



Thermal Surfacing
Glass Mould Industry Solutions

Höganäs Thermal Surfacing Solutions Play an Important Protective Role

Thermal surfacing with self-fluxing nickel based alloys plays an important role in the wear protection of tools in the glass container industry. Bottle machine tools work under very severe conditions, subjected to both wear, corrosion and fast thermal cycling.

Major properties of self-fluxing nickel based alloys are good abrasive resistance and good corrosion resistance at high temperatures. This has led to the extensive use of nickel alloys from Höganäs for surfacing cast iron parts in the glass bottle manufacturing industry.

Hardfacing processes with powder welding, flame spraying, HVOF spraying and PTA welding use self-fluxing powder in the production of new moulds, plungers, baffles, neck rings, plates etc. as well as for repair and maintenance.

This brochure focuses on the following points:

1. General properties
2. Höganäs powders
3. Pre-application procedure
4. Powder welding
5. Flame spraying
6. HVOF (High Velocity Oxy-Fuel) spraying
7. PTA (Plasma Transferred Arc) welding
8. Quick guide to Höganäs powder grades

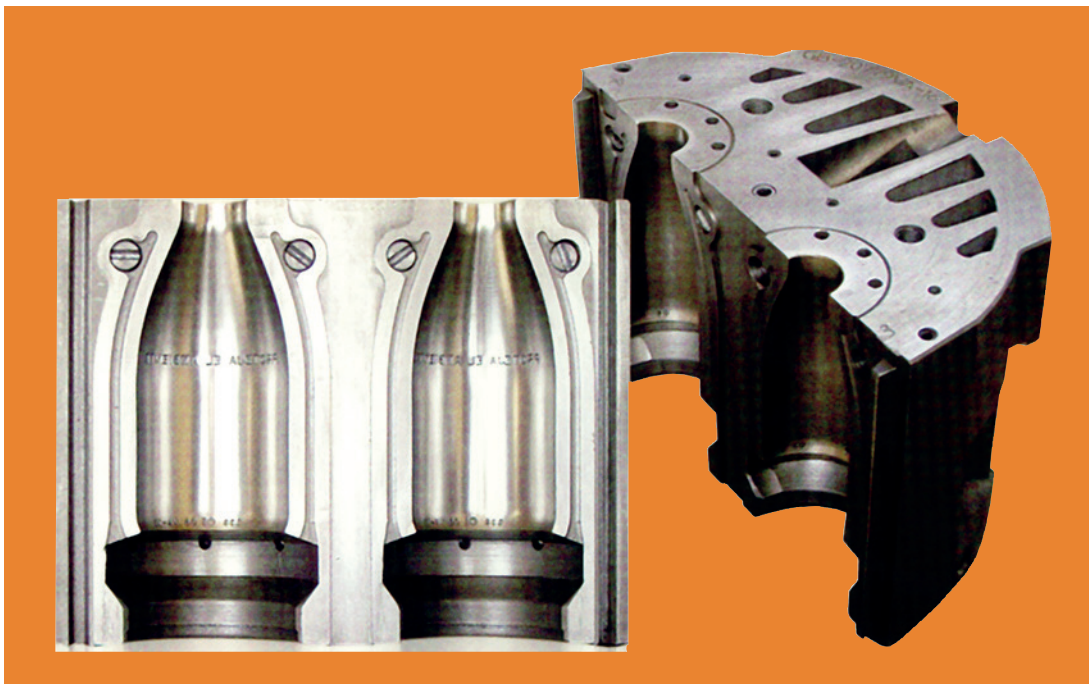


Figure 1 Bottle moulds

1. General Properties

Self-fluxing mechanism

Essential elements in a self-fluxing alloy are silicon (Si) and boron (B). These two elements have a very strong influence on the liquidus temperature. The melting temperature for pure nickel (Ni) is 1455°C. The alloy liquidus can be reduced to below 1000°C by increased concentration of Si and B. The melting temperature range is defined by the solidus and liquidus (Fig. 2a/2b). The low melting points of the self-fluxing alloys is of great advantage, as these can be coated without fusion to the

base metal. Alloys normally contain chrome (Cr), iron (Fe) and carbon (C), and at times molybdenum (Mo), tungsten (W) and copper (Cu) are also added.

Other metallic oxides, such as Fe and Ni oxides, dissolved with Si and B have the ability to form silicates. This is important during application of nickel based alloys, as the Si-B slag acts as a welding flux. This protects the fresh metal surface from being oxidised and ensures better wettability for the molten metal.

