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Indian Standard

RECOMMENDED PRACTICE FOR BUILDING-UP BY METAL SPRAYING

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 1

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0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 8 February 1965, after the draft finalized by the Welding General Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 There are two major fields in which sprayed metal coatings find application, namely, for providing protection to surfaces against corrosion and for building-up surfaces to desired dimensions. In this standard, it is intended to deal only with the latter aspect.

0.3 A variety of processes and equipments for flame spraying of metal coatings are in use today and some of the recent technical developments such as electric arc spraying and plasma arc spraying show much promise.

0.3.1 This standard, however, covers only the oxy-fuel gas flame spraying process using metal in the wire form, since this method is by far the most commonly used and sufficient information and experience is available for the formulation of a code of practice.

0.4 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. This has been met by basing the standard on the following publications:

AWS/C 2.4 - 55T Recommended practices for metallizing (Part I D). American Welding Society.

AWS/C 2.1 - 60 Recommended practices for metallizing shafts or similar objects (Part I A). American Welding Society.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS:2 - 1960*. The number of significant places retained in the rounded off value should be t,he same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard covers recommendations for building-up by metal spraying using wire and oxy-fuel equipment except and where otherwise stated, the reference is to building-up of the outside surface of the cylindrical components, such as, shafts, rolls, drums, etc, which in fact constitute the bulk of the building up applications for which this process is employed.

2. SURFACE PREPARATION

2.0 The adherence of the flame sprayed coating to the base depends upon mechanical interlocking of the first layer to the interstices of the roughened surface or to the bond coat.- For obtaining a high degree of adhesion, careful attention should be paid to the preparation of the surface.

2.1 **Cleaning Prior to Further Preparation** — Crease, paint and other foreign matter shall be removed from the area to be sprayed as well as the adjoining area, since these stand in the way of proper adhesion of the sprayed metal to the surface.

2.1.1 A chemical solvent, such as, trichloroethylene or carbon tetrachloride or heating or a combination of both methods should be employed for cleaning the surface. Surfaces which are likely to have absorbed oil should be heated to 250" to 300°C to ensure removal of all traces of oil.

2.1.2 Blasting with abrasive material is an effective method of removing ail foreign matter except oil and grease.

2.2 Inspection for Soundness -The surface should be carefully examined for freedom from cracks and other flaws which would render the component unsuitable for repair.

2.3 Undercutting — It is almost always necessary to undercut the surface to be built-up. This is done in order to **allow for** an adequate and uniform thickness of sprayed deposit on the finished job. Undercutting will not be necessary when a thin coating of molybdenum is to be applied for restoring a component to a size so that a gear, flange, wheel, or such other parts may be press-fitted.

2.3.1 *Procedure for Undercutting* — The undercutting is accomplished on a lathe or similar device by either machining or grinding to the required dimensions, care being excercised to see that the undercut section is concentric with the original axis of the shaft.

2.3.1.1 In cases where the extent of wear that has already taken place is such as to allow for an adequate thickness of sprayed deposit in the finished job, machining or grinding should be done solely for the purpose of correcting the eccentricity in wear.

2.3.1.2 Undercutting reduces the effective cross-section of the part to be metal sprayed. Since sprayed metal deposits do not restore any qualities such as tensile strength or resistance to fatigue stress, all parts to be built-up by metal spraying should be examined carefully from a design standpoint to determine that adequate strength is maintained in the part as prepared for metal spraying.

2.3.1.3 The undercutting operation should preferably be done dry, but where this is not feasible, this should be followed by a further degreasing treatment and drying.

2.3.2 ***Length of Undercut*** -The length of the undercut section should generally extend beyond both-ends of the sleeve, bearing or packing gland in which the shaft operates.

2.3.3 ***Depth of Undercut***-The depth to which the shaft should be undercut is determined by a number of factors such as the diameter of the shaft, the severity of service and the amount of wear to be expected in service. The wear allowance should always be determined for each individual job but the information provided in Table 1 may be used for guidance in determining the depth of undercut to be provided for specific service applications. Additional allowances should be made, if necessary, for more severe wear.

