Austral Wright Metals
at the cutting edge

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APPLICATION NOTE

Deep Drawing Stainless Steel

Stainless Steels

Stainless steels are frequently deep drawn into difficult shapes, often without intermediate annealing. They are very formable, and the austenitic grades have substantially higher ductility than carbon steels. While ferritic grades are less formable, they still have outstanding ductility, and can be deep drawn easily.

Austenitic Stainless Steels

The most common austenitic stainless steel is grade 304, which contains approximately 18% chromium and 8% nickel. The crystal structure of this grade at room temperature is a phase known as austenite, which is highly ductile, as well as non-magnetic. As the steel is drawn, part of the structure progressively transforms to a different phase, called martensite. Martensite is much harder and less ductile, and its formation can reduce the ductility of the steel, as well as making it magnetic. Difficult deep drawing may need a special version of grade 304 with higher nickel content (usually about 9%). This grade is often referred to as 304DDQ, which describes a family of different compositions of varying nickel content. The extra nickel suppresses the transformation to martensite, improving ductility and hence drawability.

However, most deep drawing of stainless can be readily achieved with standard grade 304, and it is not sound practice to use 304DDQ by default: it is more expensive, not as widely stocked, and not needed for the majority of parts.

The other common austenitic grade, 316, is normally used for its higher corrosion resistance: the addition of molybdenum enables it to handle more aggressive media than grade 304, particularly higher chloride contents. It also has a high nickel content, which makes the austenite stable, and the grade has excellent deep drawing ability, between that of normal 304 and 304DDQ. It may require higher forming loads than 304.

Ferritic Stainless Steels

The most common ferritic stainless steel is grade 430, which contains approximately 17% chromium, but does not have a deliberate nickel addition. Hence the crystal structure is ferrite, and the ductility is lower than austenitic stainless steels. The ductility is similar to carbon steel, and the grade is magnetic.

Table 1: Typical chemical composition of common stainless steels

Grade	Type	Carbon	Nitrogen	Chromium	Nickel	Molybdenum
304	Austenitic	0.05%	0.05%	18.5%	8.2%	-
304DDQ	Austenitic	0.05%	0.05%	18.5%	9.0%	-
316	Austenitic	0.05%	0.05%	17.5%	11.2%	2.1%
430	Ferritic	0.06%	0.04%	17.2%	-	-

Table 2: Typical tensile properties of common stainless steels

Grade	Yield Stress (0.2% Proof Stress)	Tensile Strength	Elongation	Hardness
	MPa	MPa	%	HV
304	270	650	58	155
304DDQ	260	630	58	150
316	270	605	55	145
430	325	515	28	145

PRACTICAL TIPS

Press shops experienced with carbon steel sometimes have problems making new parts from stainless steel. There are some simple steps needed to establish practices for stainless:

- **tooling** must be a hard material, finished to a high standard
  - heat treated tool steel tooling is acceptable
  - best deep drawing performance is obtained from extra hard aluminium bronze tooling
- high pressure **lubricants** should be used. See table on page 3 for more detail.
  - EP lubricants are essential for severe deep drawing
  - lubricate both sides, generously, to overcome the galling tendency of stainless steel
  - soluble oil can be used with aluminium bronze tooling
  - remove lubricants before heat treatment
- **plastic films** can be used to protect the steel surface and aid drawing. Polyethylene (PE) or poly vinyl chloride (PVC) are used. They give excellent lubrication, smoother workpiece surface and deeper draws. They reduce the friction coefficient below the values with oil lubrication, and may eliminate the need for oil lubrication. Adhesive films can be applied to the steel surface before pressing, or a loose film can be stretched over the tool
  - PE (white) is adequate for most purposes
  - PVC (blue) is needed for the deepest draws and for two stage pressings
  - both can be hard to remove, and should not be left on the steel for extended periods. Leaving them in the sun may make them very hard or impossible to remove.
- **clamping pressure** is much higher than for carbon steel
  - about 50% higher for ferritic grades (eg 430)
  - up to 3 x higher for austenitic grades (eg 304)
- **pressing speed** is much lower than for carbon steel
  - about half normal speed for ferritic grades (eg 430)
  - about 20 – 30 mm/sec for austenitic grades (eg 304)
- if the part is **splitting**:
  - warm the blank, up to a maximum of about 70^{o}C. Even a few degrees can be sufficient, so warming blanks can be a big help on cold mornings.
  - warm the lubricant to reduce friction
  - feed more metal into the pressing by:
    - relieving areas of the tool
    - reducing the clamping pressure
    - reducing the blank size
    - reduce friction by:
      - introducing a plastic film
      - using a lubricant giving lower friction
  - slow the pressing speed
  - cool the punch (changes the work hardening behaviour of the stainless steel)
  - use a thicker material – thicker blanks give better ductility
  - relieve areas of the tool which are causing excessive strain
  - change to a grade with better deep drawing ability: 430 → 304 → 316 → 304DDQ
  - introduce an intermediate annealling step
- if the part is **wrinkling**:
  - feed less metal into the pressing by:
    - increasing the hold down pressure (press pressure, draw bead height or less lubrication at the hold-down ring)
    - shaping the blank size to the part to make metal feed more uniformly
    - increasing the blank size near the wrinkling
    - stretch out minor wrinkles with a second stroke

