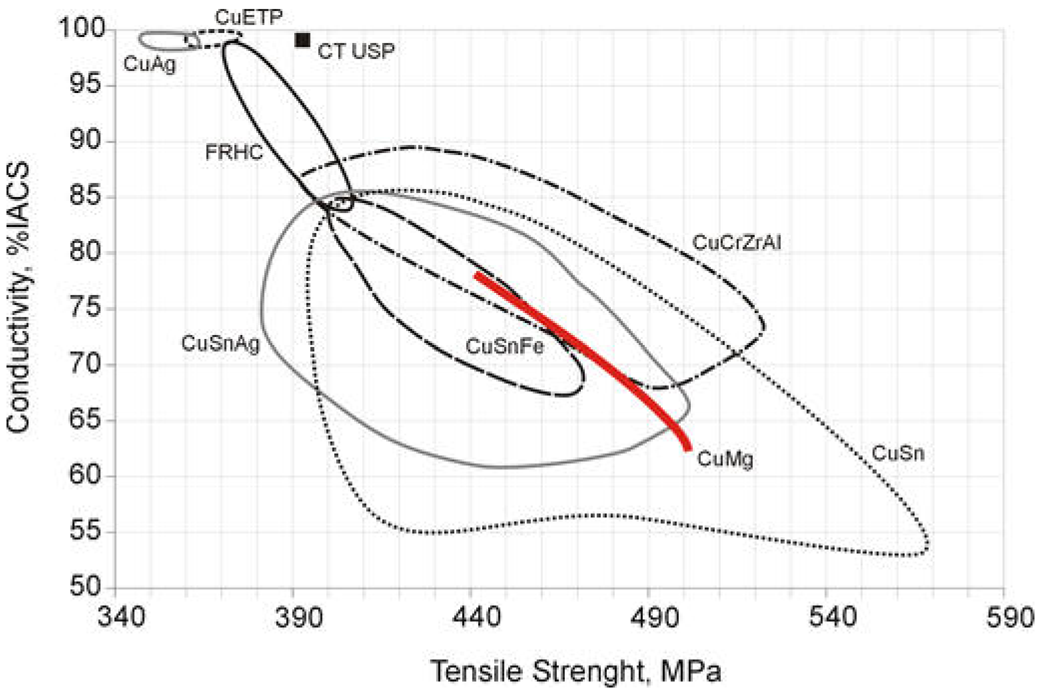
EN 1652	Plate, sheet, strip and circles for general purposes
EN 1654	Strip for springs and connectors
EN 1758	Strip for lead frames
EN 13148	Hot-dip tinned strip
EN 13599	Copper plate, sheet and strip for electrical purposes
EN 14436	Electrolytically tinned strip



Properties of square wire made of different copper alloys, dimension 0.63 x 0.63 mm. [Ref: 84]



Mechanical and electrical properties of different copper alloys [Ref: 90]



Electrical conductivity-tensile strength chart. Application of copper based alloys as trolley wire [Ref: 92]

Material properties of CuMg0,5 alloy [Ref: 97]

E-Module, GPa	120
Specific conductivity at 20°C, MS/m	≥36,0
Electric conductivity, %IACS	≥62
Linear expansion coefficient, 10-5/K	1,7
Density, 103 kg/m3	8,89

Mechanical and electrical properties of trolley wires made from CuMg0,5 alloy [Ref: 97]

Cross-section, mm2	80	100	107	120	150
Min. tensile strength, MPa 2)	520	510	500	490	470
Min. breaking load, kN 1)	40,4	49,5	51,9	57,0	68,4
Elongation at break A200, %	3-10	3-10	3-10	3-10	3-10
Yield strength, MPa	>430	>430	>430	>430	>430
Electrical resistance, Ω/km	≤0,385	≤0,286	≤0,268	≤0,239	≤0,191
1) at min. cross-section 2) other properties upon request					

Stranded conductors BzII according to DIN 48201 [Ref: 97]

Nominal section, mm2	Real cross-section, mm2	Number of wires	Wire diameter, mm	Strand diameter, mm	Weight, kg/km	Calc. break up load, kN	Permanent cross current capacity, A
10	10,02	7	1,35	4,1	90	5,88	75
16	15,89	7	1,70	5,1	143	9,33	100
25	24,25	7	2,10	6,3	218	14,24	130

35	34,36	7	2,50	7,5	310	20,17	160
50	49,48	7	3,00	9,0	446	28,58	200
50	48,35	19	1,80	9,0	437	28,39	200
70	65,81	19	2,10	10,5	596	38,64	245
95	93,27	19	2,50	12,5	845	54,76	305
120	116,99	19	2,80	14,0	1060	67,57	350
150	147,11	37	2,25	15,8	1337	86,37	410
185	181,62	37	2,50	17,5	1649	106,63	465
240	242,54	61	2,25	20,3	2209	142,40	560
300	299,43	61	2,50	22,5	2725	175,80	635
400	400,14	61	2,89	26,0	3640	231,12	765
500	499,83	61	3,23	29,1	4545	288,70	880

Flexible stranded conductors BzII according to DIN 43138 [Ref: 97]

Nominal cross-section, mm2	Real cross-section, mm2	Number of wires	Wire diameter, mm	Strand diameter, mm	Weight, kg/km	Tensile strength, MPa
10	9,6	49	0,50	4,5	89	≥589
16	16,3	49	0,65	5,9	152	≥589
16	16,3	84	0,50	6,2	152	≥589
25	26,1	133	0,50	7,5	246	≥589
35	37,6	133	0,60	9,0	353	≥589
50	51,2	133	0,70	10,5	482	≥589

	80		100		107		120		150	
	VALCOND	**standard**	**VALCOND**	**standard**	**VALCOND**	**standard**	**VALCOND**	**standard**	**VALCOND**	**standard**
Min. tensile strength 3) [MPa]	520	520	510	510	500	500	490	490	470	470
Min. breaking load 1) [kN]	40,8	40,4	50	49,5	52,4	46,3	57,6	57	69,1	68,4
Percentage elongation after fracture A200 [%]	3÷10	3÷10	3÷10	3÷10	3÷10	3÷10	3÷10	3÷10	3÷10	3÷10
Modulus of elasticity [GPa]	120	120	120	120	120	120	120	120	120	120
Yield strength [MPa]	>430	>430	>430	>430	>430	>430	>430	>430	>430	>430
Half-Hard point [°C]	>375	>385	>375	>385	>375	>385	>375	>385	>375	>385
Electrical conductivity at 20°C [MS/m]	≥40,6	≥36,0	≥40,6	≥36,0	≥40,6	≥36,0	≥40,6	≥36,0	≥40,6	≥36,0
Electrical conductivity [%IACS]	≥70	≥62	≥70	≥62	≥70	≥62	≥70	≥62	≥70	≥62
Specific electrical resistance at 20°C [10-8 Ωm]	≤2,463	≤2,770	≤2,463	≤2,770	≤2,463	≤2,770	≤2,463	≤2,770	≤2,463	≤2,770
Electrical resistance 1) [Ω/km]	≤0,314	≤0,385	≤0,251	≤0,286	≤0,235	≤0,268	≤0,209	≤0,239	≤0,168	≤0,191
Creepage elongation 2) [‰]	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1

Temperature coefficient of electrical resistance 5) [10^{-3}/K]	2,7	1,85	2,7	1,85	2,7	1,85	2,7	1,85	2,7	1,85
Linear coefficient of thermal expansion [10^{-5}/K]	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7
Specific mass 4) [10^3 kg/m^3]	8,89	8,89	8,89	8,89	8,89	8,89	8,89	8,89	8,89	8,89
1) Calculation based on the minimum cross section of 98% (EN 50149: 97%) 2) Temperature 150°C; applied load 100N pro mm2; time 1000h 3) Different tensile strength on request 4) According to EN 50149 5) Standard according to the nominal value of EN 50149, Valcond based on nkt-investigation										