TABLE 1 RECOMMENDED DEPTH OF UNDERCUT

(All dimensions in millimetres)

DIAMETER OF SHAFT	DEPTH OF UNDERCUT ON RADIUS FOR VARIOUS TYPES OF SERVICE		
	Class A*	Class B†	Class C‡
(1)	(2)	(3)	(4)
Under 25	—	0.50	0·25
25 to 50	1·00	0·80	0·25
50 to 100	1·25	1.00	0.50
100 to 150	1.50	1.25	0·50
Over 150	1·75	1.50	0·50

NOTE — *All Classes of Service* — When the molybdenum underlay method is employed, no minimum thickness is required for press fits, but where wearing surfaces are concerned, the thickness shall be such that the maximum allowable wear will be less than the coating thickness.

*For shafts and journals operating under a heavy bearing load, such as diesel engine crankshafts or rolling mill journals; for pump sleeves, piston rods and hydraulic rams subject to severe service and high pressure, where a maximum safety factor is required.

†For normal duty lubricated bearing service; for standard pressure pump rods and sleeves; where a normal safety factor is required.

‡For restoring a shaft to size where a gear, flange, wheel or other part is pressed on and the sprayed surface does not act as a bearing.

2.3.4 *Ends of Undercut* — The sprayed metal requires to be mechanically anchored into the base metal at the ends of the undercut section. Dovetailing the shoulders at the extremities of the undercut section with a radius at the bottom (see Fig. 1) is recommended for this purpose.

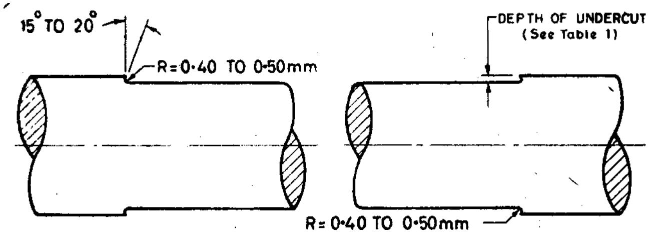


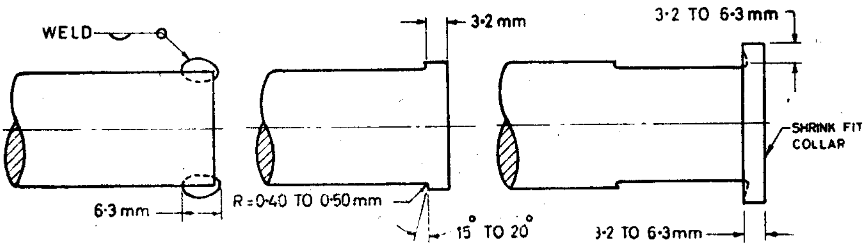
FIG. 1 METHOD OR PREPARING SHOULDERS OF UNDERCUT SECTION

2.3.5 When preparing journals of crankshafts where dovetailing at the extremities as illustrated in Fig. 1 is not permissible, about 0·25 mm should be removed from the flanges. The fillet radius should be reduced to be parallel to the original radius.

2.3.6 Where the surface to be built-up extends to the extremity of the shaft, the end should be chamfered to avoid possibilities of damage to the coating at that point. It is also good practice to chamfer the ends of hydraulic rams and pump-rods so that the sprayed deposit can be taken over the end surfaces. This prevents the possibility of the pressurized fluids exerting a lifting action on the coating under conditions of service.

2.3.7 If a chamfer at the end is inadmissible, one of the methods illustrated in Fig. 2 should be employed.

2.3.8 All sharp edges in the area to be sprayed, such as edges of oil holes and keyways should also be chamfered with 30 degree bevel to a depth of approximately 0·5 to 0·8 mm.



2 A Bead Weld Method

2 B Collar Method

FIG. 2 ALTERNATIVE METHODS OF PREPARATION WHERE BUILT-UP SECTION EXTENDS TO END OF SHAFT

2.4 Surface Roughening-To ensure adherence of the sprayed metal, a clean surface of sufficient roughness is necessary. Before the roughening operation is commenced, however, it should be made certain that all traces of oil, grease and other foreign matter on and adjacent to the undercut surface are removed.

