En introduktion till Hårdlödning och dess Användningsområden

Fogningsdagarna 2024, Lund

Torstein Grøstad, Manager Brazing Development
torstein.grostad@hoganas.com

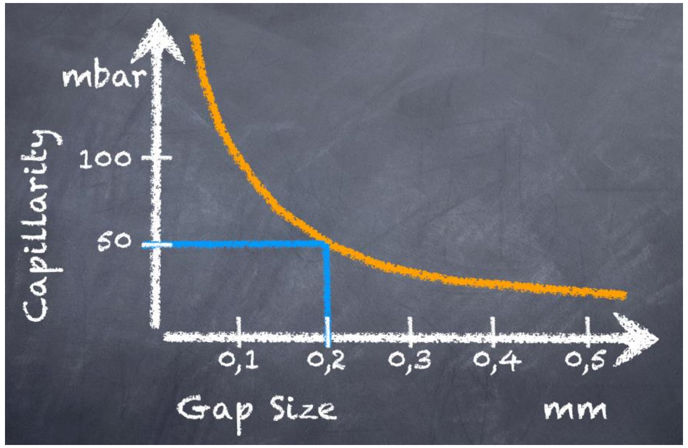
Höganäs


SAFETY FIRST
SAFETY FIRST

Brazing fundamentals

Definition of brazing

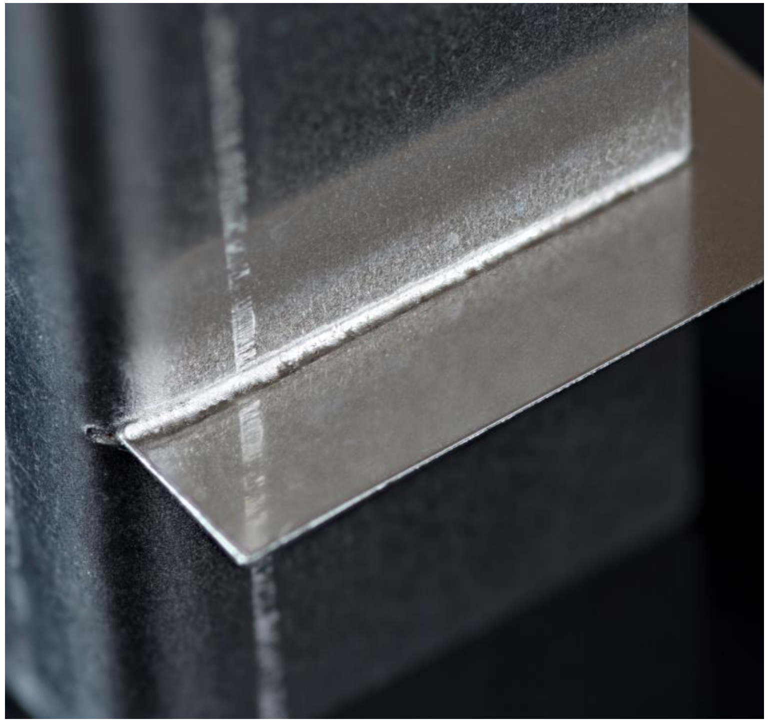
- A joining process using a filler metal with a melting temperature higher than 450 °C, but lower than the melting point of the base materials. The filler metal distributes between the closely fitted faying surfaces of the joint by capillary action
- Brazing above 950 °C is referred to as high-temperature brazing