Chemical composition

Chemical composition	Value	Comments
Cu [wt.%]	99,19-99,5	Calculated
Mg [wt.%]	0,4-0,7	
P [wt.%]	0,01	max
Others [wt.%]	0,1	
[Ref: 571]		

Chemical composition, weight percentage, (c)				Literature
Mg	P (max.)	Other	Cu	
0,4÷0,9	≤0,01	-	≥99,0	[Ref: 83]
0,4	-	-	rest	[Ref: 87]

Mechanical properties

Mechanical properties	Value	Comments	Literature
UTS [MPa]	380-1000 270-390	hard temper annealed temper	[Ref: 87, 94, 95, 83] [Ref: 94, 95, 87]
YS [MPa]	300-550		[Ref: 567]
Elongation [%]	3-14	minimum (A50)	[Ref: 83]
Hardness	115-195	[HV]	[Ref: 83]
Young’s modulus [GPa]	130	cold formed	[Ref: 83]
Kirchhoff’s modulus [GPa]	No data		
Poisson ratio	No data		

Mechanical properties of CuMg0,4 [Ref: 87]

Nominal diameter, mm	Temper	Tensile strength, MPa
1,2 - 5,0	soft	Max. 390
1,0	hard	760
1,3	hard	740
1,5	hard	720
2,0	hard	710
2,5	hard	640
3,0	hard	610
3,5	hard	600
4,0	hard	580
5,0	hard	560

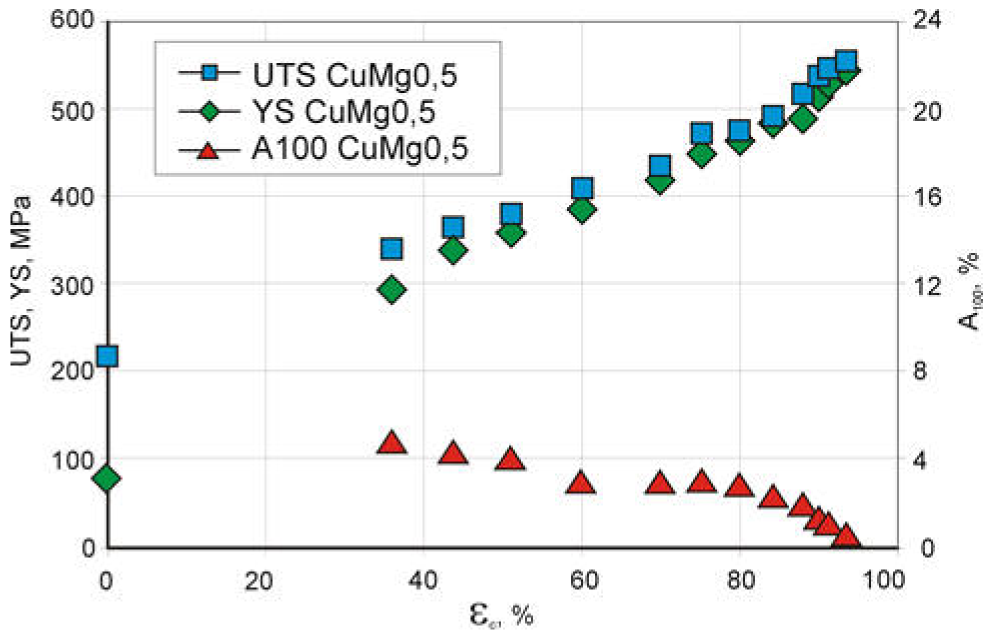
Mechanical properties of CuMg0,4 (references values, not standardized) [Ref: 94]

Highest tensile strength for diameter (mm), MPa	
Tensile strength, soft annealed	390
5,0	560
3,5	600
3,0	610
2,5	640
2,0	710
1,5	720
1,3	740

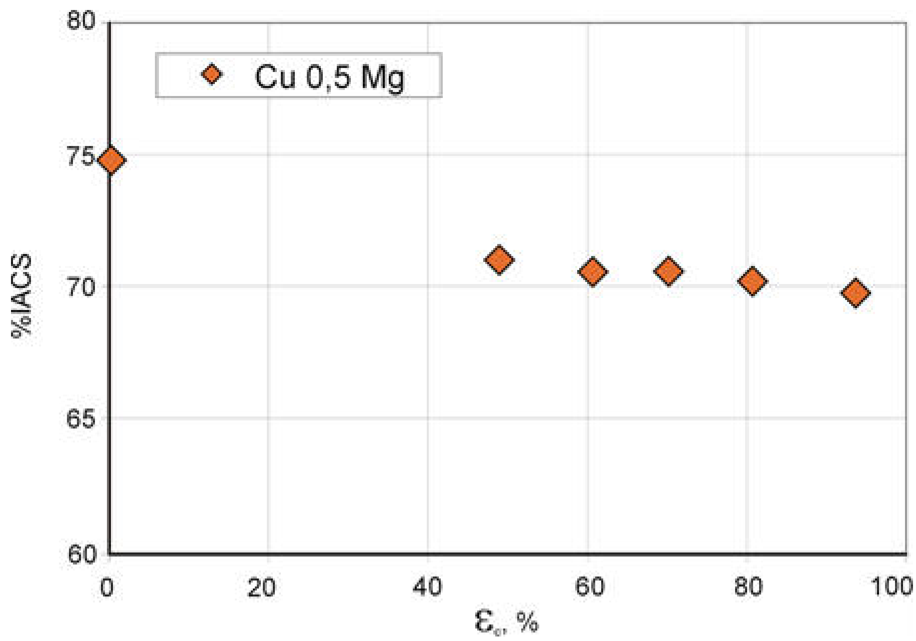
Mechanical properties of CuMg0,4 [Ref: 95]

Tensile strength (soft annealed), MPa	270 - 340
Tensile strength (hard), MPa	510 - 610
Tensile strength (spring hard), MPa	610 - 710

Tensile strength (super spring hard), MPa	710 - 1000



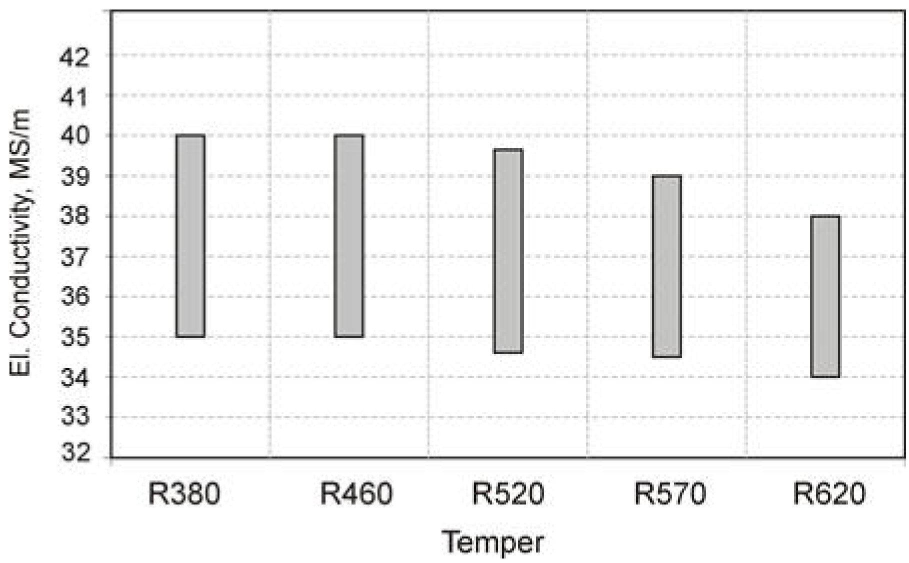
Ultimate tensile strength, yield stress and elongation as a function of deformation of CuMg0,5 alloy [Ref: 567]