A number of methods of roughening are available and the choice among them depends mainly on the materials and tools available and service requirements.

2.4.1 ***Mechanical Roughening*** — The roughening methods falling under mechanical roughening are given in 2.4.1.1 to 2.4.1.3.

2.4.1.1 ***Rough threading method***-The object of the rough threading method is to obtain roughened V threads with the sides torn and jagged and with a radius of not more than 0·4 mm at the bottom. A 50" to 60° pointed tool should be used for the purpose and Fig. 3 illustrates one of the many ways to grind the tool bit for rough threading. Another way is to grind the tool so that it has a zero or slightly negative back rake and side rake.

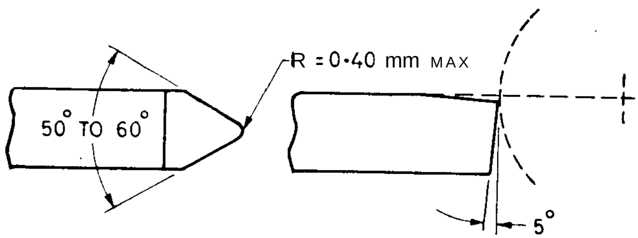


FIG. 3 METHOD OF GRINDING TOOL BIT FOR ROUGH THREADING

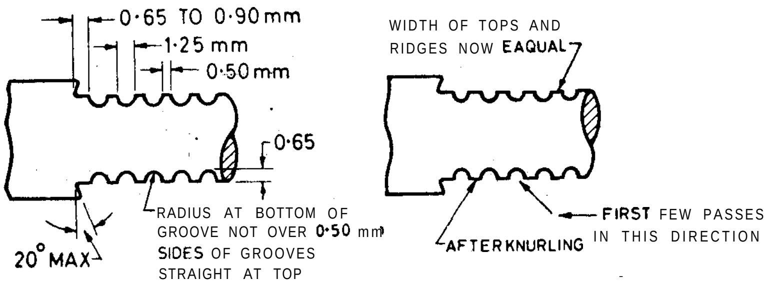
The tool should be set slightly below the centre line of the work to give a certain amount of chatter. Alternatively, a shim placed at the back of the tool assists in obtaining as rough and jagged a thread as possible. The tool should also be fed to a greater depth than normal so as to obtain a sharp thread. The work should be rotated at a low speed and 6 to 12 threads/cm with a depth of 0·5 to 0·8 mm are to be cut, larger diameter shafts usually requiring coarser threads which would be correspondingly deeper also.

The threading operation may be done in one or more passes or cuts. No coolant should be used and the surface should always be kept free from grease.

Barbs that are just above the contour of the shaft may be removed by placing a flat tool just clear of the job.

2.4.1.2 Groove *and knurl method* — This method consists of cutting spiral or' annular grooves in the undercut section in such a manner that the lands between them could be knurled subsequently with a special tool to give a dovetail effect.

The cutting of spiral or annular grooves as shown in Fig. 4A is accomplished with a round nosed cutting tool ground to the shape and dimensions shown in Fig. 5. Spiral grooves of the proper pitch may be obtained by setting the thread feed on the lathe at 6 threads per centimetre.



4A Method of Making Spiral Grooves 4B Method of Knurling

FIG. 4 DETAILS OF GROOVE AND KNURL METHOD OF PREPARATION

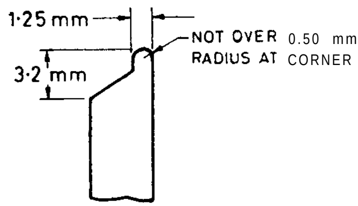


FIG. 5 GROOVING TOOL

In the case of annular grooves the machining time may be reduced by the use of multiple cutters which permit the making of several grooves at a time. Annular grooves should be cut proceeding from both ends towards the centre so that an outsize groove or land, if it occurs, is in the centre of the area to be sprayed. The depth of the groove should be approximately 0.6 mm and may be cut in one or several passes. The grooves should be so spaced that the lands between them are approximately 0.4 mm wide. The grooving should cover entire length of the undercut section except for 0.6 to 0.9 mm at each end.

