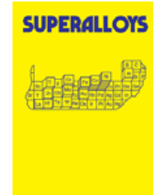
Joining, Repair and Rejuvenation of Superalloys

Provided Courtesy of Materials Technology@TMS

The following is a summary of processes for the joining of typical superalloys, including videos and citations from TMS and other publications. For more detailed information, please see the Digital Resource Center on Materials Technology@TMS.
Would you like to submit information superalloys manufacturing technologies?
Go to www.materialstechnology.org and click on "Submit a Resource".

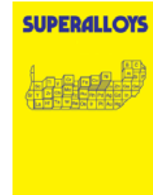


PROCESS	DESCRIPTION	VIDEO	SELECTED RESOURCE	WEBLINK
Gas Tungsten Arc Welding (GTAW)	"Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a nonconsumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by a shielding gas (usually an inert gas such as argon), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma." [from Wikipedia]	Jonathan Colton, "Tungsten Inert Gas Welding", Georgia Tech/Control Vision Inc., Copyright 1999.	M.B. Henderson, D. Arrell, M. Heobel, R. Larsson, and G. Marchant. "Nickel-Based Superalloy Welding Practices for Industrial Gas Turbine Applications." International Conference on Microstructure and Performance of Joints in High-Temperature Alloys." Institute of Materials, Mining and Materials. London. 20 November 2002.	Read the Full Article
			S.S. Babu, S.A. David, J.W. Park, and J.M. Vitek. "Joining of Nickel-Base Superalloy Single Crystals." International Conference on Microstructure and Performance of Joints in High-Temperature Alloys." Institute of Materials, Mining and Materials. London. 20	Read the Full Article
Gas Metal Arc Welding (GMAW)	"Gas metal arc welding (GMAW), sometimes referred to by its subtypes, metal inert gas (MIG) welding or metal active gas (MAG) welding, is a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used." [from Wikipedia]	Dr. Richard Dolby, "The Arc Welding Process", video, University of Cambridge/TWI, 2002.		

Joining, Repair and Rejuvenation of Superalloys

Provided Courtesy of Materials Technology@TMS

The following is a summary of processes for the joining of typical superalloys, including videos and citations from TMS and other publications. For more detailed information, please see the Digital Resource Center on Materials Technology@TMS.
Would you like to submit information superalloys manufacturing technologies? Go to www.materialstechnology.org and click on "Submit a Resource".



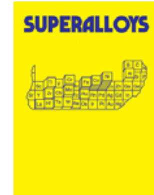
MaterialsTechnology.org

PROCESS	DESCRIPTION	VIDEO	SELECTED RESOURCE	WEBLINK
Electron Beam Welding (EBW)	"Electron beam welding (EBW) is a fusion welding process in which a beam of high-velocity electrons is applied to the materials being joined. The workpieces melt as the kinetic energy of the electrons is transformed into heat upon impact, and the filler metal, if used, also melts to form part of the weld. Pressure is not applied, and a shielding gas is not used, though the welding is often done in conditions of a vacuum to prevent dispersion of the electron beam." [from Wikipedia]		"Process Modelling of Electron Beam Welding of Aeroengine Components" R.C. Reed, H.J. Stone, D. Dye, S.M. Roberts and S.G. McKenzie. Superalloys 2000, Warrendale, PA: TMS, 2000, p. 665-674	Read the Full Article
			"The Influence of B, P and C on Heat Affected Zone Micro-Fissuring in INCONEL type Superalloy"[pp. 703-711] S. Benhaddad, N.L. Richards, U. Prasad, H. Guo and M.C. Chaturvedi. Superalloys 2000.	Read the Full Article
Laser Beam Welding (LBW)	"Laser beam welding (LBW) is a welding technique used to join multiple pieces of metal through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates." [from Wikipedia]	Jonathan Colton, "Laser Welding", Georgia Tech/Control Vision Inc., Copyright 2000	M.B. Henderson, D. Arrell, M. Heobel, R. Larsson, and G. Marchant. "Nickel-Based Superalloy Welding Practices for Industrial Gas Turbine Applications." International Conference on Microstructure and Performance of Joints in High-Temperature Alloys." Institute of Materials, Mining and Materials. London. 20 November 2002.	Read the Full Article
			S.S. Babu, S.A. David, J.W. Park, and J.M. Vitek. "Joining of Nickel-Base Superalloy Single Crystals." International Conference on Microstructure and Performance of Joints in High-Temperature Alloys." Institute of Materials, Mining and Materials. London. 20 November 2002.	Read the Full Article
Post Weld Processing	When fusion welding methods are used to join precipitation hardenend superalloys, a cast structure results at the interface. Therefore, heat treatment is required after welding to precipitate the strengthening phase.		A.E. Kolman. "Improving Properties of Single Crystal to Polycrystalline Cast Alloy Welds through Heat Treatment." Superalloys 2000, Warrendale, PA: TMS, 2000, p. 721-726.	Read the Full Article

