Hot-working

Hot-working

The HAYNES® and HASTELLOY® alloys can be hot-worked into various shapes; however, they can be more sensitive to the amounts and rates of hot-reduction than the austenitic stainless steels. In addition, the hot-working temperature ranges for the HAYNES® and HASTELLOY® alloys are quite narrow, and careful attention to hot-working parameters is necessary

In developing suitable hot-working practices, particular attention should be paid to the solidus of the alloy in question (the temperature at which the alloy begins to melt), the high strengths of the HAYNES® and HASTELLOY® alloys at elevated temperatures, their high work-hardening rates, and their low-thermal conductivities. Furthermore, their resistance to deformation increases markedly as the temperature falls to the low end of the hot-working range.

Accordingly, hot-working practices that incorporate high (heavy) initial reductions, followed by moderate final reductions, coupled with frequent re-heating, generally yield the best results. In addition, slow deformation rates tend to minimize adiabatic heating and applied force requirements.

Following any hot-working operation, the HAYNES® and HASTELLOY® alloys should be annealed, to return them to their optimal condition for service, age-hardening (in the case of the age-hardenable alloys), or for further fabrication. Annealing temperatures and techniques are detailed in the heat treatment section.

Melting Temperature Ranges

Alloy	Melting Temperature Range			
	Solidus*		Liquidus**	
	°F	°C	°F	°C
B-3®	2500	1370	2585	1418
C-4	-		-	
C-22®	2475	1357	2550	1399
C-22HS®	2380	1304	2495	1368
C-276	2415	1323	2500	1371
C-2000®	2422	328	2476	1358
G-30®	-		-	
G-35®	2430	1332	2482	1361
HYBRID-BC1®	2448	1342	2509	1376
N	2375	1302	2550	1399
ULTIMET®	2430	1332	2470	1354
25	2425	1329	2570	1410
75	2445	1341	2515	1379
188	2400	1316	2570	1410
214®	2475	1357	2550	1399
230®	2375	1302	2500	1371
242®	2350	1288	2510	1377

244®	2480	1360	2550	1399
263	2370	1299	2470	1354
282®	2370	1299	2510	1377
556®	2425	1329	2480	1360
617	2430	1332	2510	1377
625	2350	1288	2460	1349
625SQ®	2350	1288	2460	1349
718	2300	1260	2435	1335
HR-120®	2478	1359	2542	1395
HR-160®	2360	1293	2500	1371
HR-224®	2449	1343	2510	1377
HR-235®	2401	1316	2473	1356
MULTIMET®	2350	1288	2470	1354
R-41	2385	1307	2450	1343
S	2435	1335	2516	1380
W	2350	1288	2510	1377
Waspaloy	2425	132	2475	1357
X	2300	1260	2470	1354
X-750	2540	1393	2600	1427

*Temperature at which alloy starts to melt
**Temperature at which alloy is fully molten

Forging

Recommended Procedures and Temperatures Applicable to:
Corrosion-resistant Alloys
High-temperature Alloys
Wear & Corrosion-resistant Alloy

The following procedures are recommended for forging of the HAYNES® and HASTELLOY® alloys:

- Soak billets or ingots at the forging start temperature for at least 30 minutes per inch of thickness. The use of a calibrated optical pyrometer is essential.
- The stock should be turned frequently to make sure that it is heated evenly. Direct flame impingement on the alloy must be avoided.
- Forging should begin immediately after withdrawal from the furnace. A short time lapse may allow surface temperatures to drop as much as 100-200°F (55-110°C). Do not raise the forging temperature to compensate for heat loss, as this may cause incipient melting.
- Moderately heavy reductions (25-40%) are beneficial, to maintain as much internal heat as possible, thus minimizing grain coarsening and the number of re-heatings. Reductions greater than 40% per pass should be avoided.
- Care must be taken to impart sufficient hot-work during forging to ensure that the appropriate structure and properties are achieved in the final part. For parts with large cross-sections, it is advisable to include a number of forging upsets in the hot-working schedule, to allow for adequate forging reductions. Upset L/D ratios of 3:1 are generally acceptable.
- Light-reduction finish sizing sessions should generally be avoided. If required, they should be performed at the lower end of the forging temperature range.
- Do not make radical changes in the cross-sectional shape, such as going directly from a square to a round, during initial forming stages. Instead, go from a square to a “round cornered square”, then to an octagon, then to a round.
- Remove (condition) any cracks or tears developed during forging. This can be done at intermediate stages, between forging sessions.