After the grooving is completed, the spreading and roughening operation should be done with a special knurling tool usually consisting of several hardened and grooved wheels. With the work turning at a surface speed of from 60 to 90 m/min, the tool should be fed into the work at 0·1 mm infeed per pass and traversed over the lands of the grooves at a feed of about 0·5 mm per revolution. This operation should be continued until the land is spread out and the land width and the groove width are approximately 0·8 mm. When this operation has been completed the U shaped grooves will have been converted into a series of dovetails. The surface of the land will be spread and roughened (Fig. 4B).

2.4.1.3 ***Blasting with abrasive material*** — This method is used in certain instances where (a) the rough threading and (b) the grooving and knurling preparations cannot be adopted because of the nature of the component, a typical example being the journal of a crankshaft. Blasting should be done with angular grit particles having grain size varying from 0·70 to 1·70 mm, crushed fused alumina (aluminous abrasive) or clean, sharp, crushed chilled iron grit being particularly suitable.

The most common method of blasting surfaces prior to building-up by metal spraying is the pressure method in which the grit is fed from a machine where the abrasive is kept under pressure into a jet of compressed air which propels the abrasive particles on to thesurface at a high velocity. Pressures used range from 2·5 kg/cm^2 to 7 kg/cm^2, the higher pressures in the range being used for treating the comparatively hard materials.

It is necessary that the compressed air used as the propellent should be free from moisture and traces of oil which adversely affect the bond between the sprayed coating and the base. Portions adjacent to the area to be treated which need to be protected from the grit should be heavily wrapped with rubber tape. Oil holes on the surface to be blasted should be plugged. Moulded rubber is best for the purpose and these plugsshould be capable of withdrawal outwards after grit blasting and spraying.

Blasting as a method of preparation is not suitable in cases where the applied metal coating is subject to severe torsional stress.

2.4.2 ***Electric Bonding*** — When the surface is too hard to be grit blasted or machined according to the methods described under 2.4.1.1 and 2.4.1.2, it may be roughened by electric bonding in which spattering with a low power welding set using a bundle of nickel wires as electrodes leaves small, irregularly shaped particles of the electrodes on the surface which is, as a result, roughened.

Special equipment is required for this type of preparation and for details of the working of this method, reference should be made to technical literature available on the subject from the manufacturers of the equipment.

This process which is slow in application is little used except for the treatment of hardened or irregular surfaces.

2.4.3 *Molybdenum Underlay* — While this method may be adopted for general use also, it is particularly useful in treating hardened surfaces which cannot be prepared by the methods described under **2.4.1.1**, **2.4.1.2** and **2.4.1.3**. It consists of applying by metal spraying a thin coating of molybdenum on to the surface which should be clean, free from grease and slightly roughened or abrasing with medium grade emery cloth, taking a light grinding cut or light grit blasting being usually adequate. Grit blasting is definitely of benefit in that it produces compressive stresses in the surface of the steel and offsets the tendency to the lowering of the fatigue strength. The molybdenum coating acts as the base for the coating that follows the metal to be used for building-up.

When used as a bonding coat, the thickness of the molybdenum should only be sufficient to cover the surface completely. This will be equal to an average coating thickness of 0·04 to 0·05 mm, which will then measure 0·07 to 0·08 mm due to surface irregularities. The underlay coating should be sprayed coarse since such a coating provides a better key for the following coat. The correct degree of atomisation may be achieved by reducing the propellent air pressure to less than the usual figure recommended for normal spraying of other metals and alloys.

It is essential that acetylene be used as the fuel gas for spraying molybdenum. Adjustment of both the acetylene and oxygen pressures is critical Molybdenum will oxidise badly and not bond if even a slight excess of oxygen is used. Conditions of spraying molybdenum involving high oxygen gas ratios are confined to the application of hardened molybdenum coatings and are not used for underlays. The operating conditions recommended by the manufacturers of the metal spraying equipment should be carefully followed.

