Machinability in tapping

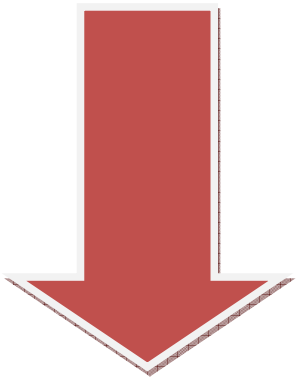
(Source of data: Vergnano –Chieri -Torino)

In tapping, machinability can be defined as the ease with which a material can be tapered through a cutting process, or can be plastically deformed in the case of forming taps.
In contrast to other material properties, machinability is difficult to measure or quantify.
Machinability depends on numerous factors, concerning the specific properties
Of the material to be tappered but also external factors regarding the working conditions, the tap and the machine.
The following table summarises the typical behaviour of the different material classes in tapping.

Material	Description	Machinability	Lubrication
1 - Steel	Steel are iron-carbon alloys mostly with the addition of other alloying elements., Since steels are heat treatable it is possible to obtain wide range of mechanical properties tailored to the specific application.		
1.1	These are non-alloy or low alloy steels with tensile strengths <850 N/mm^2, in some cases special alloying elements are added (S, Pb) in order to improve machinability (free cutting steels).	Despite the relatively low tensile strengths, these steels are difficult to machine due to galling and the formation of built-up-edge.	Emulsion Oil M.Q.L.
1.2		The machinability is good. The increased carbon content increases the tensile strength but decreases the tendency of galling	
1.3			
1.4	These are alloyed steels with tensile strengths up to 1600 N/mm^2. It is important to know the heat treatment received by the steel (annealed or hardened state)	Machinability decreases with increasing tensile strength. These steels can be abrasive due to the presence of hard particles	
1.5			Oil M.Q.L
1.6			
2 Stainless steels	Stainless steels are alloyed steels resistant to corrosion. The presence of Cr as the primary alloying element forms a protective surface layer-		
2.1	These are non heat treatable alloys with a ferritic structure.	Average machinability.	Oil M.Q.L.
2.2	The most widely used stainless steels. The addition of Ni a san alloying element guarantees an austenitic structure.	Machinability is low due to work-hardening tendency and high toughness. Galling and the formation of a built-up-edge is often observed on these steels.	
2.3		Martensitic stainless steels have good machinability. Abrasiveness increases with increasing carbon content. Ferric-austenitic duplex steels and precipitation hardening steels are more difficult to machine because of higher tensile strength.	
3 Cast iron	Cast iron is a Fe-C alloy with carbon content superior to 2%. It is the ferrous alloy most widely used in foundries		
3.1	Grey cast iron consist of a metallic matrix interrupted by graphite lamelae	Grey cast iron is easily machinable because the graphite breaks up the chips and acts as a lubricant.	oil M.Q.L. Dry
3.2	Nodular cast iron consist of a metallic matrix interrupted by graphite nodules. In comparison to graphite lamellae, the nodular graphite weakens the matrix less. The tensile strength can be increased by heat treatment such as hardening. Malleable cast iron also exhibits good ductility.	Machinability is similar to steel with comparable hardness. The graphite particles break up the chips (although to a lower extent than in grey cast iron). Machinability is more difficult in tempered cast iron due to higher tensile strength.	Emulsion Olio M.Q.L.
4 Aluminium and aluminium alloys	Aluminium and aluminium alloys have interesting properties such a low specific weight, high electrical conductivity and good corrosion resistance. The tensile strenght can be increate through the addition of alloying elements.		
4.1	These groups include commercially pure alluminium and alloys with low alloy elements content.	Machinability is good provided the long chips can be evacuated efficiently and galling is reduced	Emulsion Oil M.Q.L.
4.2			
4.3	These alluminium alloys have good mechanical properties due to the possibility of heat treatment	Good machinability due to shorter chips	
4.4	These are alluminium alloys with high Si content for die casting	Average machinability. The high Si content makes these alloys abrasive.	