Joining, Repair and Rejuvenation of Superalloys

Provided Courtesy of Materials Technology@TMS

The following is a summary of processes for the joining of typical superalloys, including videos and citations from TMS and other publications. For more detailed information, please see the Digital Resource Center on Materials Technology@TMS.
Would you like to submit information superalloys manufacturing technologies?
Go to www.materialstechnology.org and click on "Submit a Resource".

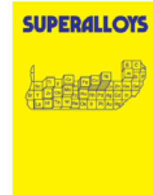


PROCESS	DESCRIPTION	VIDEO	SELECTED RESOURCE	WEBLINK
Diffusion Bonding	"Diffusion bonding, as a subdivision of both solid-state welding and liquid-phase welding, is a joining process wherein the principal mechanism is interdiffusion of atoms across the interface. Diffusion bonding of most metals is conducted in vacuum or in an inert atmosphere (normally dry nitrogen, argon or helium) in order to reduce detrimental oxidation of the faying surfaces. Bonding of a few metals which have oxide films that are thermodynamically unstable at the bonding temperature (e.g. silver) may be achieved in air." from Amir Shirzadi. University of Cambridge Website, www.msm.cam.ac.uk/phase-trans/2005/Amir/bond.html		A.A. Shirzadi and E. R. Wallach. "New Method to Diffusion Bond Superalloys." Science & Technology of Welding and Joining, 2004, V.ol 9 no. 1 p. 37	Read the Full Article
Friction Welding	"Friction Welding (FW) is a group of solid-state welding processes using heat generated through mechanical friction between a moving workpiece, with the addition of an upsetting force to plastically displace the material. Technically, because no melt occurs, friction welding is not actually a welding process in the traditional definition, but a forging technique. However, due to the similarities between these techniques and traditional welding, the term has become common." [from Wikipedia]	"Friction Welding Demo", Manufacturing Technology, Inc.		
		"Friction Welding", TWI World Center for Materials Joining Technology.		

Joining, Repair and Rejuvenation of Superalloys

Provided Courtesy of Materials Technology@TMS

The following is a summary of processes for the joining of typical superalloys, including videos and citations from TMS and other publications. For more detailed information, please see the Digital Resource Center on Materials Technology@TMS.
Would you like to submit information superalloys manufacturing technologies? Go to www.materialstechnology.org and click on "Submit a Resource".

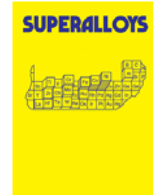


PROCESS	DESCRIPTION	VIDEO	SELECTED RESOURCE	WEBLINK
Inertia Friction Welding	"Inertia Friction Welding is a variation of friction welding in which the energy required to make the weld is supplied primarily by the stored rotational kinetic energy of the welding machine. In Inertia Welding, one of the work pieces is connected to a flywheel and the other is restrained from rotating. The flywheel is accelerated to a predetermined rotational speed, storing the required energy. The drive motor is disengaged and the work pieces are forced together by the friction welding force. This causes the faying surfaces to rub together under pressure. The kinetic energy stored in the rotating flywheel is dissipated as heat through friction at the weld interface as the flywheel speed decreases. An increase in friction welding force (forge force) may be applied before rotation stops. The forge force is maintained for a predetermined time after rotation ceases." [from Manufacturing Technology, Inc. www.mtiwelding.com/inertia-friction-welding		G. Baxter, M. Preuss and P. J. Withers. "Inertia Friction Welding of Nickel Base Superalloys for Aerospace Applications. " International Conference on Microstructure and Performance of Joints in High-Temperature Alloys. Institute of Materials, Mining and Materials. London. 20 November 2002.	Read the Full Article
Transient Liquid Phase Bonding	"The TLP process produces a strong, interface-free joint with no remnant of the bonding agent. It differs from diffusion bonding in that the formation of a thin liquid layer eliminates the need for a high bonding or clamping force. The interlayer can be provided by foils, electroplate, sputter coats, or any other process that deposits a thin film on the faying surfaces." [from W. D. McDonald and T. W. Eagar. Annu. Rev. Mater. Sci. 22:23-46. Annual Reviews Inc. 1992]		W. D. McDonald and T. W. Eagar, "Transient Liquid Phase Bonding". Annu. Rev. Mater. Sci. 22:23-46. Annual Reviews Inc. 1992.	Read the Full Article
			Y. Zheng and K. Tangri. "Microstructure and Bonding Behavior of a New Zr-Bearing Interlayer Alloy for Single Crystal Nickel-Base Superalloy." Superalloys 1992, Warrendale, PA: TMS, 1992, p. 857-866	Read the Full Article
			Y. Nakao, K. Nichimoto, K. Shinozaki and C. Kang. "Theoretical Research on Transient Liquid Insert Metal Diffusion Bonding of Nickel Base Alloys." Superalloys 1988, Warrendale, PA: TMS, 1988, p. 775-784	Read the Full Article