Höganäs

Fundamental Criteria for Good Brazing

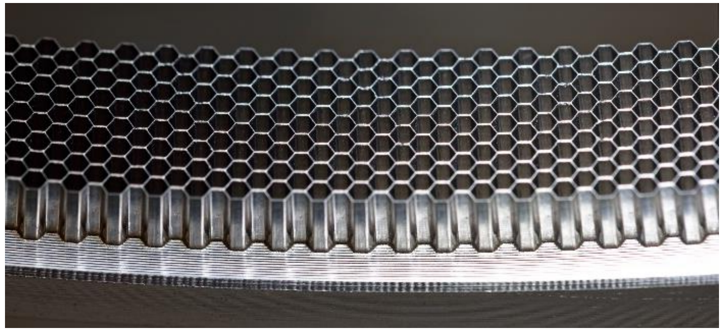
- Properly **designed braze joints**, appropriate for service conditions to be encountered
- Proper **cleaning** before brazing
- Proper **joint fitup** (gap clearance, flatness, squareness, burrs, etc.)
- Correct **brazing filler metal** choice, handling and application
- Proper **fixturing**
- Proper **brazing cycle** (atmosphere, heating / cooling rates and temperature control)
- Knowledgeable **inspection** of finished brazed assemblies



Brazing fundamentals

Benefits of Brazing

- Virtually any metallic materials and some ceramics can be combined
- Tighter tolerance control compared to welding
- Suitable for complex parts that are not practical to weld and have higher service requirements than what can be managed by adhesives
- Results in a clean joint without any need for secondary finishing (if performed in a protective atmosphere)
- Many parts can be brazed simultaneously in a batch process or continuously in a belt furnace in a controlled environment



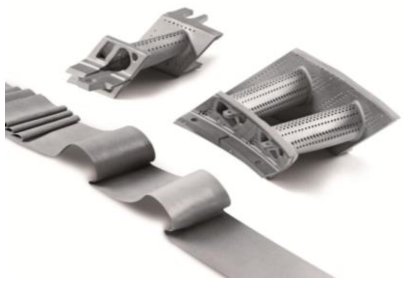
Brazing Filler Materials

- A lot of different brazing filler materials based on elements such as Ag, Al, Au, Co, Cu, CuP, CuZn, **Fe**, **Ni**, Pd, Ti etc.
- Overlapping usage of filler materials for some applications
- Different product forms available such as rod, wire, strips, preforms (numerous shapes including foils), powder, paste and tape/cloth
- Different applications have different requirements and different equipment. Not easy to change filler material

Brazing powder

Brazing preforms
(Courtesy of Bellman-Melcor)

Brazing paste



Braze Tape / Cloth
(Courtesy of Kymera International)

Brazing processes with BrazeLet®

Induction brazing

- Brazing paste is applied with or without flux depending on atmosphere
- Local heating by induction coil in protective atmosphere
- Fit for industrialized applications
- High melting point alloys can be applied

Vacuum brazing

- Brazing paste is applied without flux
- The whole component is heated to the brazing temperature in vacuum
- Allows brazing of numerous complicated joints simultaneously
- Especially suited for larger complex components where other atmospheres do not reach all areas effectively

Controlled atmosphere brazing

- Brazing paste is applied with or without flux depending on atmosphere
- The whole component is heated to the brazing temperature in a protective or reducing atmosphere such as H_2, N_2/H_2 or Ar
- Allows high productivity for simpler component geometries

» ***Further processes include:*** *Torch brazing, Dip brazing (Salt bath or Liquid metal bath), Resistance Brazing and Braze Welding (Electron Beam, Laser Beam, MIG/MAG)*