Copper and copper alloys	*Copper has excellent electrical properties and good corrosion resistance*		
5.1	*This group includes commercially pure copper for electrical application*	*Machinability is good despite the gummy behaviour*	*Emulsion Oil M.Q.L.*
5.2	*These copper alloys have good ductility at high and low temperature*	*Machinability is good provided the long chips can be evacuated efficiently and galling is reduced*	
5.3	*Copper alloys with lower ductility in comparison to group 5.2.*	*Good machinability. The addition of lead improve machinability*	
5.4	*Bronze with both excellent mechanical properties and excellent resistance to aggressive environments*	*Low machinability due to high tensile strength*	
6 *Magnesium and magnesium alloys*	*Magnesium and magnesium alloys have interesting properties due to low specific weight.*		
6.1	*This group includes commercially pure magnesium for electrical applications*	*Machinability is good due to low forces needed for cutting. Fire hazard.*	*Emulsion Oil M.Q.L.*
6.2	*The addition of alloying elements increases the tensile strength.*		
7 *Titanium and titanium alloys*	*Titanium and titanium alloys combine low specific weight and excellent mechanical properties*		
7.1	*Pure titanium has excellent corrosion resistance*	*Machinability is good despite galling and the tendency to work-harden*	*Emulsion oil M.Q.L.*
7.2	*Titanium alloys combine low specific weight and excellent mechanical properties*	*Poor machinability due to high tensile strength.*	*Oil M.Q.L.*
8 *Nickel and nickel alloys*	*These material have excellent resistance to aggressive environments and to high temperature.*		
8.1	*Pure nickel has excellent corrosion resistance and good mechanical properties*	*Average machinability due to galling and formation of built-up-edge*	*Emulsion Oil M.Q.L.*
8.2	*Nickel alloys maintain good mechanical properties also at high temperatures*	*Poor machinability due to high tensile strength*	*Oil M.Q.L.*

In the following pages there are the tables of different standard comparison of materials and the correspondence with the codes of Vergnano company.



Application	Werkstoff Nr.	DIN	UNI	AFNOR	AISI/SAE/ASTM	MG Vergnano
Steel						
Mild magnetic	1.1015	RFe60				1.1
	1.1014	RFe80				1.1
	1.1013	RFe100				1.1
Structural	1.0037	St 37-2	Fe360B	E 24-2	1015	1.2
	1.0044	St 44-2	Fe430B	E 28-2	1020	1,2
	1.0050	St 50-2	Fe490	A50-2	A 570 (50)	1.2
	1.0060	St 60-2	Fe590	A 60-2	A 572 (65)	1.2
	1.0570	St 52-3	Fe510B	E 36-3	1024	1.2
Case hardening	1.0301	C10	C10	C10	1010	1.2
	1.0401	C15	C15	C18	1015	1.2
	1.7131	16MnCr5	16MnCr5	16MC5	5115	1.2
	1.7147	20MnCr5	20MnCr5	20MC5	5120	1.2
	1.7243	18CrMo4	18CrMo4			1.2
	1.5919	15CrNi6	16CrNi6	16NC6		1.2
	1.6523	20NiCrMo2	20NiCrMo2	20NCD2	8620	1.2
	1.6587	17CrNiMo6	18CrNiMo6	18NCD6		1.2
Nitriding	1.8515	31CrMo12	31CrMo12	30CD12		1.4
	1.8519	31CrMoV9	31CrMoV10			1.5
	1.8507	34CrAlMo7	34CrAlMo7	30CAD6.12		1.4
	1.8509	41CrAlMo7	41CrAlMo7	40CAD6.12		1.5
Free cutting	1.0711	9S20	9S20		1212	1.1
	1.0715	9SMn28	9SMn28	S250	1213	1.1
	1.0718	9SMnPb28	9SMnPb28	S250Pb	12L13	1.1
	1.0726	35S20	35S20	35MF4	1140	1.2
	1.0736	9SMn36	9SMn36	S300	1215	1.1
	1.0737	9SMnPb36	9SMnPb36	S300Pb	12L14	1.1
Heat treatable	1.0406	C25	C25	AF50C30	1025	1.3
	1.0528	C30	C30		1030	1.3
	1.0501	C35	C35	AF55C35	1035	1.3
	1.0511	C40	C40	AF60C40	1040	1.3
	1.0503	C45	C45	AF65C45	1045	1.3
	1.0540	C50	C50		1050	1.3
	1.0535	C55	C55	C54	1055	1.3
	1.0601	C60	C60	C60	1060	1.3
	1.7035	41Cr4	41Cr4	41Cr4	5140	1.4(ricotto)/1.5
	1.8159	51CrV4	51CrV4	50CV4	6145	1.4(ricotto)/1.5
	1.7218	25CrMo4	25CrMo4	25CD4	4130	1.4(ricotto)/1.5
	1.7220	34CrMo4	34CrMo4	35CD4	4137	1.4(ricotto)/1.5
	1.7225	42CrMo4	42CrMo4	42CD4		1.4(ricotto)/1.5
	1.7228	50CrMo4	50CrMo4	50CrMo4	4150	1.4(ricotto)/1.5
	1.6580	30CrNiMo8	30CrNiMo8	30NCD8		1.5(ricotto)/1.6
	1.6582	34CrNiMo6	34CrNiMo6	35NCD6	4337	1.5(ricotto)/1.6
	1.6511	36CrNiMo4	36CrNiMo4	40NCD3	4340	1.4(ricotto)/1.5
	1.6773	36NiCrMo16	36NiCrMo16			1.5(ricotto)/1.6
Ball bearing	1.3505	100Cr6	100Cr6	100C6	52100	1.4 (ricotto)
	1.3536	100CrMo7-3	100CrMo7			1.4 (ricotto)
Spring	1.1231	Ck67	C67	XC68		1.3
	1.1248	Ck75	C75		1078	1.3
	1.1269	Ck85	C85	C90		1.3
	1.1274	Ck101	C100	C100		1.3
	1.5021		48Si7			1.4(ricotto)/1.5
	1.5026	55Si7	55Si7	56SC7		1.4(ricotto)/1.5
	1.5027		60Si7	60Si7		1.4(ricotto)/1.5
	1.7108	60SiCr7	60SiCr8			1.4(ricotto)/1.5
	1.8159	50CrV4	50CrV4	50CV4		1.4(ricotto)/1.6
	1.7176	55Cr3	55Cr3	55C3	5155	1.4(ricotto)/1.6
	1.7701	51CrMoV4	51CrMoV4			1.4(ricotto)/1.6
Superficial hardening	1.1183	Cf35	Cf36	XC68H1TS		1.3
	1.1193	Cf45	Cf43	XC42H1TS		1.3
	1.1213	Cf53	Cf53	XC48H!TS	1050	1.3
	1.7005	45Cr2	45Cr2			1.4
	1.7043	38Cr4	38Cr4			1.5
	1.7034	37Cr4	36CrMn4	38C4	5135	1.5
	1.7223	41CrMo4	41CrMo4	42CD4TS	4140	1.5