Since molybdenum sticks even to smooth surfaces, it is necessary to mask areas adjacent to the portion to be treated with tape or a masking compound. Oil holes in the area to be treated should be protected by the use of carbon, wood or brass plugs and keyways by inserting a brass, bronze or carbon dummy key.

A molybdenum coat when applied correctly on a freshly prepared surface will adhere satisfactorily to steel either in the hardened or in the soft state, cast iron, stainless steel, nickel and nickel alloys and most aluminium and magnesium alloys. It does not bond well with copper and copper alloys and on nitrided steel. Molybdenum has a marked tendency to oxidization at elevated temperatures and because of the danger of deterioration of the bond on account of this, a molybdenum underlay is not generally recommended for work which will be subjected to temperatures over 320°C.

3. SPRAYING

3.1 General- Parts should be sprayed as 'soon as possible after preparation. Where, for special reasons, the spraying has to be delayed for even a short period of time or the part has to be handled, the prepared surface should be protected from oxidation and contamination. Wrapping with clean paper and handling with clean protective gloves usually provides adequate protection. Since condensation of moisture on the prepared surface impedes satisfactory adhesion of the sprayed metal, warming the surface prior to spraying is recommended but if a gas flame is used care has to be taken to ensure that surface oxidation and contamination do not occur in the process. Oil holes and keyways on the surface to be treated should be plugged with moulded rubber or carbon insets.

When spraying steel and other metals, particularly molybdenum, the bright spray is liable to strain the eyes of the operator and he should, therefore, be provided with tinted glasses of the right shade and quality (see IS : 1802 - 1961*).

When spraying large quantities of metals of the copper group and nickel, it will be necessary for the operator to protect the nose and mouth by means of a respirator or by other suitable means.

The shop where metal spraying is carried out should be airy and well ventilated or provided with efficient dust removal and air circulation facilities.

3.2 **Equipment** — Spraying is done with a tool commonly known as the metal spraying pistol or gun. The motive power for the feeding of the wire into the flame is provided usually by an air turbine in the pistol (or an electric motor in some heavy duty pistols) geared down to drive rollers which pull the wire into the pistol and feed it into the flame. Suitable means of adjustment of feed speed are also provided. Compressed air is also used as the propellent for the atomised molten particles.

An adequate supply of dry air free from traces of oil and at pressures required for operating the tool efficiently should be arranged. In addition, supplies of oxygen and the fuel gas that is recommended for theequipment as well as ancillary equipment such as pressure regulators and hoses should be available. Fuel gases commonly used are acetylene and propane.

The use of flowmeters for the oxygen and the fuel gas is recommended since these assist in setting and maintaining correct spraying conditions without difficulty.

3.3 **Wires-The** wire to be used for spraying should be kept wound in reels or spools and shall be free from kinks which hamper the smooth feeding of the wire through the nozzle.

*Specification for ionones.

The choice of the metal and the wire size for a specific job would depend on a number of factors and recommendations of manufacturers of metal spraying equipment and other technical literature on the subject should be consulted. A few points of importance are, however, given below:

a) Where a choice of the metal to be sprayed is possible, that metal should be selected which gives a coating with the lowest shrinkage rate (lowest co-efficient of expansion). An instance is the rebuilding of steel shafts where, as a general rule, high carbon steel (0·7 percent) is preferred to low carbon mild steel which has a higher shrinkage rate and also oxidises excessively during spraying with resultant tendencies to cracking.

   Where the finished surface has to be of a metal with a high shrinkage rate and the deposit has to be relatively thick, a metal having a low shrinkage rate should be chosen for building-up to within 0·5 to 1·0 mm of the finished size and the job may then be completed by spraying the desired wire.

b) Where an 18/8 chrome-nickel stainless steel deposit is required to serve under corrosive conditions, it is necessary that the wire chosen should contain, in addition to these alloying elements, a stabilizer such as niobium or titanium.