DETAILED DATA

Limiting strain
- 304D should be capable of 40 – 60% reduction
- 304 & 430 should achieve 40 – 50% reduction
- reduction = [(D – d)/D] x 100, where D = diameter of blank, d = ID of drawn piece

Punch & die radius affect drawability strongly
- typically, use a minimum of 5 – 10 x metal thickness

Presses require more power than for carbon steel
- typically 100% more power (ram force)
- stiffer frame

Dies must resist higher forces & the tendency of stainless steel to gall
- D2 tool steel is good for short runs
- Carbide draw rings are beneficial on long runs
- High strength aluminium bronze for lowest friction & galling

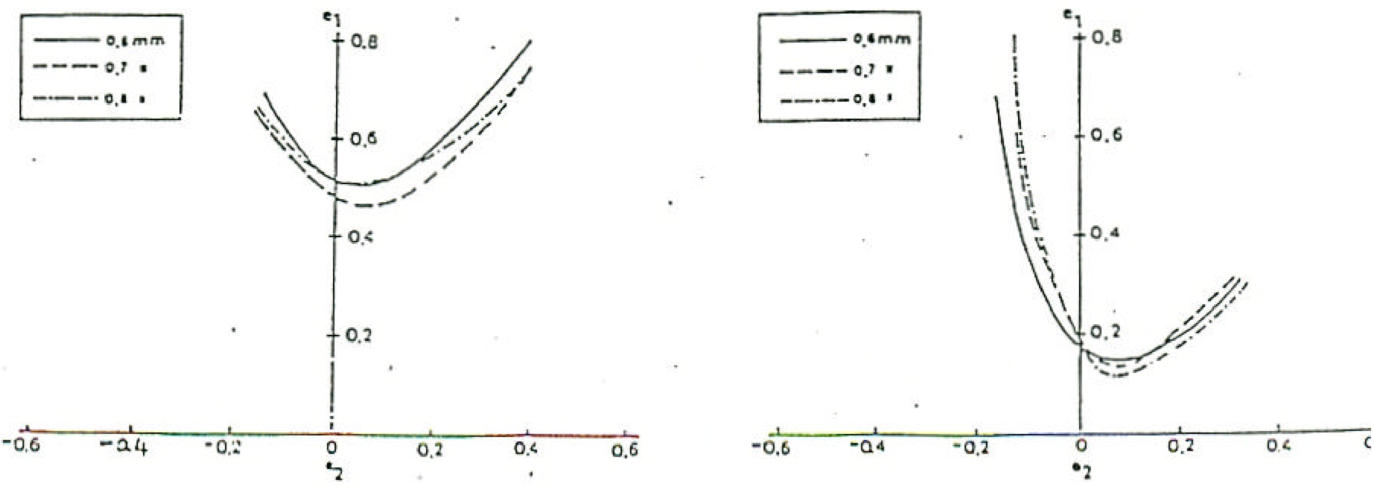
Die clearance for heavy draws
- 35 – 40% of metal thickness for austenitic alloys
- 10 – 15% of metal thickness for ferritic alloys
- avoid ironing (i.e. die clearance less than metal thickness)

Drawing cylindrical parts
- aim for 40 – 50% reduction in first draw, <30% reduction in second draw
- second draw can be increased to 30 – 40% by annealing the workpiece between draws