Höganäs

BrazeLet® Brazing Filler Metals

Product name	Chemistry (weight %)										Specification			Melting range	Min. brazing temperature
BrazeLet®	Ni	Cr	Si	Fe	B	C	P	Cu	Nb	Mo	ISO 17672	AMS	AWS A5.8		
BNi1	Bal.	14	4.5	4.5	3.2	0.75	-	-	-	-	Ni 600	4775	BNi-1	980 – 1060 °C	1150 °C
BNi1A	Bal.	14	4.5	4.5	3.2	-	-	-	-	-	Ni 610	4776	BNi-1a	977 – 1077 °C	1175 °C
BNi2	Bal.	7	4.5	3	3	-	-	-	-	-	Ni 620	4777	BNi-2	970 – 1000 °C	1050 °C
BNi3	Bal.	-	4.5	-	3.2	-	-	-	-	-	Ni 630	4778	BNi-3	980 – 1040 °C	1100 °C
BNi4	Bal.	-	3.5	-	2	-	-	-	-	-	Ni 631	4779	BNi-4	980 – 1065 °C	1120 °C
BNi5	Bal.	19	10.1	-	-	-	-	-	-	-	Ni 650	4782	BNi-5	1080 – 1135 °C	1150 °C
BNi6	Bal.	-	-	-	-	-	11	-	-	-	Ni 700	n/a	BNi-6	875 °C	950 °C
BNi7	Bal.	14	-	-	-	-	10.1	-	-	-	Ni 710	n/a	BNi-7	890 °C	980 °C
BNi9	Bal.	15	-	-	3.6	-	-	-	-	-	Ni 612	n/a	BNi-9	1055 °C	1100 °C
BNi12	Bal.	25	-	-	-	-	10	-	-	-	Ni 720	n/a	BNi-12	880 – 950 °C	1050 °C
Ni613	Bal.	29	4	-	-	-	6	-	-	-	Ni 740	n/a	BNi-15	970 – 1030 °C	1090 °C
Ni623	Bal.	29	7	11	-	-	6	-	-	7.5	n/a	n/a	n/a	1160 – 1200 °C	1240 °C
F300-20	20	20	4	Bal.	-	-	7	6.5	-	-	n/a	n/a	n/a	1025 – 1060 °C	1100 °C
F86	18	29	6.5	Bal.	-	-	6	-	0.5	-	n/a	n/a	n/a	1050 – 1100 °C	1150 °C

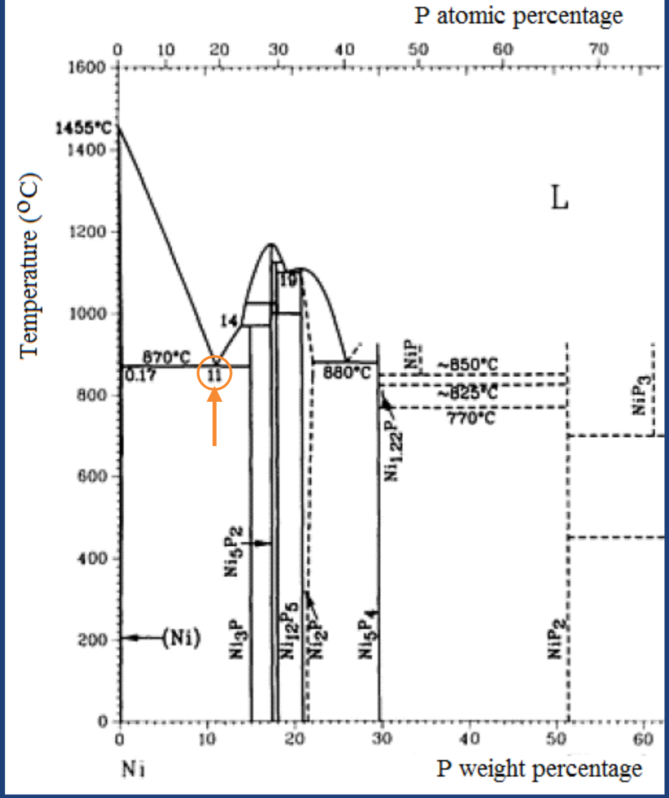
Metallurgy of our Brazing Filler Materials

- High melting point of pure metals require alloying with effective melting point depressant elements to lower the melting point of the brazing filler material below the base material
  - Examples:

5 B Boron Metalloid	14 Si Silicon Metalloid	15 P Phosphorus Nonmetal

- Elements can also be added to improve certain properties of the brazing filler metal such as corrosion resistance, oxidation resistance, microstructure
  - Examples:

14 Si Silicon Metalloid	24 Cr Chromium Transition Metal	29 Cu Copper Transition Metal	41 Nb Niobium Transition Metal	42 Mo Molybdenum Transition Metal