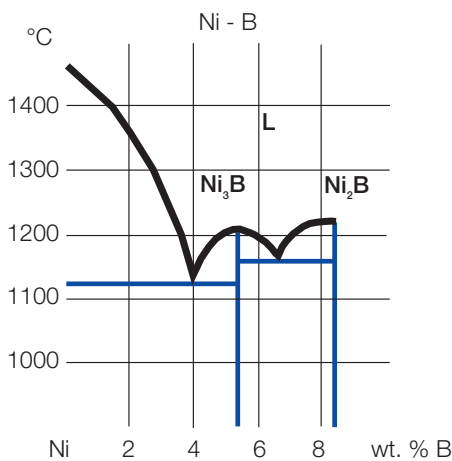


Figure 2a Phase diagram for Ni-B

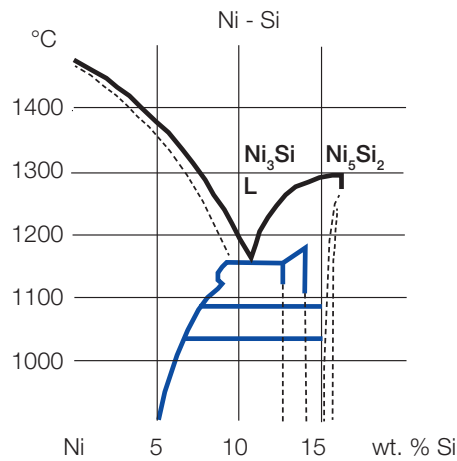


Figure 2b Phase diagram for Ni-Si

Microstructure

The microstructure of Ni-Cr-Si-B-alloys is a relatively ductile Ni-rich matrix with various amounts of hard particles (Fig. 3 and Fig. 4). Increasing the amount of alloying elements increases the number of hard particles and consequently the hardness of the alloy. Increased hardness also makes the material more difficult to machine.

In soft alloys with low concentrations of Si, B and Cr, the predominant hard phase is Ni₃B (Fig. 3). Higher concentrations of Si and Cr cause Cr_xB_y and Cr_xC_y phases to develop and increase (Fig. 4). At even higher concentrations, Ni₃Si phases can also develop.

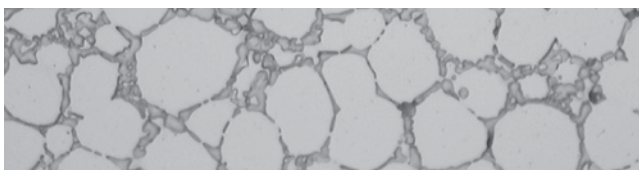


Figure 3 Predominant hard phase is Ni₃B

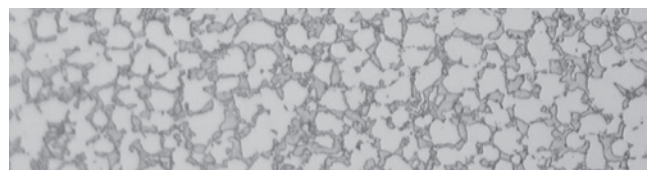


Figure 4 Cr_xB_y and Cr_xC_y phases develop and increase

Wear and corrosion

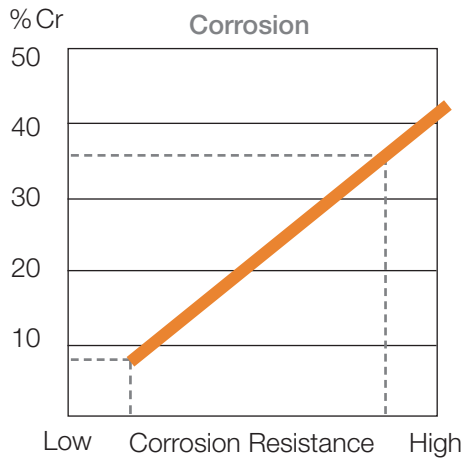


Figure 5 Ni, Cr, Mo and Cu improve corrosion resistance, C and B reduce it.

The very good wear resistance of Ni-Cr-Si-B-alloys to hot glass is explained by the formation of a Cr oxide layer on the coating surface. This layer is not miscible with the Si oxide in the glass, which enhances its wear properties. The effect is especially important when the surface layer is heated to a temperature above 600°C.

2. Höganäs Powders

Product designation codes

As an independent manufacturer we offer a powder range that suits all equipment.

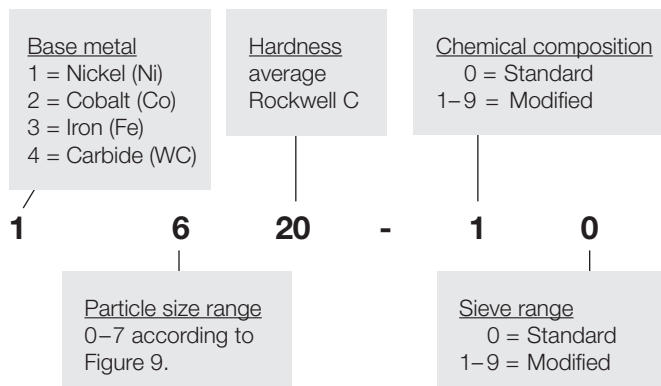


Figure 7 Powder designation

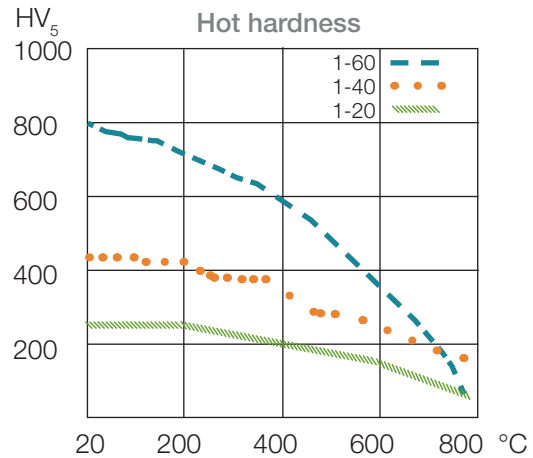


Figure 6 Effect of temperature on hardness.