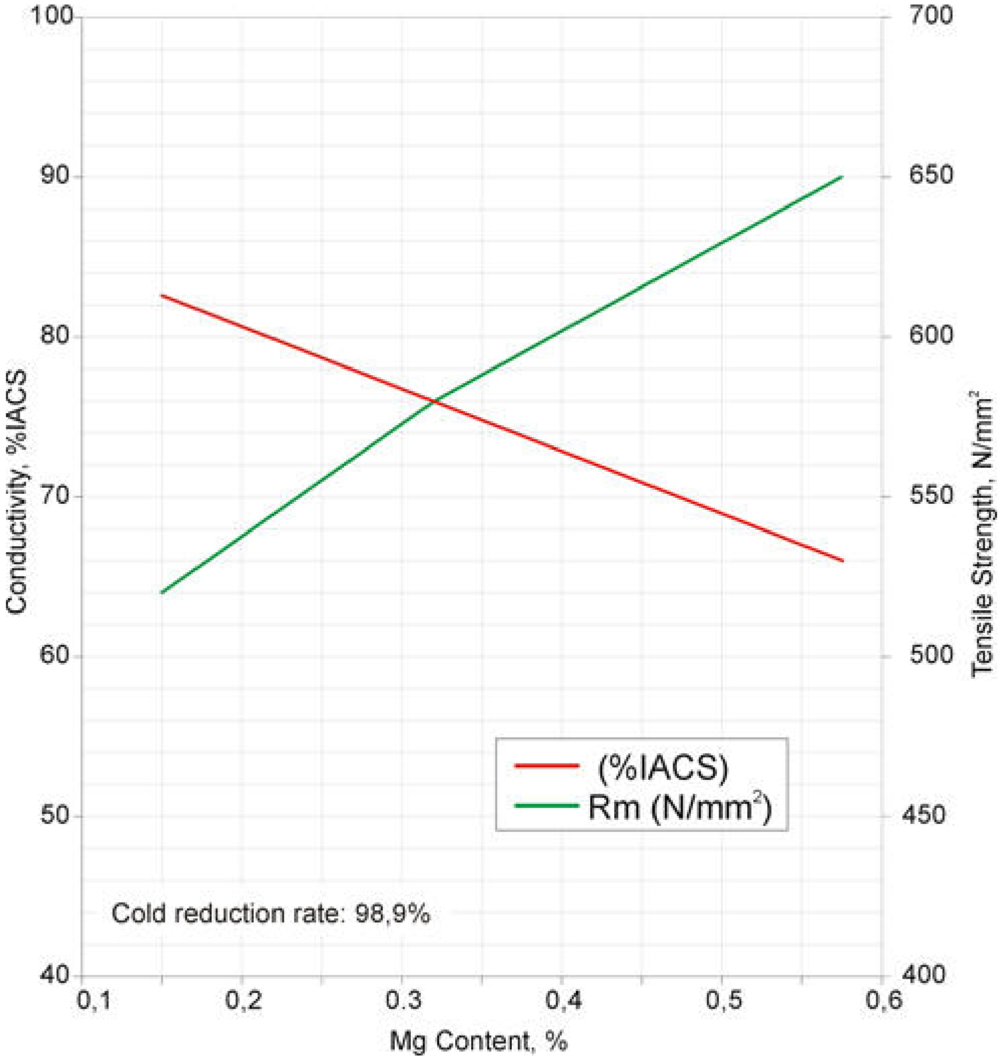
Electrical properties aas a function of deformation of CuMg0,5 alloy [Ref: 567]

Mechanical properties (EN 1652) [Ref: 83]

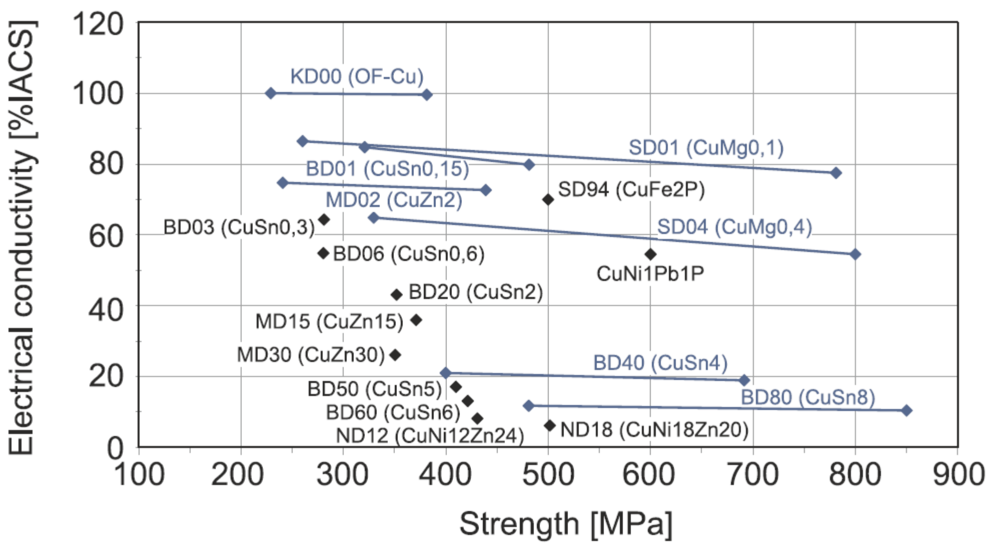
Temper	Tensile strength, MPa	Yield strength min., MPa	Elongation A50, min, %	Elongation (thermal stress relieved) A50, min, %	Hardness HV
R380	380-460	330	14	17	115-145
E460	460-520	410	10	12	140-165
R520	520-570	460	8	10	160-180
R570	570-620	500	6	8	175-195
R620≤0,5mm	>620	550	3	8	>190



Electrical conductivity as a function of CuMg0,5 alloy temper [Ref: 83]



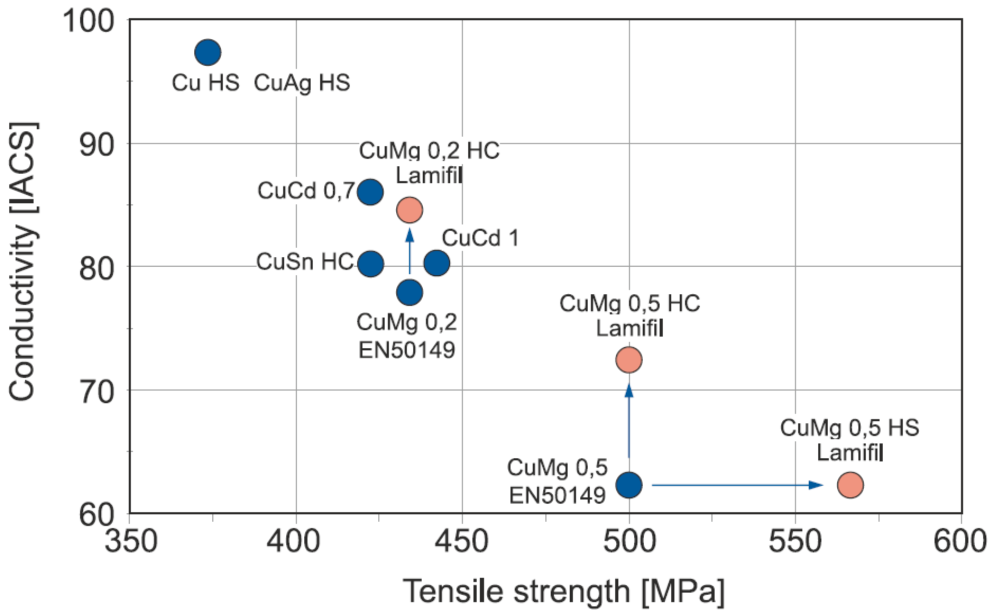
Change of Conductivity and Strength with the Mg-Content for CuMg alloys [Ref: 94]