Hot work	1.2767	45NiCrMo16	40NiCrMoV16KU	Y35NCD16		1.5 (ricotto)
	1.2713	55NiCrMoV7	55NiCrMoV7KU	55NiCrMoV7		1.4 (ricotto)
	1.2311		35CrMo8KU			1.4 (ricotto)
	1.2365	32CrMoV12-28	30CrMoV12-27KU	32CDV12-28	H10	1.4 (ricotto)
	1.2343	X38CrMoV5-1	X37CrMoV5-1KU	Z38CDV5	H11	1.4 (ricotto)
	1.2344	X40CrMoV5-1	X40CrMoV5-1KU	Z40CDV5	H13	1.4 (ricotto)
	1.2567	X30WCrV5-3	X30WCrV5-3KU	Z32WCV5		1.4 (ricotto)
	1.2681	X30WCrV9-3	X30WCrV9-3KU	Z30WCV9	H21	1.4 (ricotto)
Stainless steel						
Ferritic	1.4002	X6CrAl13	X6CrAl13	Z8CA12	405	2.1
	1.4512	X2CrTi12	X6CrTi12	Z3CT12	409	2.1
	1.4016	X6Cr17	X8Cr17	Z8C17	430	2.1
	1.4104	X14CrMoS17	X10CrS17	Z13CF17	430F	2.1
Austenitic	1.4319	X3CrNiN17-8	X10CrNi1809		302	2.2
	1.4305	X8CrNiS18-9	X10CrNiS1809	Z8CNF18-09	303	2.2
	1.4301	X5CrNi18-10	X5CrNi1810	Z4CN19-10FF	304	2.2
	1.4306	X2CrNi19-11	X2CrNi1811	Z1CN18-12	304L	2.2
	1.4303	X4CrNi18-12	X8CrNi1812	Z5CN18-11FF	305	2.2
	1.4828	X15CrNiSi20-12	X16CrNi2314	Z9CN24-13	309	2.2
	1.4841	X15CrNiSi25-20	X22CrNiSi2520	Z15CNS25-20	310	2.2
	1.4401	X5CrNiMo17-12-2	X5CrNiMo1712	Z3CND17-11-01	316	2.2
	1.4404	X2CrNiMo17-12-2	X2CrNiMo1712	Z2CND17-12	316L	2.2
	1.4541	X6CrNiTi18-10	X6CrNiTi1811	Z6CNT18-10	321	2.2
	1.4550	X6CrNiNb18-10	X6CrNiNb1811	Z6CNNb18-10	347	2.3
Martensitic	1.4006	X12Cr13	X12Cr13	Z10C13	410	2.3
	1.4005	X12CrS13	X12CrS13	Z11CF13	416	2.3
	1.4021	X20Cr13	X20Cr13	Z20C13	420	2.3
	1.4028	X30Cr13	X30Cr13	Z30C13	420F	2.3
	1.4057	X17CrNi16-02	X16CrNi16	Z15CN16-02	431	2.3
	1.4125	X105CrMo17		Z100CD17	440C	2.3
Duplex	1.4462	X2CrNiMoN22-5-3	X2CrNiMoN22-5-3	Z3CND22-05Az		2.3
	1.4501	X2CrNiMoCuWN25	X2CrNiMoCuWN25			2.3
Precipitation hardening	1.4542	X5CrNiCuNb16-4		Z7CNU15-05	630	2.3
Cast iron						
Grey cast iron	0.6010	GG10	G10	Ft10D	A48-20B	3.1
	0.6015	GG15	G15	Ft15D	A48-25B	3.1
	0.6020	GG20	G20	Ft20D	A48-30B	3.1
	0.6025	GG25	G25	Ft25D	A48-40B	3.1
	0.6030	GG30	G30	Ft30D	A48-45B	3.1
	0.6035	GG35	G35	Ft35D	A4850B	3.1
	0.6040	GG40	G40	Ft40D	A48-60B	3.1
Nodular cast iron tempered	0.7040	GGG40	GS-400-15	FGS-400-12	60-40-18	3.2
	0.7050	GGG50	GS500-7	FGS500-7	65-45-12	3.2
	0.7060	GGG60	GS600-3	FGS600-3	80-55-06	3.2
	0.7070	GGG70	GS700-2	FGS700-2	100-70-03	3.2
Malleable cast iron	0.8035	GTW35-04				3.2
	0.8055	GTS55-05				3.2
Aluminium and aluminium alloys						
Pure aluminium	3.0205	Al99				4.1
	3.0305	Al99.9				4.1
Aluminium wrought alloys	3.0505	AlMn0.5Mg0.5				4.2
	3.0915	AlFeSi				4.2
	3.3315	AlMg1				4.2
	3.3525	AlMg2Mn0,3				4.2
	3.3527	AlMg2Mn0,8				4.2
	3.3545	AlMg4Mn				4.2
	3.3555	AlMg5				4.2
	3.0615	AlMgSiPb				4.2
	3.1255	AlCuSiMn				4.2
	3.1325	AlCuMg1				4.2
	3.1355	AlCuMg2				4.2
	3.1645	AlCuMgPb				4.2
	3.4335	AlZn4.5Mg1				4.2