At lower temperatures, coatings without Cr can be used successfully. The general influence of the alloying content on corrosion resistance is illustrated in Fig. 5.

Fig. 6 shows the decreasing hardness of different grades with increasing temperature.

Choice of particle size range

It is important to choose the right powder grade, chemical composition and hardness etc., but also the right particle size range. Our powder grades have seven main standard sieve ranges, see Fig. 9.

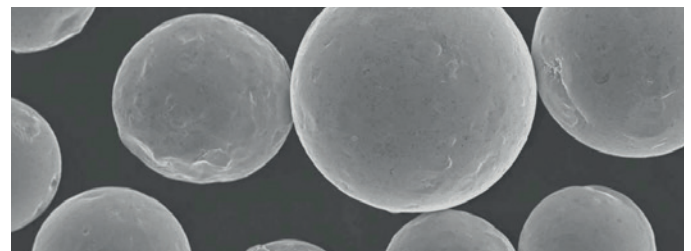


Figure 8 Spherical Ni-based powder particles without satellites

Recommendations for spraying and welding methods

Powder welding

Sieve No. 0/1/6/6-01 or 6-05. Finer powders increase deposition efficiency and improve surface smoothness but limit the thickness of the layer.

Flame spraying (spray-fuse)

Sieve No. 2/2-01/3 and 6-02.

No. 3 for Metco 5P/6P.

No. 2/2-01 for Terodyn 2000/DS Castodyn 8000, Uni Spray Jet and Colmonoy J-gun.

No. 6-02 for Metco 5P/6P with air or O₂/H₂.

HVOF spraying

Sieve No. 6-01 or 6-02.

PTA welding

Sieve No. 5 (most common).

No. 3 for Eutronic GAP PTA.

No. 7 for Commercald PTA.

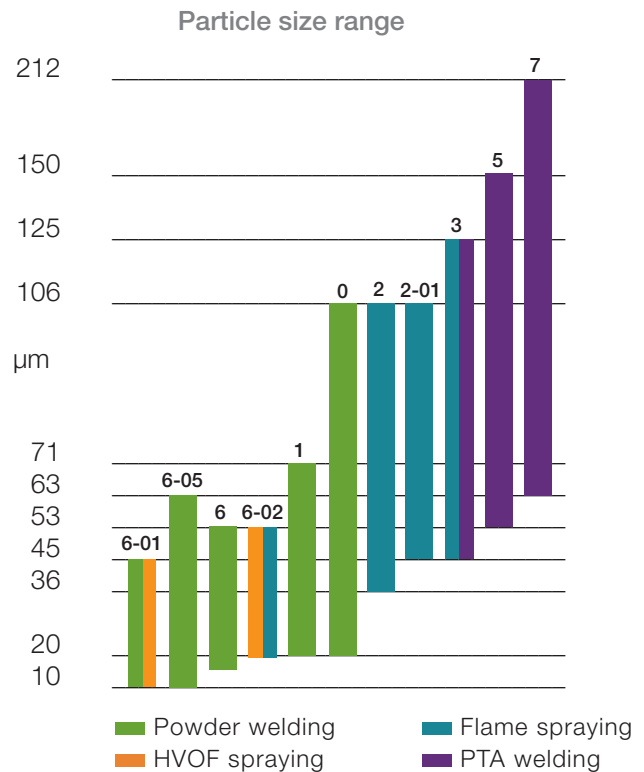


Figure 9

Measure of hardness

Rockwell (HRC) or Vickers (HV) are used as a measure of hardness. Indicative conversions can use the curve, (Fig. 10).

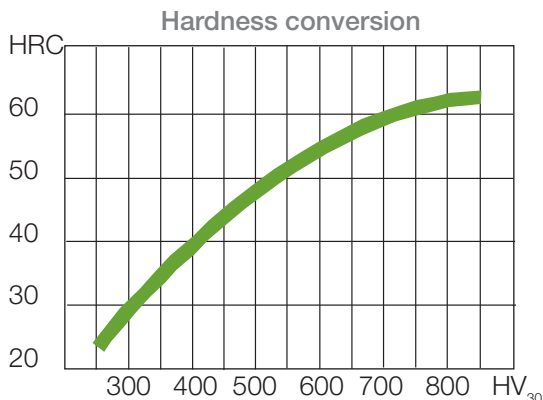


Figure 10 Measured on powder-welded flat welds

Hardness below 35 HRC is measured as HV₃₀. Hardness depends on both powder grade and weld quality. An average of welding results over time is used to generate results.



Figure 11 Hardness test

Choice of chemical composition

We have designed our grades to offer various properties.

By varying the amount of alloying elements we have developed them to deliver hardness in the range of 210-860 Vickers (15-64 HRC). The hardness is mainly controlled by C, Si, B and Cr content.

Different alloy compositions and sieve ranges also influence other properties, such as melting range, fluidity of the melt and spraying efficiency.