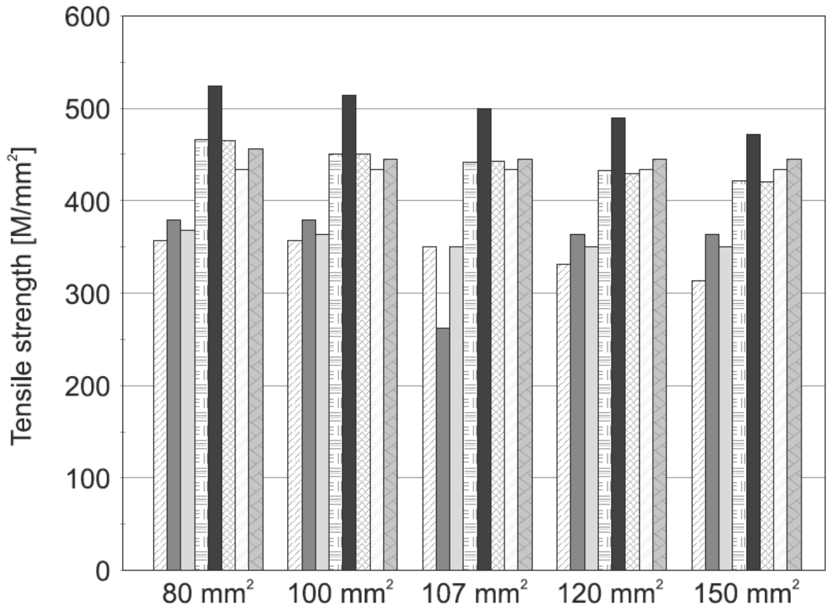
Tensile strength and electrical conductivity of selected copper alloys [Ref: 667]

Comparison of the electrical and mechanical characteristics and heat resistance of trolley wires made from different copper alloys [Ref: 668]

Material	Electrical conductivity, %IACS	Tensile strength, MPa	Elastic limit, MPa	Recrystallization temperature, °C
CuETP	99,5	370	356	220
CuAg0,1	98,7	370	360	340
EVELEC	87,2	405	374	380
CuMg0,2	77,8	440	432	410
CuMg0,5	60,5	500	440	420

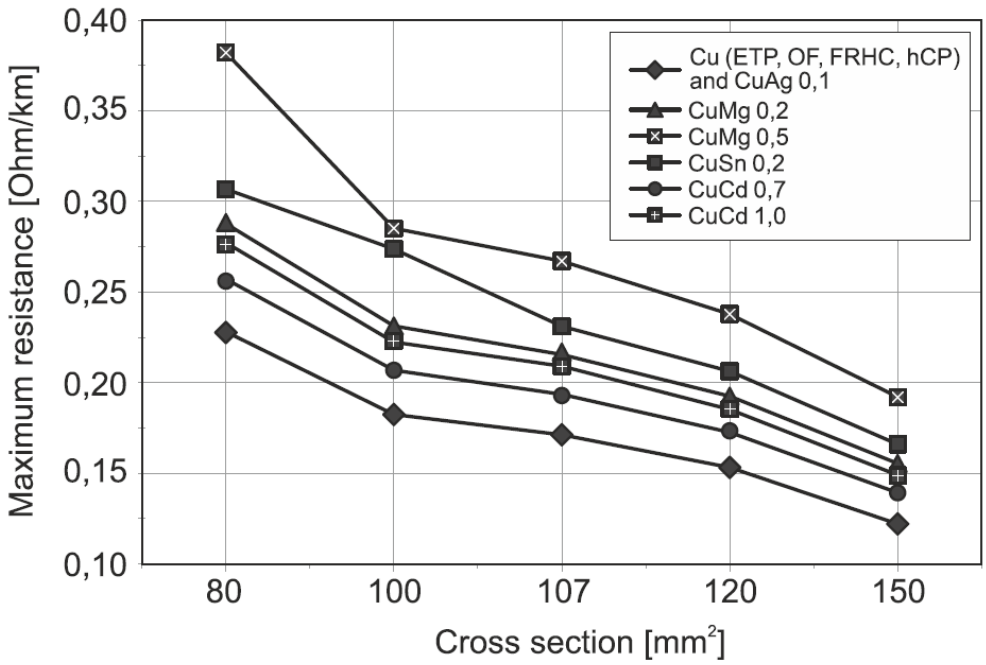


Comparison of the electrical and mechanical characteristics of some of copper alloys designed for trolley wires [Ref: 663]

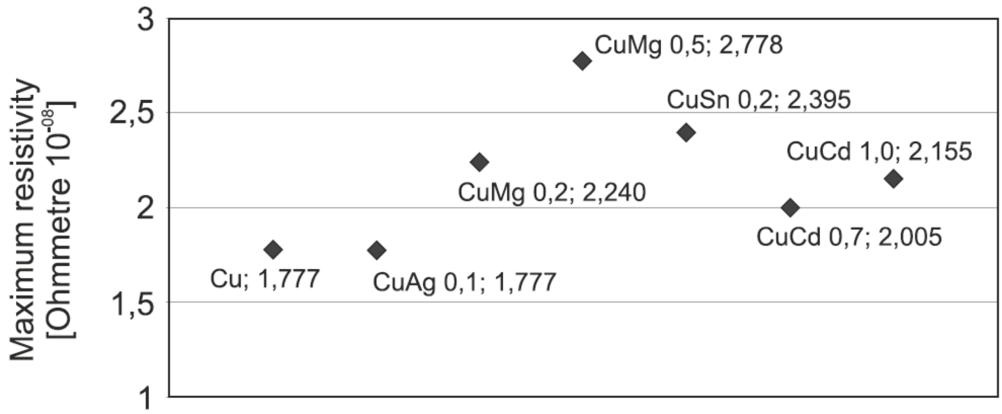


Cu	355	355	350	330	310
HighSt.Cu&CuAg	375	375	260	360	360
CuAg 0,1	365	360	350	350	350
CuMg 0,2	460	450	440	430	420
CuMg 0,5	520	510	500	490	470
CuSn 0,2	460	450	440	430	420
CuCd 0,7	430	430	430	430	430
CuCd 1,0	455	445	445	445	445

Tensile strength comparison of trolley wires made from copper and copper alloys [Ref: 662]



Maximum resistance comparison of trolley wires made from copper and copper alloys [Ref: 662]

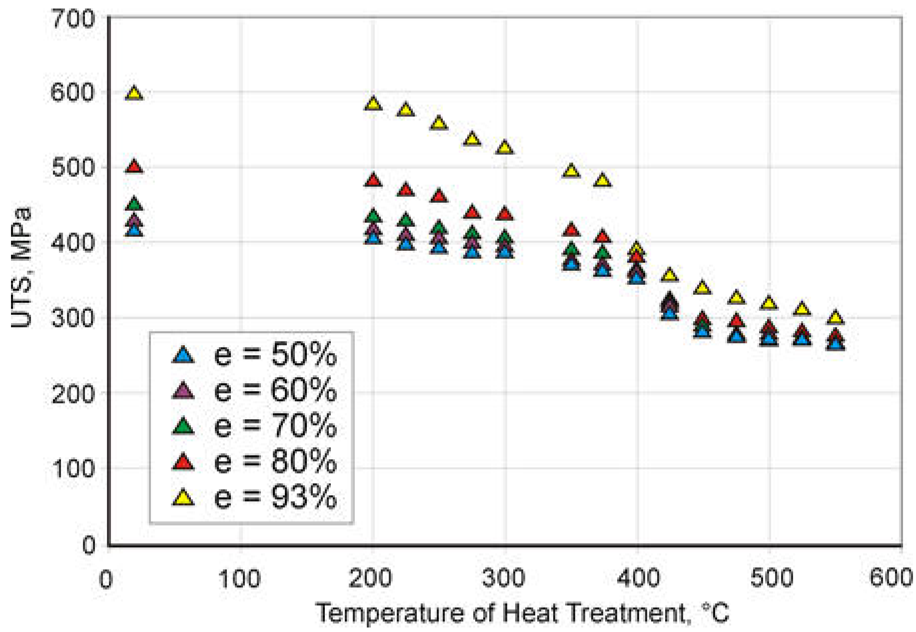


Maximum resistivity comparison of trolley wires made from copper and copper alloys [Ref: 662]