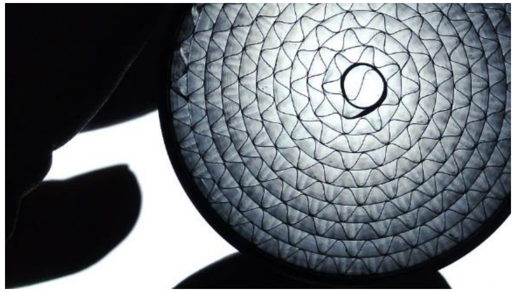
Binary Ni-P phase diagram with BNi-6 composition (Ni – 11 wt% P) highlighted as an example

Höganäs

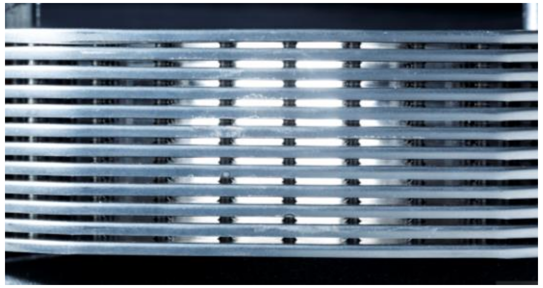
Brazing applications

We help you finding solutions for your needs

Automotive



Catalytic converters
Minimize applied brazing filler metal amount by roller coating



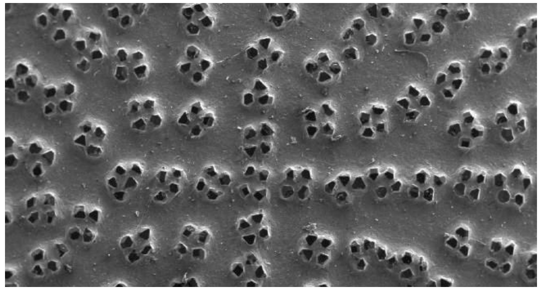
Oil coolers
Increase lifetime with Cu-free brazing solutions

EGR coolers
Corrosion, oxidation and high-temperature resistant braze alloys

General industry / Aviation & Energy

Brazed plate heat exchangers
Sustainable Cu-free brazing solutions

Aviation & Gas Turbines
Extend the lifetime of turbine components by repair brazing



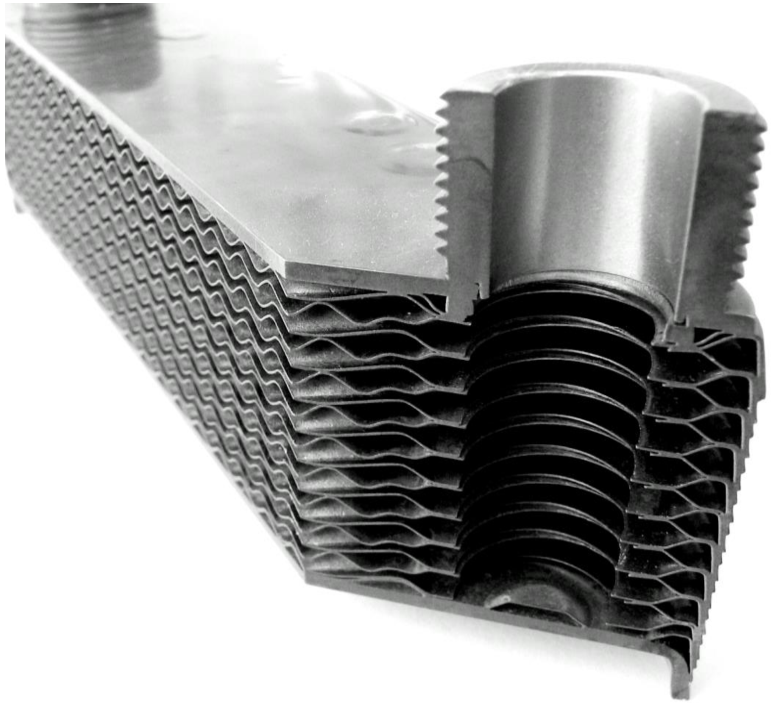
Diamond disks
Screen printing pastes for reliable brazing filler metal application