With an increasing proportion of alloying elements, the powder melts at a lower temperature and becomes more fluid (Fig. 12). Thus a smoother surface can be obtained. Also less slag is seen on the solid surface of harder alloys. Increased Cr content, as in harder alloys, is more resistant to oxidation. Such alloys are used at higher temperatures – up to 700°C. The melting range is very strongly influenced by B and Si. So the chemical tolerance ranges must be kept very narrow.

Choice of properties

A comparison of the weld shape of different powder sieve cuts when powder-welded to moulds, see Fig. 13. This shows that when good building properties are required a coarser powder is recommended. When extremely good fluidity is required, choose a finer powder.

When choosing the best powder grade, it is important to remember that both particle size range and shape of the workpiece influence the deposition efficiency. The nominal deposition efficiency is close to 100% on a flat surface, but only 60% when welding on an edge (Fig. 14). The diagram also shows that fine powder such as 1620-01 gives much better deposition efficiency compared to coarse grade 1020. Of course deposition can vary between operators, operating parameters and equipment brands.

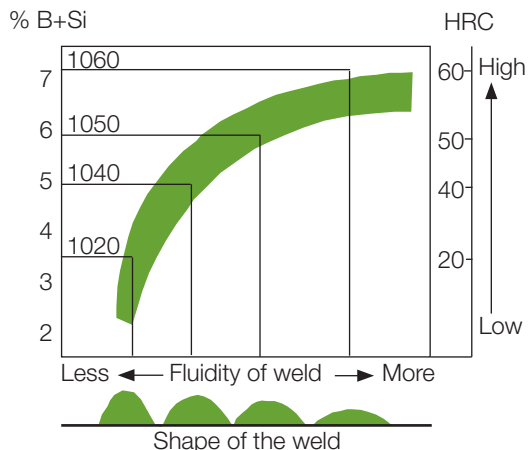


Figure 12 Effect of B+Si on fluidity and hardness

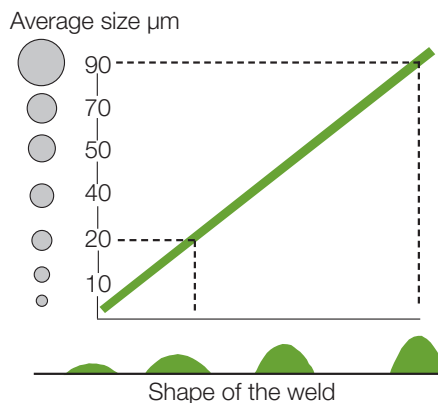


Figure 13 Particle size effect on weld shape

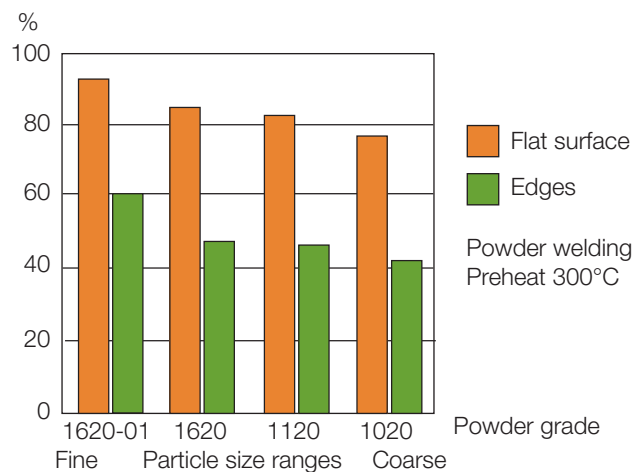


Figure 14 Deposition efficiency

3. Pre-application Procedure

Cleaning

Preparation of the surface includes using a suitable degreasing agent to remove dirt and oil. Most important is the creation of a fresh metallic surface by filing, grinding, turning, and/or blasting with angular steel grit (Fig. 15). We recommend a steel grit particle size of 0.8 mm (20 mesh). Preparation by blasting of the surface gives a profile roughness parameter of 5-6 Ra.

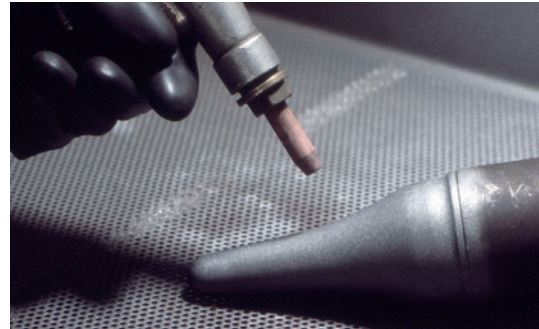


Figure 15 Blasting for a clean surface

4. Powder Welding

Basically, this method uses a simple oxy-acetylene torch. Finely divided powder (10-100 μm) is fed through an injector from the hopper into the flame. The deposition rate is 1-2 kg/h.

Powder welding is used for a deposit thickness of between 0.1 mm to 10 mm – e.g. on neck rings, blanks, and final moulds – both for repairs and original parts. This method is especially suitable for building up edges and corners (Fig. 16).