   It should be noted that sprayed stainless steel is not stainless unless it is ground and polished.

c) In view of the fact that it is permissible to finish molybdenum deposits to a feather edge without any danger of the coating peeling off, it is used for building-up where only a small amount of metal is required such as for instance restoring a press fit. In such cases, after the initial bonding coat is sprayed, further building-up is done with the coarseness of the spray reduced slightly by an increase of the propellent air pressure. This results in a finer surface which may be finished speedily and more economically. Heavy thickness of sprayed molybdenum coatings are not recommended both on considerations of cost and cracking of the deposit.

3.4 Spraying Procedure — The operating conditions such as wire speed, gas pressure and flame conditions recommended by the manufacturers of the pistol should be strictly adhered to. The practice of increasing spraying rates over those recommended by increasing gas pressures is, in particular, to be avoided since this could give rise to poor results.

The pistol should be lighted and adjusted with the spray directed away from the work. The work should be held in a device such as a lathe and made to rotate at a surface speed of 9 to 15 m/min. During spraying the pistol which is usually mounted on the toolpost of the lathe should be at a distance of 80 to 250 mm from the work depending upon the equipment and size of wire used.

The ends of the undercut sections should be sprayed first with the angle of impingement continually varying from about 30 to 60 degrees (see Fig. 6). Corners should be built up from quarter to half the depth of the undercut before proceeding further.

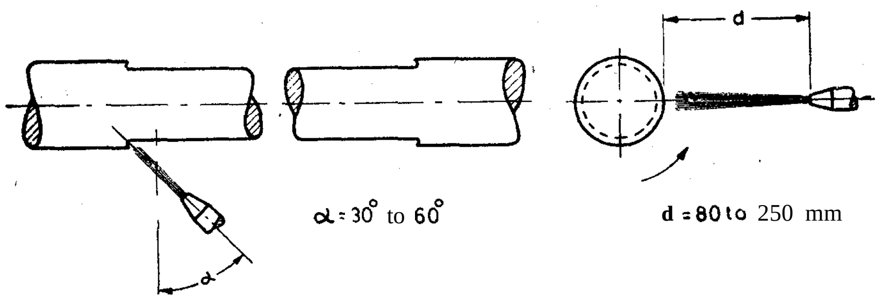


FIG. 6 METHOD OF SPRAYING END OF UNDERCUT SECTION

In treating shafts prepared by the grooving and knurling method, after spraying the ends of the undercut sections, spraying should be continued with the gun held at an angle of 45 degrees to the work for at least five passes in each direction in order to deposit metal under each dovetail. Subsequent procedure is the same as that for work prepared by other methods.

In work prepared by method other than grooving and'knurling, after the ends of the undercut sections are sprayed, the job should be completed by spraying at right angles to the surface.

The spraying process shall be continuous and where practicable the total thickness should be applied in one pass progressively along the length of surface to be sprayed. It is advisable when heavy deposits are being applied in a single pass, to cool the work with a diffused blast of clean dry compressed air. Suitable means shall also be provided to prevent the accumulation of metal dust ahead of the spraying operation.

If spraying in one pass is not possible, a, large number of very rapid light passes are permissible but separate layers of medium thickness in the range of 0·5 to 1·0 mm are not good practices.

It is necessary to put on sufficient metal to allow for finishing (usually about 0·25 to 0·40 mm on radius over the finished size).

The temperature of the work should, on no account, be allowed to exceed 150°C. Spraying should be stopped periodically if it is not possible, by other means, to keep down the temperature within this limit.

After spraying is completed, the work should be allowed to cool slowly to room temperature. If necessary, an air blast may be used to cool the work as it is rotated.

The plugs for the oil holes and dummy keys for the keyways may be removed at this stage but where possible, it is recommended that these are not removed until the finishing operation is also over.

4. FINISHING

4.1 **General**- Sprayed deposits may be finished either by grinding or by turning, the former method being preferred.