Höganäs

Brazing applications

Cu-free Brazed Plate Heat Exchangers

- The complex geometry and number of joints to be made, makes brazing the preferred joining method for large scale production
- Largest volume of BPHEs are brazed with Cu-foil, which is good enough for many applications, simple and robust, but leads to accumulation of 10 – 15 wt% Cu in stainless steel scrap
- Ni-base brazing filler metals (foil and paste) are used, but are more expensive than Cu and require careful material selection depending on service conditions
- Fe-base brazing filler metals began emerging in the 1980s as a cheaper alternative to Ni-base brazing filler metals, but has not made its way into the market in volume until the last 5-8 years
- No universal brazing solution suitable for all applications

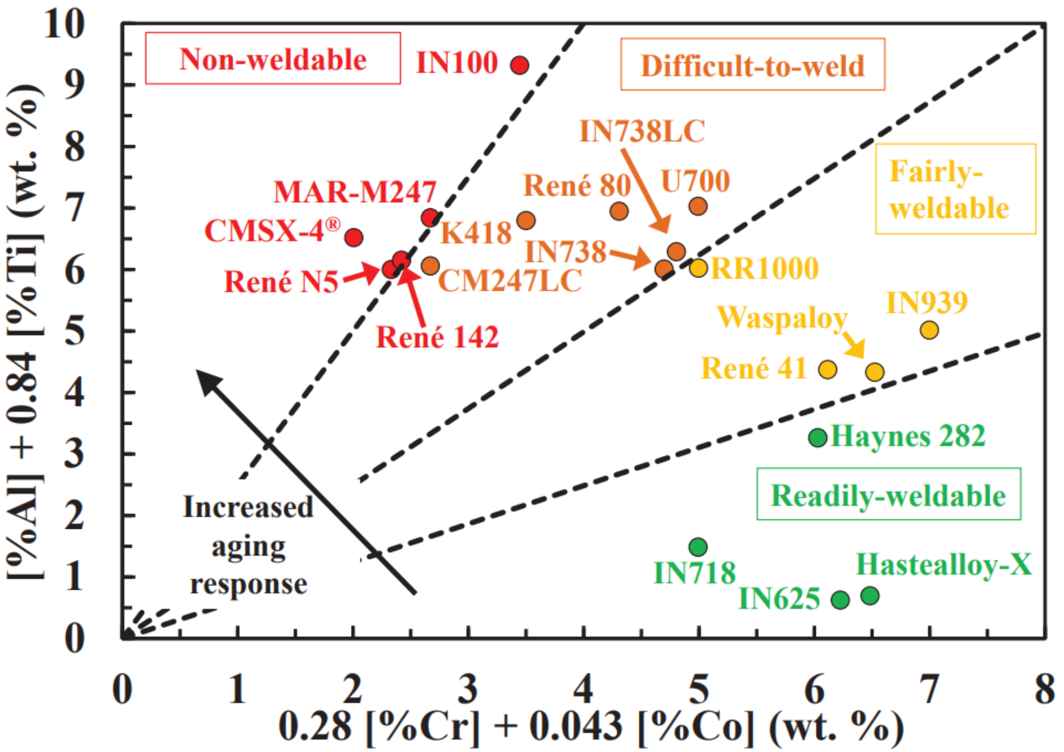


Höganäs

Brazing applications

Joining of Ni-base superalloys for turbines

- Ni-base superalloys optimized for performance are **generally not optimized for welding in assembly or repair**, and weld cracking is a prominent concern for these materials
- This is especially true for cast alloys with a high volume-fraction of strengthening precipitates, containing **many alloying additions that enhance solidification cracking**