Figure 16 Powder welding of mould edge

Preheating

To obtain the best result with powder welding, it is necessary to preheat the workpiece. Depending on size, the preheating temperature can vary from 300°C to 700°C. Preheating enables a better bond of the weld to the workpiece and a faster welding time (Fig. 17). A higher preheat temperature also reduces the amount of oxides and overspray.

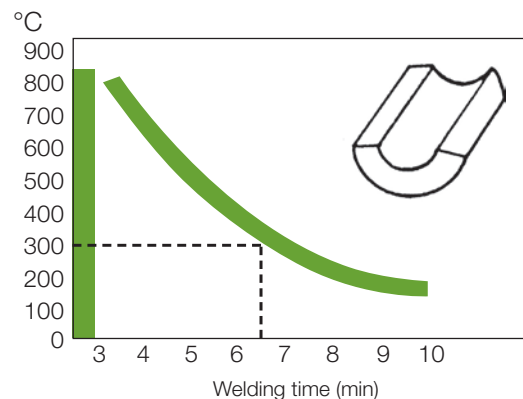


Figure 17 Importance of preheating for welding time

Preheating summary

Small pieces weighing up to 500 g, such as sealing rings and small moulds, need less preheating, as enough heat is applied to the workpiece during welding. Too much preheating may cause overheating, resulting in sagging of the weld and melting of the base metal.

Bigger parts must be preheated to 600-700°C (Fig. 18). It is important to preheat as fast as possible to avoid excessive oxidation of the workpiece.



Figure 18 Preheating in furnace

Surface protection

Before preheating the mould a thin layer of powder should be applied to the surface in order to minimise surface oxidation (Fig. 19).

To avoid contaminating other surfaces with overspray and oxides during spraying, they should be protected with heat-resistant paste.



Figure 19 Thin layers minimise oxidation

Powder welding of moulds, neck rings and plates

After selection of a suitable nozzle and adjustment to obtain the recommended gas pressure, the torch can be lit. Using a neutral flame, the starting point is progressively heated until it becomes dull red. The powder feeder is opened slightly and the particles should meet the surface and form a melt pool. Powder flow should be concentrated on the melt pool or slightly in front of it. The torch should be moved slowly, in order to keep the melt pool open and ensure all particles are melted (Fig. 20).

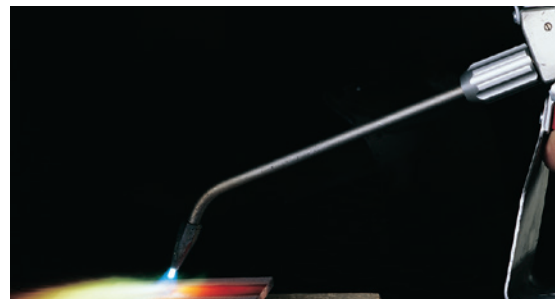


Figure 20 Maintain open melt pool

Powder welding grades

Nickel-base	Particle size μm	C %	Si %	B %	Fe %	Cr %	Ni %	Mo %	Others %	Hardness		Recommended use/Features/Comments
										HRC	HV ₃₀	
1015-00	20-106	0.03	2.0	1.1	0.5	–	Bal.	–	Cu=20.0	15*	210**	Repair of cast iron.
1020-00	20-106	0.03	2.4	1.4	0.4	–	Bal.	–	–	20*	230**	Welding of new cast iron moulds and repair of worn moulds and other parts. Repair of machining errors. Easy to machine. Can be filed by hand.
1120-00	20-71											
1620-00	15-53											
1620-01	10-36											
1021-10	20-106	0.03	2.0	0.65	0.3	3.0	Bal.	–	P=2.0	21*	250**	Lower melting point especially for bronze moulds.
1023-00	20-106	0.04	2.5	1.6	0.4	–	Bal.	–	–	23*	270**	Easy to machine. Can be filed by hand.
1623-05	10-53											
1025-40	20-106	0.05	2.7	1.8	0.4	–	Bal.	–	–	28*	295**	
1031-10	20-106	0.03	2.2	0.9	0.3	3.0	Bal.	–	P=2.2	28*	290**	Improved fluidity, lower melting point.
1035-40	20-106	0.32	3.7	1.2	3.0	7.0	Bal.	–	–	35*	360**	Repair and build-up of small plungers and neck rings.
1135-40	20-71											
1036-40	20-106	0.15	2.8	1.2	0.4	4.5	Bal.	2.5	P=1.9	36*	375**	Improved fluidity, lower melting point.
1038-40	20-106	0.05	3.0	2.2	0.4	–	Bal.	–	–	38*	380**	Very good fluidity for thin layers.
1040-00	20-106	0.25	3.5	1.6	2.5	7.5	Bal.	–	–	40*	425**	Repair and build-up of worn moulds and other parts.
1140-00	20-71											
1045-00	20-106	0.35	3.7	1.8	2.6	8.9	Bal.	–	–	47**	500**	Good fluidity.

Other compositions or particle size ranges can be requested.