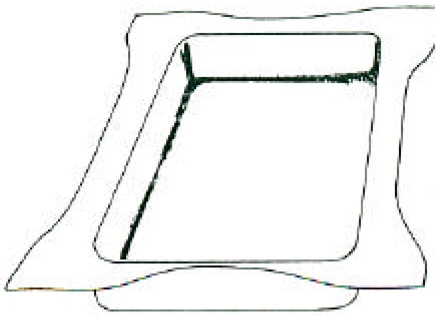
Table: Suitability of various lubricants
(considers effectiveness, cleanliness, ease of removal etc)
A = excellent, B = good, C = acceptable

Lubricant	Rating	Lubricant	Rating
Fatty oils & blends	C	Sulphurised or sulphochlorinated oils	C
Soap-fat pastes	B	Chlorinated oils or waxes:	
Wax based pastes	B	High viscosity (4,000 – 20,000 SUS)	A
Heavy duty emulsions	B	Low viscosity types (200 – 1,000 SUS)	B
Dry film (wax, or soap + borax)	B	Graphite or molybdenum disulphide	Hot forming only
Pigmented pastes	A		

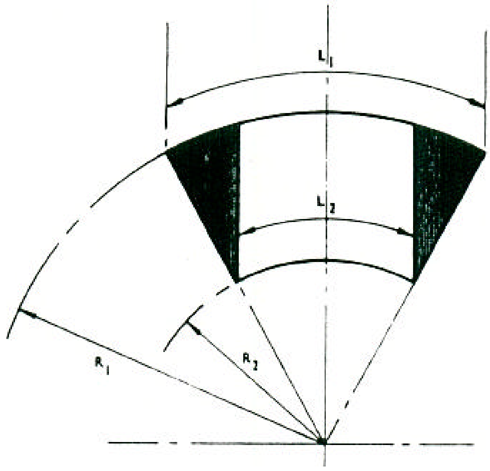
SUS = Saybolt Universal Seconds. Divide by 4.62 for centistokes.



Forming limit diagrams for grade 304 (left) and grade 430 (right)



A typical deep drawn tray, combining both drawing and forming. Earing is clearly visible.



Wrinkling.
The material in length L_1 at the outside edge of the blank is drawn over segment L_2 of the lip of the cup. Since L2 is shorter than L1, the material in the flange thickens, and tends to wrinkle unless constrained by the blankholder or pressure plate pressure.

Drawing Force

A good approximation of the drawing force required is given by:

$$\text{Drawing force} = \frac{(\text{Yield Stress} + \text{Tensile Strength})}{2} \times \text{Cross sectional area of product walls}$$

Table of approximate pressure (tonnes) required to deep draw stainless steel

Stainless steel grade 304, typical properties: Yield Stress (0.2% Proof) 260 MPa; Tensile Strength 630 MPa

PL*	Material Thickness, mm								PL*								
mm	**0.55**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.2**	**1.6**	**mm**	**0.55**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.2**	**1.6**
150	3.7	4.0	4.7	5.3	6.0	6.7	8	11	**1250**	31	33	39	45	50	56	67	89
200	4.9	5.3	6.2	7.1	8.0	8.9	11	14	**1500**	37	40	47	53	60	67	80	107
250	6.1	6.7	7.8	8.9	10	11	13	18	**1750**	43	47	55	62	70	78	93	125
300	7.3	8.0	9.3	11	12	13	16	21	**2000**	49	53	62	71	80	89	107	142
350	8.6	9.3	11	12	14	16	19	25	**2250**	55	60	70	80	90	100	120	160
400	9.8	11	12	14	16	18	21	28	**2500**	61	67	78	89	100	111	134	178
450	11	12	14	16	18	20	24	32	**2750**	67	73	86	98	110	122	147	196
500	12	13	16	18	20	22	27	36	**3000**	73	80	93	107	120	134	160	214
550	13	15	17	20	22	24	29	39	**3500**	86	93	109	125	140	156	187	249
600	15	16	19	21	24	27	32	43	**4000**	98	107	125	142	160	178	214	285
700	17	19	22	25	28	31	37	50	**4500**	110	120	140	160	180	200	240	320
800	20	21	25	28	32	36	43	57	**5000**	122	134	156	178	200	223	267	356
900	22	24	28	32	36	40	48	64	**5500**	135	147	171	196	220	245	294	392
1000	24	27	31	36	40	45	53	71	**6000**	147	160	187	214	240	267	320	427

PL = peripheral length of the pressing