Joining, Repair and Rejuvenation of Superalloys

Provided Courtesy of Materials Technology@TMS

The following is a summary of processes for the joining of typical superalloys, including videos and citations from TMS and other publications. For more detailed information, please see the Digital Resource Center on Materials Technology@TMS.
Would you like to submit information superalloys manufacturing technologies? Go to www.materialstechnology.org and click on "Submit a Resource".



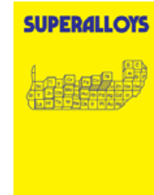
MaterialsTechnology.org

PROCESS	DESCRIPTION	VIDEO	SELECTED RESOURCE	WEBLINK
Brazing	"Brazing is a joining process whereby a non-ferrous filler metal or alloy is heated to melting temperature (above 450°C; 842°F) and distributed between two or more close-fitting parts by capillary action. At its liquid temperature, the molten filler metal and flux interacts with a thin layer of the base metal, cooling to form an exceptionally strong, sealed joint due to grain structure interaction. The brazed joint becomes a sandwich of different layers, each metallurgically linked to the adjacent layers. Common brazements are about 1/3 as strong as the materials they join because the metals partially dissolve each other at the interface and usually the grain structure and joint alloy is uncontrolled. To create high-strength brazes, sometimes a brazement can be annealed, or cooled at a controlled rate, so that the joint's grain structure and alloying is controlled. It is also at 1/3 strength because the metal used to braze is usualy weaker than the other metal because it is		Improving Repair Quality of Turbine Nozzles Using SA650 Braze Alloy, W.A. Demo, S. Ferrigno, D. Budinger and E. Huron. Superalloys 2000, pp. 713-720	Read the Full Article
		Brazing of Nickel Superalloys. R. Broomfield. "International Conference on Microstructure and Performance of Joints in High-Temperature Alloys." Institute of Materials, Mining and Materials. London. 20 November 2002. (Presentation)	Introduction to Furnace Brazing. Allentown, PA: Air Products and Chemicals, Inc, 2001.	Read Pamphlet

Joining, Repair and Rejuvenation of Superalloys

Provided Courtesy of Materials Technology@TMS

The following is a summary of processes for the joining of typical superalloys, including videos and citations from TMS and other publications. For more detailed information, please see the Digital Resource Center on Materials Technology@TMS.
Would you like to submit information superalloys manufacturing technologies?
Go to www.materialstechnology.org and click on "Submit a Resource".



PROCESS	DESCRIPTION	VIDEO	SELECTED RESOURCE	WEBLINK
Repair (various methods)	Repair is a general term intended to encompass many actions aimed at putting a superalloy component back into service. Actions may include hot isostatic pressing to heal creep cavitation, use of joining techniques to close cracks, machining to remove damage or corrosion attack, recoating and others. [from M. J. Donachie and S. J. Donachie. Superalloys: A Technical Guide. 2nd Edition. Materials Park, OH: ASM International, 2002.]		Gandy, D.W., G. Frederick, J.T. Stover, and R. Viswanathan. "Overview of Hot Section Component Repair Methods." ASM International Materials Solutions Conference 2000 Gas Turbine Materials Technology Session. St. Louis, MO. October 2000.	Read the Full Article
Hot Isostatic Pressing	Cavities which form during creep deformation may be healed by hot isostatic processing. Elevated temperature and pressure are simultaneously applied in an autoclave under an inert gas.		Rejuvenation of Service-Exposed in 738 Turbine Blades. A.K. Koul, J P. Immarigeon, R. Castillo, P. Lowden and J. Liburdi. Superalloys 1988, Warrendale, PA: TMS, 1988, p. 755-764.	Read the Full Article
Re-coating	When environmental conditions have degraded coatings, they must be removed and re-applied.		T. Sourmail. "Coatings for High Temperature Applications". University of Cambridge.	Launch Site