* Indicative value

** Measured value

Recommended use
Features
Comments

5. Flame Spraying

The flame spraying process consists of two steps: spraying with a spray gun and fusing of the deposit with a fusing torch (Fig. 21). The powder is fed into an oxy-acetylene or oxy-hydrogen gun by injection and is projected towards the base material at high speed. The hot particles flatten under impact and interlock both with the base material and each other, forming a mechanical bond. Flame spraying is recommended for cylindrical and flat pieces, which can be rotated on a lathe or turntable. A plunger is a good example.

Fusing of deposits

A fusion treatment is required to obtain a dense and well bonded coating of the sprayed layer. The coating is heated to a temperature between its solidus and liquidus – normally around 1000°C. At optimum temperature, the material is a mix of melted and solid particles. Shrinkage of 15-20% takes place during fusing, when the melt fills the gaps between the particles.

Flame spray guns

Depending on the type of gas and brand of spray gun both fine and coarse powders can be used. The market's most common types of flame spray equipment are Metco gun 5P/6P, Castolin Terodyn 2000, DS Castodyn 8000, Colmonoy J-gun and IBEDA gun Uni Spray jet. All are excellent for this kind of work with a broad choice of materials and the highest productivity in kg sprayed powder per hour. The equipment listed works with acetylene and oxygen for normal spraying. If fine powder is used, e.g. 15-53 μm , hydrogen can replace acetylene or air can be added (possible with Metco gun 5P/6P).

Typical spray rates for these spray guns are 5-10 kg/h. The gun nozzle and control valve must be clean and in good condition if the best results are to be obtained. The pressure of acetylene, oxygen and air must be carefully adjusted to the recommended values. Just as importantly, the powder flow rate must also be correctly adjusted. If the flow rate is too low, it causes overheating, and if it is too high the particles will be insufficiently heated – in both cases this leads to an inferior layer quality with pores or oxides.

Recommended settings

Torch	Oxygen		Acetylene		Powder Flow	Air		Particle size μm
	Bar	Flow	Bar	Flow		Bar	Flow	
Metco 5P/6P	1.7	34	1.0	34	17			45 - 125
Terodyn 2000		35		48				36 - 106 45 - 106
Castodyn 8000	4		0.7					36 - 106 45 - 106
Colmonoy J	2.0	50	1.0	30		1.7	55	36 - 106 45 - 106
Uni Spray Jet	4		0.5			0	0.5	36 - 106 45 - 106

Note: Individual guns may require settings that fall outside the range.



Figure 21 Correct spray conditions

Flame spraying of plungers

The coarsest sections of the plunger must first be pre-heated to 200-300°C. Several layers of powder are then sprayed, beginning at the top of the plunger (Figure 22). The gun should be moved with a smooth, even action and should never be held still, as this causes the coating to overheat. It should be taken into account that the layer shrinks about 20% during the subsequent fusing. A normal thickness of 1.5 mm can be reached after 8-10 passes.

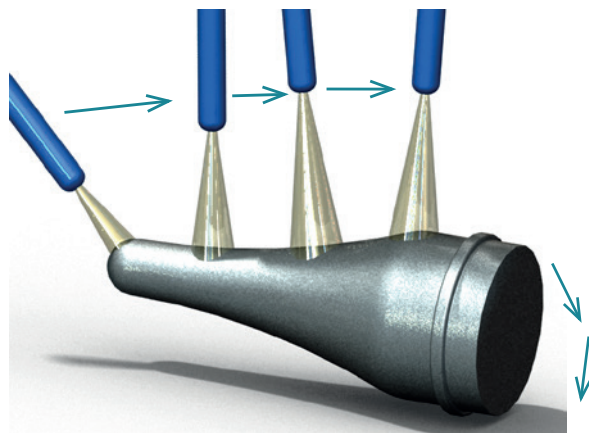


Figure 22 Start to spray at the top of plungers

Fusing of plungers

After spraying, the deposit must be fused (Fig. 23). A fusing burner of adequate size is used, i.e. a 1 000 l/min burner capacity for small plungers and up to 4 000 l/min for large plungers. If a burner is too small, this may lead to an excessively long fusing time, resulting in an oxidised layer. Fusing with a burner that is too large will overheat the layer and give rise to pores or unevenness.

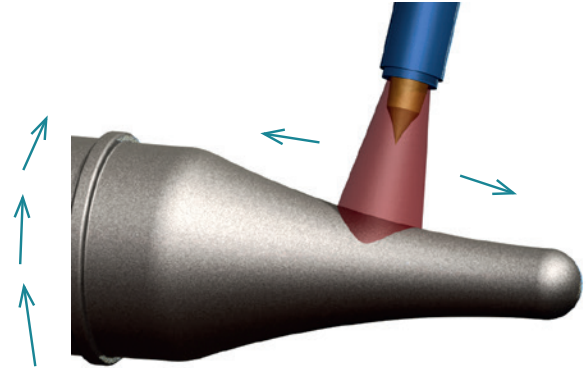


Figure 23 Fusing of plungers

Plunger fusing practice

The plunger should be heated to about 900°C. The flame should then be adjusted to acetylene gas surplus – a so-called “soft flame”. Start the fusing about 30 mm from the top. When the coating begins to shine like a mirror, move the flame towards the point of the plunger and fuse that section first (Fig. 24 and 25). Return to the starting point and complete the fusing of the plunger. It is recommended that dark welding glasses are worn, in order to see the shine correctly.