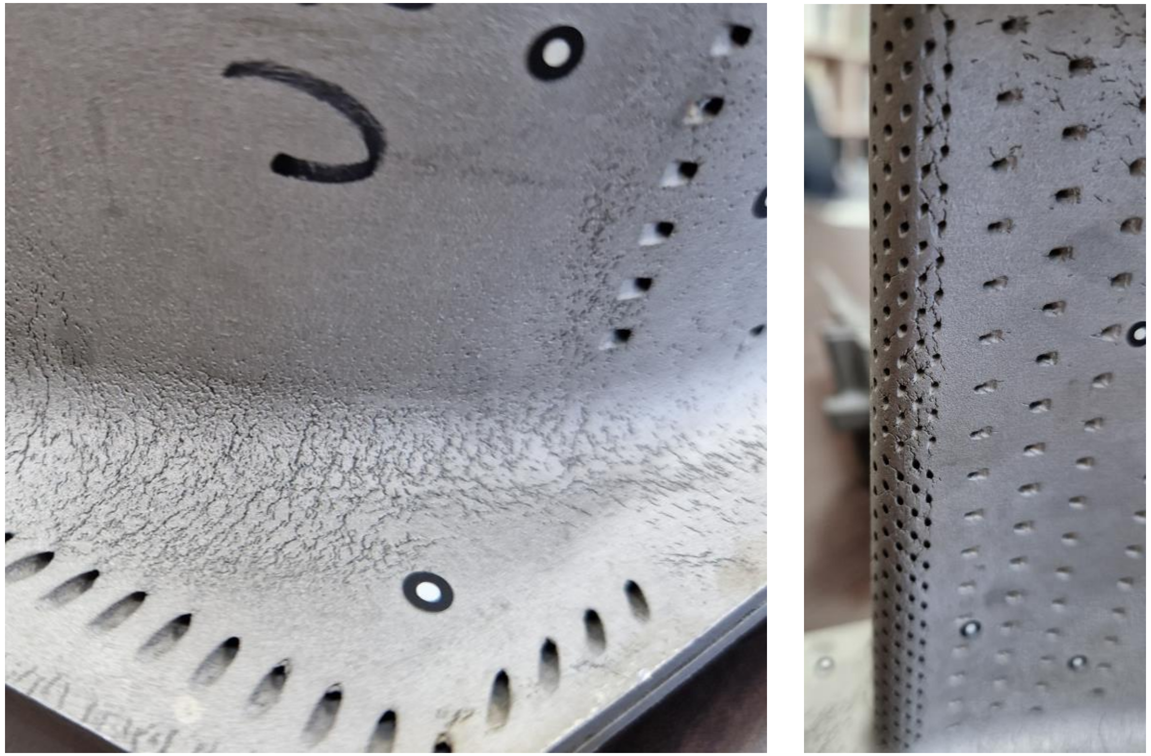
Basak, A., 2019, Additive Manufacturing of High-Gamma Prime Nickel-Based Superalloys through Selective Laser Melting (SLM)