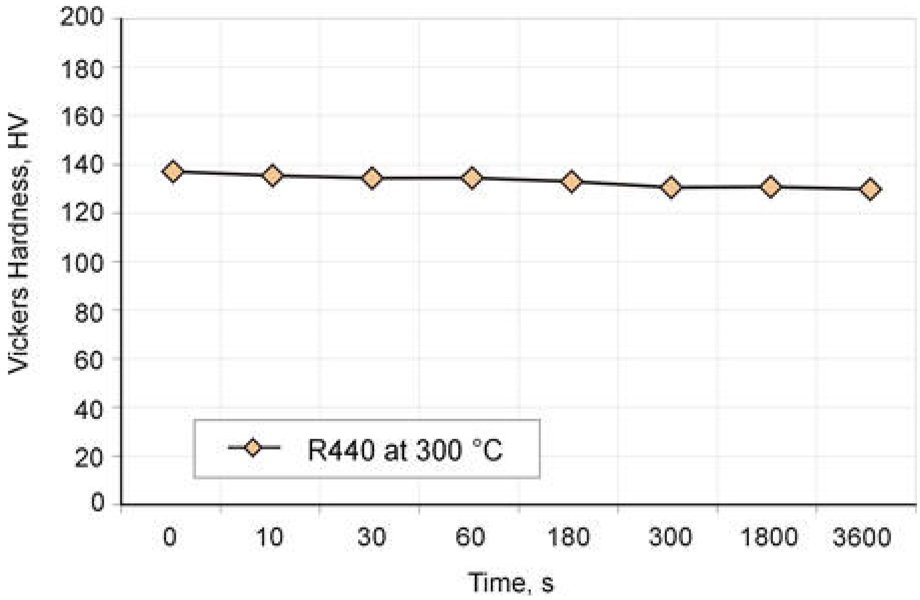
Exploitation properties

Heat resistance

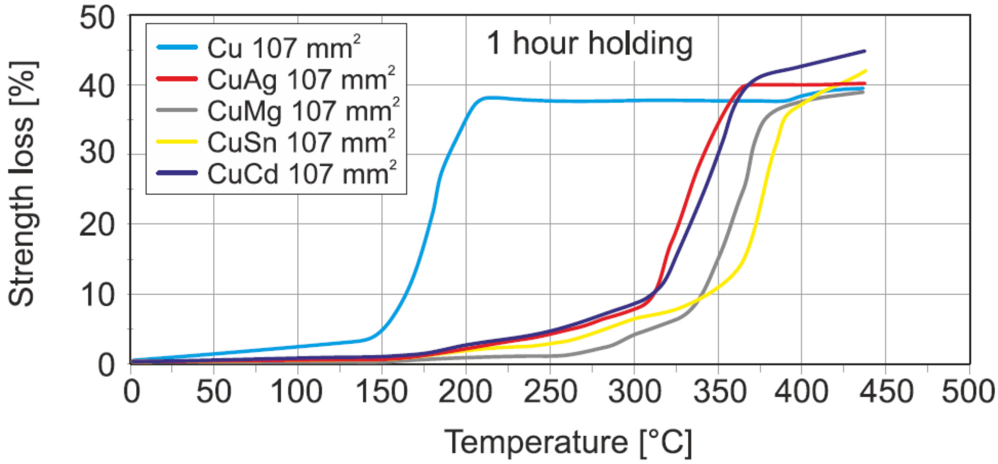
Mechanical and electrical properties vs temperatures



Ultimate tensile strength as a function of heat treatment temperature for different strain of CuMg0,5 alloy [Ref: 567]

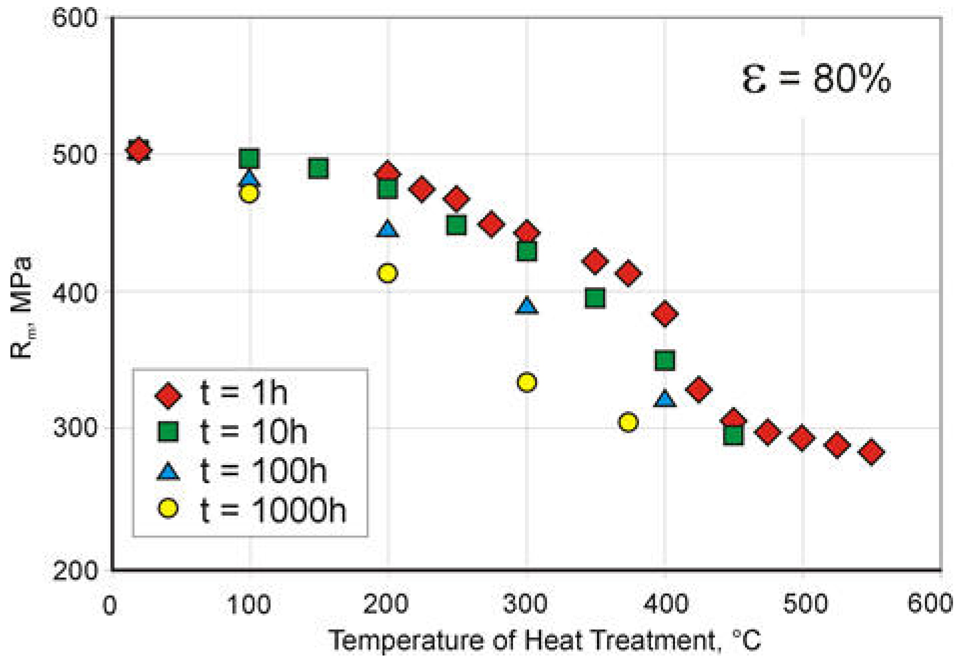


Vickers hardness as a function of time heat treatment (300°C) of CuMg0,5 alloy (In R440 temper) [Ref: 83]



Strength properties of different Cu alloys (Cu-Mg alloy included) designed for trolley wires as a function of heating temperature for 1h heating time [Ref: 663]

Long-therm heat resistance, e.g. Arrhenius curve



Ultimate tensile strength as a function of temperature and time of heat treatment of CuMg0,5 alloy [Ref: 567]

Half- softening temperature

Trolley wire mechanical properties [Ref: 59]

Material, cross-section	Tensile strength half-hard, MPa	Tensile strength hard, MPa	Temperature half-hard, °C
CuMg0,5 120mm2	394	516	375

Mechanical properties of CuMg0,4 alloy [Ref: 87]

Tensile strength, MPa	Soft annealing temperature, °C	Stress relieving temperature
max. 390 (soft) ÷ 750 (hard)	420 ÷ 520	180 ÷ 220 °C

Corrosion resistance

Hydrogen embrittlement resistance

CuMg0,5 has a good hydrogen-resistance [Ref: 83]