If fusing temperature is too low, insufficient material will melt. This results in bad adherence properties and high porosity.

Too much heat causes failures such as sagging of the deposit, dilution, distortion of the base material and excessive fluxing, which creates excessive slag and makes the deposit too soft.

When spraying a plunger with a diameter of less than 25 mm, it is more economical to use an additional air cap on the gun. This concentrates the powder stream on the plunger's small surface area. Thus spraying time is reduced and deposition efficiency increased.



Figure 24 Moving the flame toward plunger point

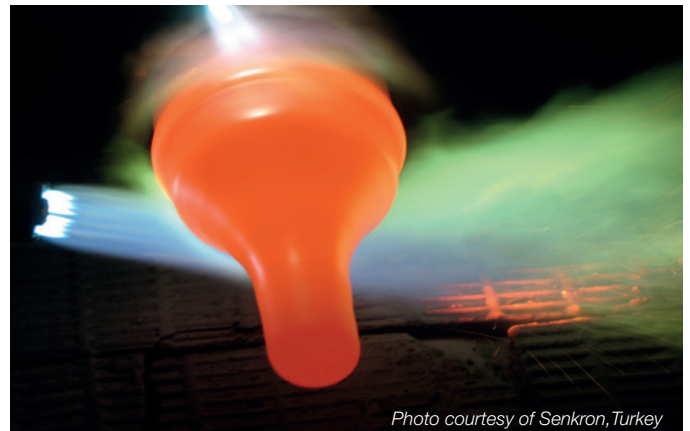


Figure 25 Complete fusing of the plunger

Post-treatment of plungers

After fusing, the plunger is cooled to about 600° C under rotation. Thereafter, it can be left to cool slowly in air. If a hard alloy (50-60 HRC) is used, it is recommended that the piece is placed in a heat-insulating material such as vermiculite. This will slow the cooling to prevent cracks.



Figure 26 Plungers and neck ring completed



Figure 27 Glass bottle production

Flame spraying grades

Nickel-base	Particle size µm	C %	Si %	B %	Fe %	Cr %	Ni %	Mo %	Others %	Hardness		Recommended use/Features/Comments
										HRC	HV ₃₀	
1235-40	36-106	0.32	3.7	1.2	3.0	7.0	Bal.	–	–	35*	325**	Build-up of layers on plungers where good machinability is required.
1335-40	45-125											
1240-00	36-106	0.25	3.5	1.6	2.5	7.5	Bal.	–	–	38*	380**	
1340-00	45-125											
1245-00	36-106	0.35	3.7	1.8	2.6	8.9	Bal.	–	–	44**	450**	
1345-00	45-125											
1250-00	36-106	0.45	3.9	2.3	2.9	11.0	Bal.	–	–	51**	570**	
1350-00	45-125											
1362-10	45-125	0.60	3.7	2.8	3.5	14.3	Bal.	–	W=9.5	59**	700*	Provide carbide-rich matrix, wear resistant.

Other compositions or particle size ranges can be requested.

* Indicative value

** Measured value

Recommended use
Features
Comments

6. HVOF Spraying

In the glass mould industry, HVOF (High Velocity Oxy-Fuel) spraying is normally used for coatings on narrow neck plungers (Fig. 28) and to a limited extent on both press and blow plungers.

Narrow neck plungers have a diameter of less than 25 mm and require hard and dense coatings. It is therefore more economical to use the HVOF-process. This has a more concentrated flame than flame spraying and creates very dense coatings due to the high speed of the powder particles.



Photo courtesy of Kobatek, Turkey

Figure 28 Narrow neck plungers

HVOF requires finer powder than flame spraying. The most common solution is a powder with a particle size range of 20-53 micron. Some HVOF systems require even finer powders such as 15-45 micron.

Most HVOF coatings can be used without fusing. In the case of narrow neck plungers, fusing of the coating is still recommended.

Spraying and fusing instructions are the same as for flame spray, see pages 9-12.



Photo courtesy of Praxair

Figure 29 HVOF gun

HVOF spraying grades

Nickel-base	Particle size μm	C %	Si %	B %	Fe %	Cr %	Ni %	W %	Co %	Hardness		Recommended use/Features/Comments
										HRC	HV ₃₀	
1660-02/ 46712-10	20-53	3.15	2.3	1.6	1.75	7.5	Bal.	41.3	6.0	>64**	>850*	Mix with 50% agglomerated WcCo 88/12. Most common for use on narrow neck plungers.
1662-12	20-53	0.65	3.7	2.8	3.5	14.2	Bal.	9.5	-	62**	700*	Provide carbide-rich matrix, wear resistant.

Other compositions, mixes (percentage) or particle size ranges can be requested.

* Indicative value

** Measured value

Recommended use
Features
Comments

7. PTA Welding

PTA (Plasma Transferred Arc) welding is a coating method increasingly used in the glass mould industry. As PTA is a welding method, it enables a metallic bonding with the base material (recommended dilution 5-15%). It can be used for both cast iron, bronze moulds and even bronze containing Zn (zinc), without problems.