Alluminium casting alloys	3.1371	G-AlCu4TiMg				4.2
	3.2134	G-AlSi5Cu1Mg				4.3
	3.3241	G-AlMg3Si				4.2
	3.3261	G-AlMg3Si				4.2
	3.3541	G-AlMg3				4.2
	3.2373	G-AlSi9Mg				4.3
	3.2381	G-AlSi10Mg				4.4
	3.2383	G-AlSi10Mg(Cu)				4.4
	3.2581	G-AlSi12				4.4
	3.2583	G-AlSi12(Cu)				4.4
Copper and coppe alloys						
Pure copper	2.0060	E-Cu57				5.1
	2.0065	E-Cu58				5.1
Copper wrought alloys	2.1525	CuSi3Mn				5.2
	2.0855	CuNi2Si				5.2
	2.1247	CuBe2				5.2
	2.1285	CuCo2Be				5.2
Brass	2.0240	CuZn15				5.2
	2.0250	CuZn20				5.2
	2.0265	CuZn30				5.2
	2.0280	CuZn33				5.2
	2.0321	CuZn37				5.2
	2.0360	CuZn40				5.3
	2.0410	CuZn44Pb2				5.3
	2.0550	CuZn40Al2				5.3
Bronze	2.1016	CuSn4				5.2
	2.1020	CuSn6				5.2
	2.1030	CuSn8				5.2
	2.1086	G-CuSn10Zn				5.3
	2.0978	CuAl11Ni6FE5				5.4
	2.0940	CuAl10Fe				5.4
	2.0882	CuNi30Mn1Fe				5.4
Magnesium and magnesium alloys						
	3.5312	MgAl3Zn				6.1
	3.5632	MgAl6Zn3				6.1
	3.5912	MgAl9Zn1				6.1
	3.5161	MgZn6Zr				6.2
Titanium and titanium alloys						
Pure titanium	3.7024	Ti99.5				7.1
	3.7034	Ti99.7				7.1
Titanium alloys	3.7165	TiAl6V4				7.2
	3.7174	TiAl6V4Sn2				7.2
Nickel and nickel alloys						
Pure nickel	1.3011	RNi24				8.1
	1.3926	RNi12				8.1
Nickel alloys	2.4858	NiCr21Mo(Incoloy-825)				8.2
	2.4668	NiCr19Fe19NbMo (Inconel 718)				8.2
	2.4630	Ni-Cr20Ti(Nimonic- 75)				8.2
	2.4665	NiCr22Fe18Mo (Hastelloy X)				8.2
Plastic materials						
Thermoplastic		Polyethylene				9.1
		Polypropylene				9.1
		Polystyrene				9.1
		Polymethylmethacrylate				9.1
		Polycarbonate				9.1
		Polyamide				9.1
		Polytetrafluoroethylene				9.1
Thermosetting		Bachelite				9.2