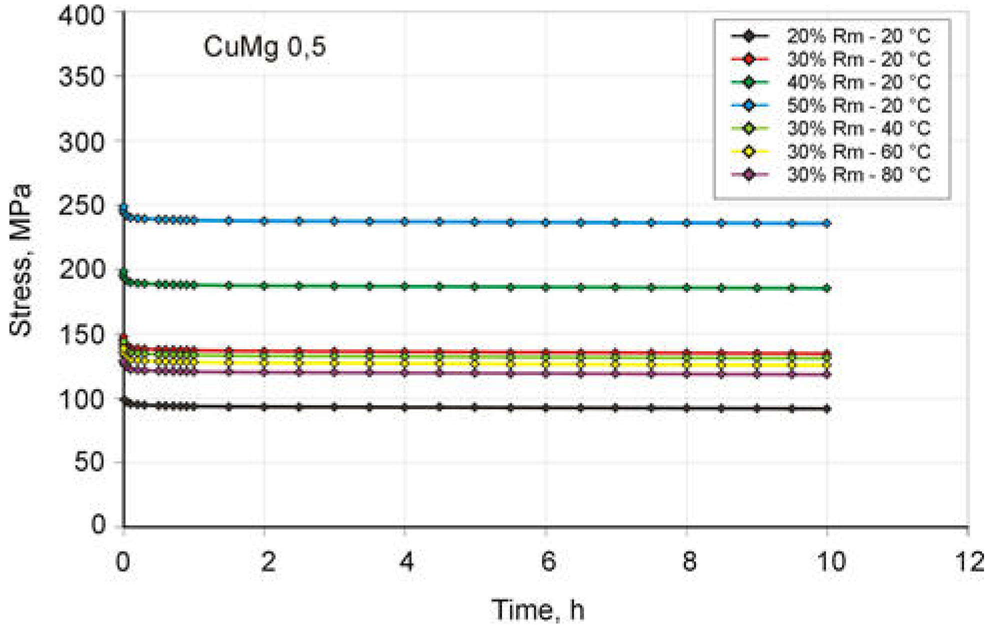
Other kind of corrosion elements

CuMg has a good resistance in in natural and industrial atmosphere (maritime air too). Industrial and drinking water, aqueous and alkaline solutions (not oxidizing), pure water vapour (steam), non-oxidizing acids (without oxygen in solution) and salts, neutral saline solutions. Not resistant to oxidizing acids, solutions containing cyanides, ammonia or halogens, hydrous ammonia and halogenated gases, hydrogen sulphide, seawater. *Literature* [Ref: 83]

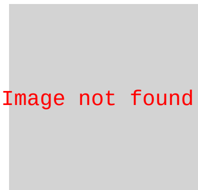
Type of corrosion	Suitability	Literature
Atmospheric	CuMg0,5 has a good resistance in in natural and industrial atmosphere	[Ref: 83]
Marine environment	CuMg0,5 has a good resistance in maritime air.	
Stress crack	Practically resistant against stress corrosion cracking	
Hydrogen embrittlement	CuMg0,5 has a good hydrogen-resistant	
Electrolytic	No data	-
Other - oxidising acids	Not resistant	[Ref: 83]

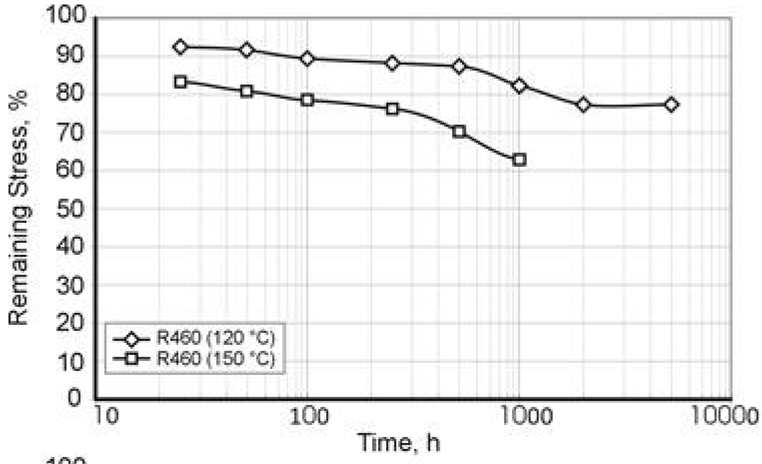
Rheological resistance

Stress relaxation

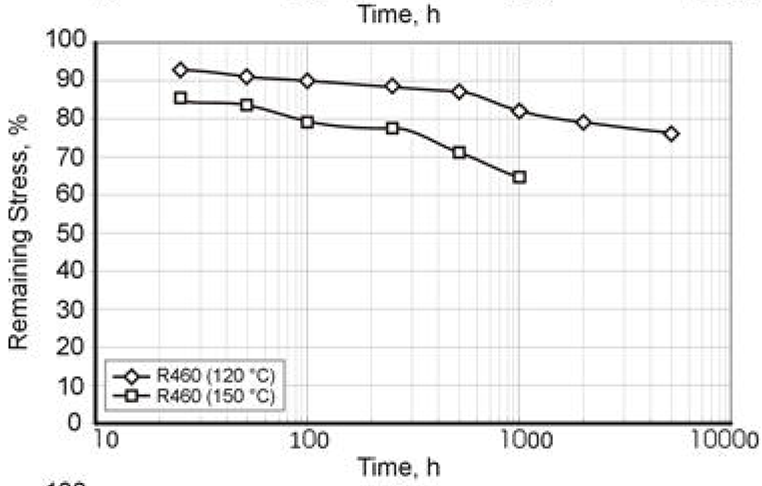


Stress relaxation as a function of initial stress, temperature and time for wires made from CuMg0,5 alloy.
Test parameters: wire diameter 3,5mm (c=80%), initial stress 20-50% of UTS [Ref: 567]

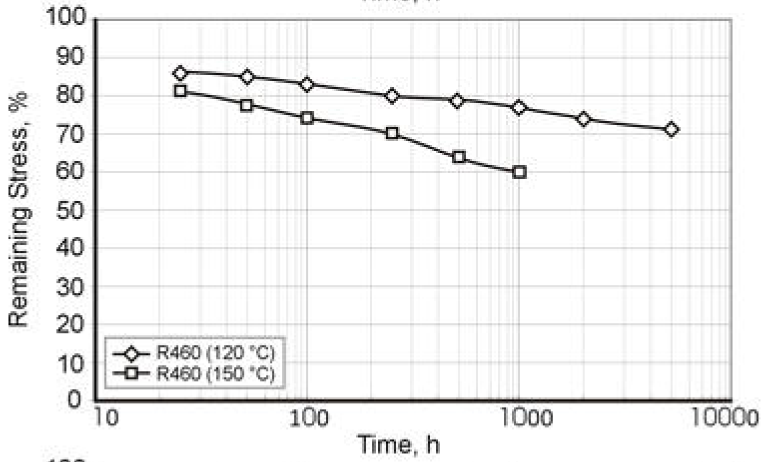




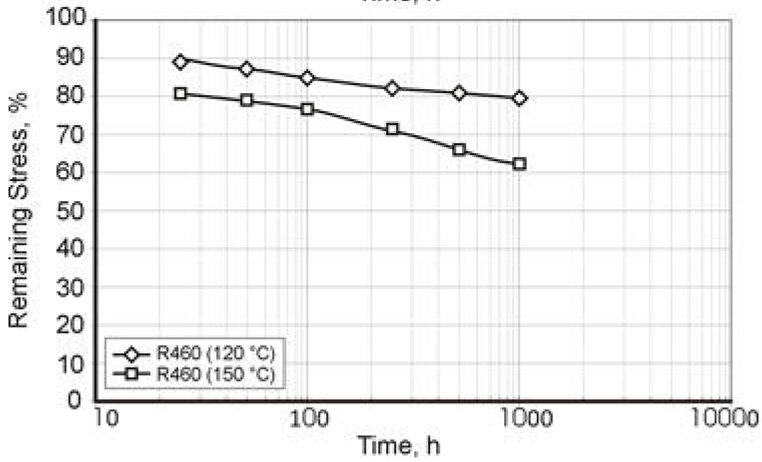
Initial Stress:
50% of Rp0,2
Parallel
Rolling Direction