Forging/Hot-working Temperature Ranges

Alloy	Forging/Hot-Working Temperature			
	Start Temperature*		Finish Temperature**	
	°F	°C	°F	°C
B-3®	2275	1246	1750	954
C-4	2200	1204	1750	954
C-22®	2250	1232	1750	954
C-22HS®	2250	1232	1750	954
C-276	2250	1232	1750	954
C-2000®	2250	1232	1750	954
G-30®	2200	1204	1800	982
G-35®	2200	1204	1750	954
HYBRID-BC1®	2250	1232	-	
N	2200	1204	1750	954
ULTIMET®	2200	1204	1750	954
25	2200	1204	1750	954
75	2200	1204	1700	927
188	2150	1177	1700	927
214®	2150	1177	1800	982
230®	2200	1204	1700	927
242®	2125	1163	1750	954
244®	-		-	
263	2150	1177	1750	954
282®	2125	1163	1850	1010
556®	2150	1177	1750	954
617	2125	1163	1600	871
625	2150	1177	1600	871
625SQ®	-		-	
718	2050	1121	1650	899
HR-120®	2150	1177	1700	927
HR-160®	2050	1121	1600	871
HR-224®	-		-	
HR-235®	2250	1232	1750	954
MULTIMET®	2150	1177	1700	927
R-41	2150	1177	1850	1010
S	2100	1149	1700	927
W	2240	1227	1800	982
Waspaloy	2150	1177	1850	1010

X	2100	1149	1750	954
X-750	2150	1177	1750	954

*Maximum
**Dependent upon the nature and degree of working

Hot-rolling

Recommended Procedures and Temperatures Applicable to:
Corrosion-resistant Alloys
High-temperature Alloys
Wear & Corrosion-resistant Alloy

Hot rolling of the HAYNES® and HASTELLOY® alloys can be performed to produce conventional rolled forms, such as bars, rings, and flats. The hot rolling temperature range is the same as that listed above (in the Forging section, under Forging/Hot-working Temperature Ranges).

Moderate reductions per pass (15 to 20 percent reduction in area), and rolling speeds of 200 to 300 surface feet per minute tend to provide good results, without overloading the mill. The total reduction per session should be at least 20 to 30 percent. It is usual to finish at the low end of the hot-working temperature range, since this generally provides the optimum structure and properties.

Care should be taken to ensure that the work piece is thoroughly soaked at the hot working start temperature before rolling. Frequent re-heating may be required during hot-rolling, to keep the temperature of the work piece in the hot working range.

Hot-forming

Recommended Procedures and Temperatures Applicable to:
Corrosion-resistant Alloys
High-temperature Alloys
Wear & Corrosion-resistant Alloy

The hot-forming of plates into components, such as dished heads is normally performed by cold-pressing or spinning, with intermediate anneals. However, sometimes the size and thickness of the material is such that hot-forming is necessary.

When hot-forming is required, the start temperature (to which the furnace is heated) is approximately mid-way between the annealing temperature (of the alloy in question) and its lower (finish) forging temperature. During hot-forming, the temperature of the piece should not fall below the lower (finish) forging temperature. Re-heating may be necessary to maintain the correct hot forming temperature, and dies should be warmed to avoid excessive chilling of the surfaces.

Other Hot-Working Processes

Recommended Procedures and Temperatures Applicable to:
Corrosion-resistant Alloys
High-temperature Alloys

Wear & Corrosion-resistant Alloy

The HAYNES® and HASTELLOY® alloys are amenable to several other hot-working processes, such as hot-extrusion and hot-spinning. Impact extrusion should be performed at the solution annealing temperature of the alloy involved. Uniform and accurate temperatures throughout the work-piece are necessary during impact extrusion, and re-strikes should be avoided. The parameters for hot extrusion and hot spinning are specific to the exact nature of the intended work and material. For more information, please contact our technical support team.