Höganäs

Brazing applications

Joining of Ni-base superalloys for turbines

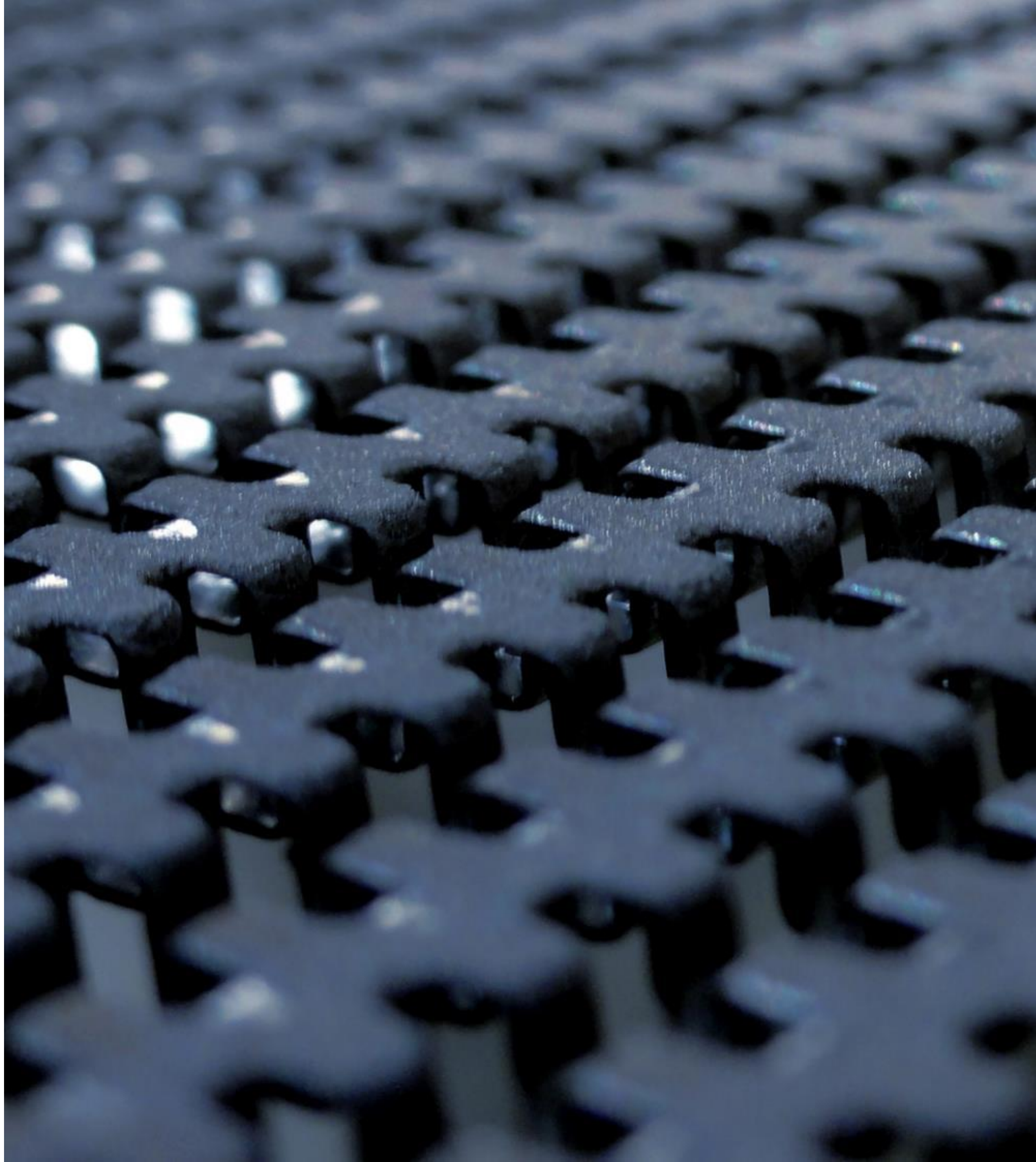
- Brazing is used for both OEM joining applications and repair, as the expensive components justify repair rather than replacement (10-20% of cost)
- Make use of Transient Liquid Phase (TLP) bonding and sufficiently long brazing cycles to avoid brittle intermetallic phases in the joint
- Often with specially formulated brazing filler metals resembling the superalloy compositions (by adding Al, Co, Ta, Ti, W)
- Brazing of AM components is emerging where there are technical size limitations or cost / productivity benefits from joining multiple components instead of making one larger one



- *Example repairable defects in Siemens V84 vane*

Summary

- Brazing is a wide field that has been used for around 6500 years and is still being developed today
- Brazing will remain as a preferred joining technology in the future in particular for complex geometries and base materials with weldability challenges



hoganas.com

linkedin.com/company/hoganas-ab

facebook.com/hoganas

instagram.com/hoganas_ab

youtube.com/@hoganas-ab

How can we inspire you?

Höganäs