Initial Stress:
50% of Rp0,2
Transverse
Rolling Direction



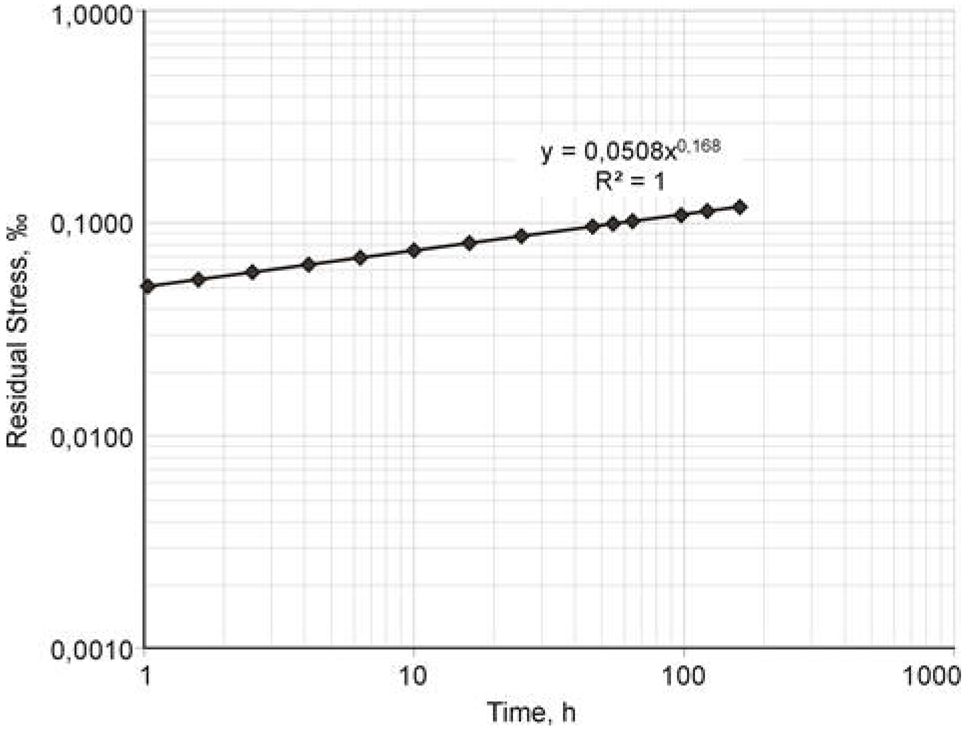
Initial Stress:
80% of Rp0,2
Parallel
Rolling Direction



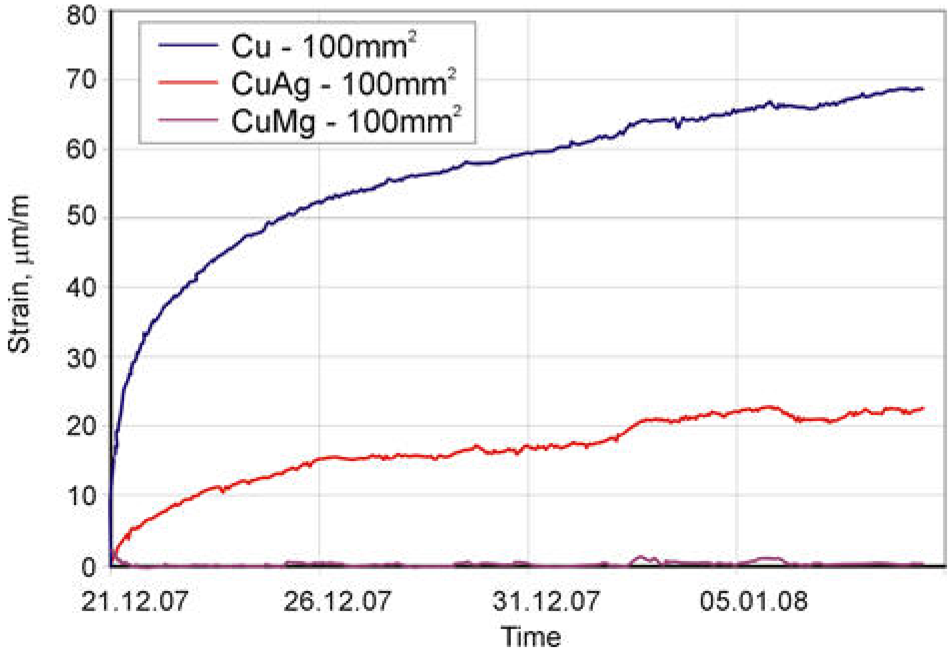
Initial Stress:
80% of Rp0,2
Transverse
Rolling Direction

Remaining stress as a function of initial stress value, rolling direction, temperature and *test time for CuMg0,5 alloy. Typical test sample thickness is 0.3 - 0.6 mm* [Ref: 83]

Creep



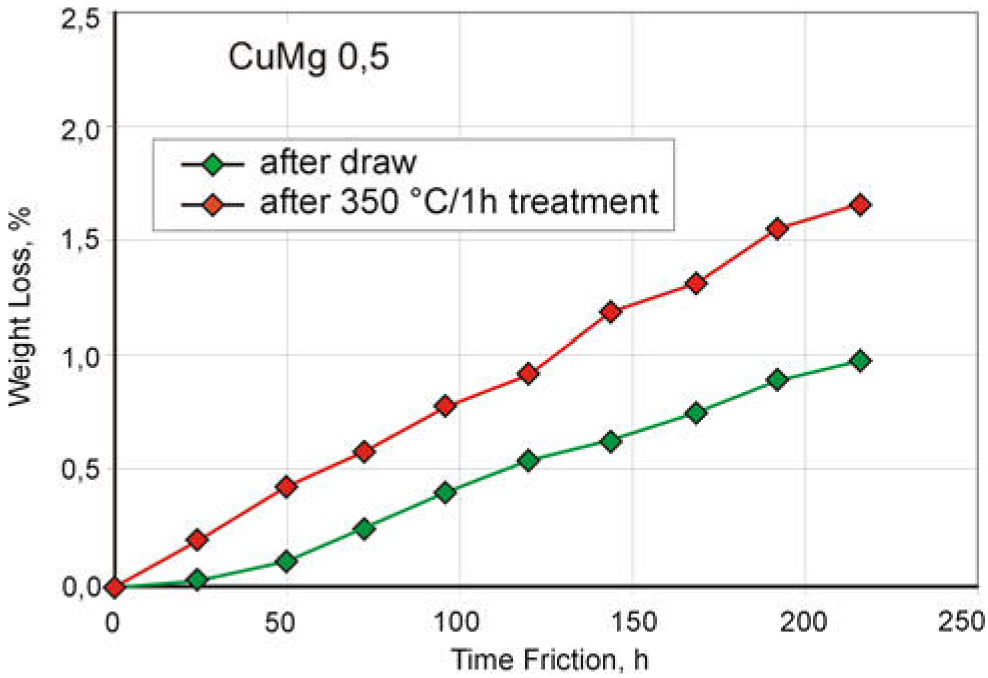
Residual stress as a function of timetest for wire made of CuMg0,5 alloy. Test parameters: wire diameter 3,5mm (*c*=80%), initial stress 30% of UTS, t=20°C [Ref: 567]



Progress of additional strain as a function of test time for wires made from Cu, CuAg and CuMg alloys. Test Parameters: RT (18°C), Load: F=11,25 kN [Ref: 59]

Wear resistance

Friction resistance



Weight loss as function of material conditions (after drawing and after heat treatment) and time of friction for CuMg0,5 alloy. Test parameters: □ε=80%, antispecimen: metal-carbon composite, load force F=30N, friction velocity V=11 m/s [Ref: 567]