The method is most commonly used on bottom-plates and different types of guide rings. Today there are fully automated PTA systems on the market for coating moulds and neck rings (Fig. 30-32). PTA welding eliminates manual work and, once the parameters are fixed for a certain design, consistent final results are achieved for every mould.

Coating procedure

A clean, machined surface is sufficient as it is a welding procedure. It is recommended that parts are preheated to 300-400°C. The parameters should be fixed to ensure that a dilution of 5-15% is achieved. If the dilution is higher, there is a risk for cracks when welding on cast iron. This is due to an increased C content in the coating. When welding on bronze, a dilution that is too high creates a risk for hard Cu-phase formation in the coating. This also causes cracks. If the dilution is too low, there is a risk for poor bonding to the base material. Welded parts also need to be cooled down slowly to avoid cracks.



Figure 30 Automated PTA equipment

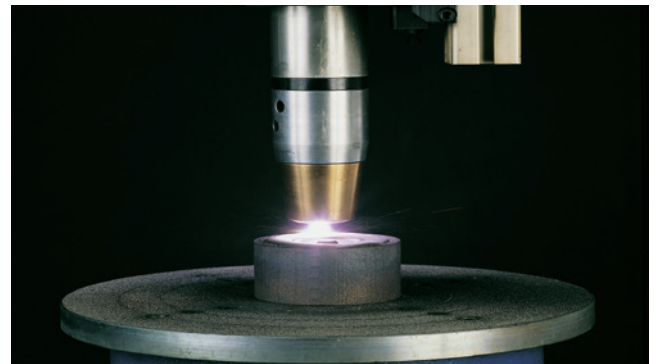


Figure 31 PTA deposition



Figure 32 PTA weld

PTA welding grades

Nickel-base	Particle size μm	C %	Si %	B %	Fe %	Cr %	Ni %	Others %	Hardness		Recommended use/Features/Comments
									HRC	HV ₃₀	
1525-30 SP570	53-150	0.13	2.55	1.0	1.9	3.3	Bal.	Al=0.4	24**	250*	Mould edges, guide rings (both cast iron & bronze)
1532-30 SP523	53-150	0.10	2.4	0.9	2.3	4.9	Bal.	Al=1.4	28**	280*	
1529-30	53-150	0.20	2.6	0.9	2.3	5.0	Bal.	Al=1.5	31*	310**	
1535-30	53-150	0.25	3.0	1.0	2.4	5.6	Bal.	Al=1.0	32*	310**	
1535-40	53-150	0.32	3.7	1.2	3.0	7.0	Bal.		35*	360**	Neck rings, bottom-plates (both cast iron & bronze)

* Indicative value

** Measured value

Recommended use
Features
Comments

Quick Guide to Höganäs Powder Grades

Glass mould industry solutions

Powder	Typical HV ₃₀	Typical HRC	Fluidity 1=high, 5=low	Method	Application
1340	380	38	-	Flame spraying	
1345	450	44	-	Flame spraying	
1350	570	51	-	Flame spraying	
1660-02 + 50% 46712-10	>850	>64	-	HVOF/Plasma	
1662-12	700	62	-	HVOF/Plasma	
1020	230	20	5	Powder Welding	
1021-10	250	21	3	Powder Welding	
1623-05	270	23	2	Powder Welding	
1025-40	295	28	2	Powder Welding	
1031-10	290	28	3	Powder Welding	
1525-30 SP570	250	24	-	PTA	
1532-30 SP523	280	28	-	PTA	
1535-30	310	32	-	PTA	
1015	210	15	5	Powder Welding	
1020	230	20	5	Powder Welding	
1021-10	250	21	3	Powder Welding	
1025-40	295	28	2	Powder Welding	
1031-10	290	28	3	Powder Welding	
1040	425	40	2	Powder Welding	
1535-30	310	32	-	PTA	
1535-40	360	35	-	PTA	
1025-40	295	28	2	Powder Welding	
1031-10	290	28	3	Powder Welding	
1040	425	40	2	Powder Welding	
1535-30	310	32	-	PTA	
1535-40	360	35	-	PTA	
1031-10	290	28	3	Powder Welding	
1035-40	360	35	3	Powder Welding	
1036-40	375	36	2	Powder Welding	
1040	425	40	2	Powder Welding	
1535-30	310	32	-	PTA	
1535-40	360	35	-	PTA	
1020	230	20	5	Powder Welding	
1040	425	40	2	Powder Welding	

Equipment specific products on request.

Power of Powder®

Metal powder technology has the power to open up a world of possibilities. The inherent properties of metal powders provide unique possibilities to tailor solutions to match your requirements. This is what we call Power of Powder, a concept to constantly widen and grow the range of metal powder applications.

With its leading position in metal powder technology, Höganäs is perfectly placed to help you explore those possibilities as your application project partner.

Power of Powder is being applied far beyond its traditional role in the production of components for vehicles. Iron powder is used in food fortification to combat anaemia. Nickel powders are vital ingredients in valve coatings to enhance wear resistance. Specially formulated iron-based powders offer new solutions for high-temperature brazing. Soft Magnetic Composites with 3D magnetic properties are opening the way for innovative electric motors. In fact, metal powder technology generates virtually endless possibilities.

To find out how you can apply the Power of Powder, please contact your nearest Höganäs office.



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