Fatigue resistance

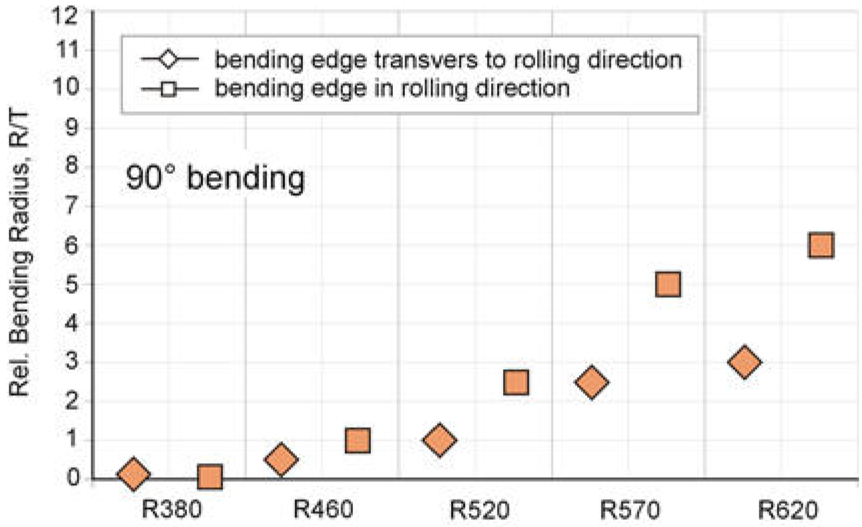
Fatigue cracking

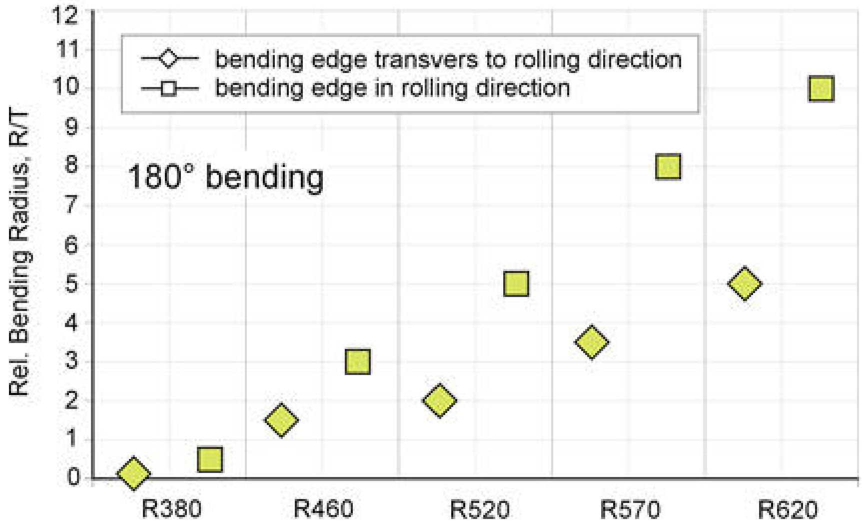
Bending test according to EN ISO 7438 is done with 10 mm wide samples. Smaller samples in general - as well as lower thickness - allow a lower bending radius without cracks.
Minimum Bending Radius Calculation

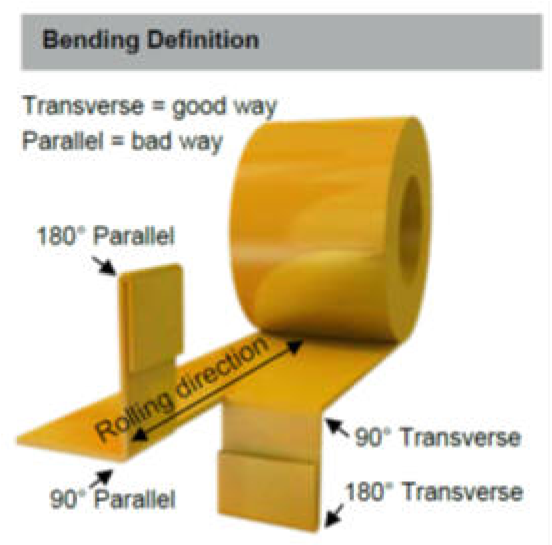
To find out the minimum possible bending radius take the R/T value from the list.

Example: R/T = 0.5 and thickness 0.3 mm

Minimum radius = (R/T) x thickness = 0.5 x 0.3 mm = 0.15 mm







Bending properties of CuMg0,4 alloy as a function of material conditions and rolling direction (measured at sample width 10mm according to EN 1654, possible bending radius=(R/T) x thickness) [Ref: 83]

Bending properties of CuMg0,4 alloy [Ref: 83]

Temper	Thickness range, mm	Bending 90°		Bending 180°	
		Transvers, R/T	Parallel, R/T	Transvers, R/T	Parallel, R/T
R380	≤ 0,5	0	0	0	0,5
R460	≤ 0,5	0,5	1	1,5	3
R520	≤ 0,5	1	2,5	2	5
R570	≤ 0,5	2,5	5	3,5	8
R620	≤ 0,5	3	6	5	10

Impact strength

NO DATA AVAILABLE

Fabrication properties

Fabrication properties	Value	Comments
Soldering	Excellent	
Brazing	Excellent	
Hot dip tinning	Excellent	
Laser welding	Fair	
Gas Shielded Arc Welding	Excellent	
Capacity for Being Cold Worked	Excellent	
Machinability Rating	20	
[Ref: 83]		

Technological properties

Technological properties	Value	Comments	Literature
Annealling temperature [°C]	250-650	time of annealling: 1-3h	[Ref: 83]
Stress relievieng temperature [°C]	150-200	time of stress relievieng: 1-3h	[Ref: 83]

References:

59. **Optimization and development of contact wire for high speed lines** - F. Pupke, NKT Cables GmbH.

83. **CuMg C18665 STOL 78** - KME

84. **Precipitation hardened high copper alloy Precipitation alloys for connector pins made of wire** - R. Zauter and D.V. Kudashov , Wieland-Werke AG, D- 89070 Ulm.

85. **Data sheet - Innovation in railway technology** - NKT Cable

87. **Data sheet - WIRE Alloy SD 04 CuMg0,4** - Diehl Metall

90. **Data sheet - High-performance copper-alloy wire** - Wieland

92. **Comparative study of electrical and mechanical properties of fire-refined and electrolytically refined cold-drawn copper wires** - Monica Martinez, Ana I. Fernandez, Merce Segarra, Helena Xuriguera, Ferran Espiell, Nuria Ferrer, J Mater Sci (2007) 42:7745–7749

94. **Copper Alloys for connector, springs and lead frames** - Jürgen Langer DIEHLMetall

95. **Kupfer-Magnesium-Legierungen** - Diehl Metal

97. **Data sheet - CONTACT WIRE AND STRANDED CONDUCTORS FOR OVERHEAD CATENARY SYSTEMS** - LILJEDAHL BARE WIRE

115. **Data sheet - High-copper alloy** - Wieland-K81

567. **AGH-UST - own research** - contact person: tknych@agh.edu.pl

571. **EN 50149:2012, Railway applications - Fixed installations - Electric traction - Copper and copper alloy grooved contact wires** -

662. **THE USE OF COPPER AND COPPER ALLOYS IN RAILWAY SYSTEMS** - A.Gamze ONUK, Sarkuysan Elektrolitik Bakır San. ve Tic. A.Ş., İstanbul, Türkiye, Uluslar arası Raylı Sistemler Mühendisliği Sempozyumu (ISERSE’13), 9-11 Ekim 2013, Karabük, Türkiye

663. **Catenary Wires, SOLUTIONS FOR URBAN TRANSPORT SYSTEMS AND HIGH - SPEED RAIL NETWORKS** - Lamifil

664. **Overview of Copper Alloys for Wire** - Diehl

665. **Copper magnesium: SD01 / SD02 / SD03 / SD04 / SD05** - Diehl Metall

667. **Tensile strength and electrical conductivity of selected copper alloys** - Diehl Metall

668. **High performance copper alloy** - Patent: EP 2505679 B1, La Farga Lacambra, S.A.U.

669. **Data sheet - Histral® H64 Copper based alloy, CuMg0.4** - LEONI