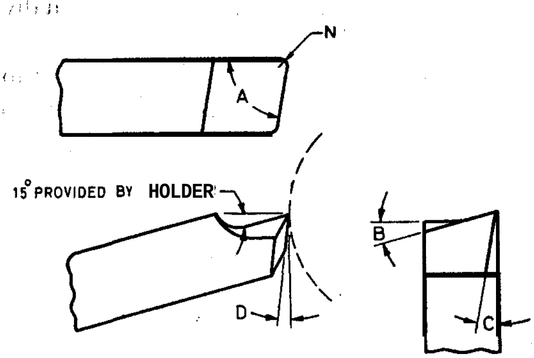
4.2 **Grinding**- Finishing sprayed deposits by grinding requires no special technique, normal grinding practice usually being followed. Medium soft wheels having vitrified bond with a No. 40 grit or soft ones with a No. 60 grit, the abrasive being bauxite or silicon carbide, are generally recommended for the purpose (see IS : 715 - 1962*). When grinding sprayed metals, the wheel glazes quickly and more frequent dressing may be found necessary. If fine grain wheels are used, clogging may/cause chatter.

Grinding wet is always preferred and the surface speed of the wheel should be approximately 1800 to 1950 m/min, with the work turning at a surface speed of25 to 30 m/min. The infeed should **be very** light. For rough grinding an infeed of approximately 0·04 mm is used and as the job approaches finished size this is reduced to 0·02 mm. Two percent soluble oil, clean and free from foreign matter is a suitable coolant. The grinding wheel should never be allowed to remain immersed in the coolant, due to the wheel absorbing moisture and thereby becoming unbalanced.

In dry grinding on tool post grinders, wheel speeds are usually lower by about 10 percent than for wet grinding. Keeping the **work smeared** with a light layer or machine oil helps in reducing the glazing of the wheel. The tool post grinder used for finishing sprayed deposits should be of **a** robust type.

4.3 **Turning** — If turning has to be resorted to as the method of finishing, tools tipped with tungsten carbide or high speed steel should be used. While the shape of the tool is not critical, it has been found advantageous to have the tool ground as shown in Fig. 7 and to the dimensions given in Table 2.

*Specification for coated abrasives, glue bond (*revised*).



A = Nose angle
B = Side rake angle
C = Side relief angle
D = Working relief angle
N = Nose radius

FIG. 7 GRINDING TOOL BITS FOR MACHINING SPRAYED METALS

TABLE 2 DIMENSIONS FOR GRINDING TOOL BITS

(*Clause* 4.3)

DIMENSION	HIGH SPEED TOOL BITS	CEMENTED CARBIDE TOOL BITS
Nose angle	80” approximately	75” approximately
Side rake angle	0” to 15”	0”
Side relief angle	10”	7”
Working relief angle	7” *Max*	7” *Max*
Back rake angle	8” *Max*	8” *Max*
Nose Radius	0·8 to 1·0 mm	0·8 to 1·0 mm

The cutting edge of the tool should be either on the centre line of the work or not more than 5 degree above.

The peripheral speed of cutting should be in the range of 15 to 30 m/min for finishing sprayed steels, stainless steel and nickel. For copper and copper alloys speeds may be as high as 60 to 100 m/min when using carbide tools and 30 to 45 m/min when using high speed steel tools.

Machining should be started near the middle of the sprayed length and worked out to the edges. Only very light cuts should be taken and the traverse of the tool should be as low as is convenient on the lathe. A coolant such as soluble oil may be used.

Even with carbide tipped tools, sprayed molybdenum deposits are unmachinable.

4.4 Plugs for the oil holes and dummy keys for keyways shall be removed after the finishing operation if this has not already been done after spraying. The oil ways should then be thoroughly cleaned to ensure that no metal particle or grit is left inside.

PUBLICATIONS OF INDIAN STANDARDS INSTITUTION

INDIAN STANDARDS

Over 2800 Indian Standards, broadly classified under the following main heads, have been issued so far:

Agriculture & Food
Chemical
Civil Engineering
Consumer Products
Electrotechnical
Mechanical Engineering
Structural & Metals
Textile

Of these, the standards belonging to the Structural & Metals Group fall under the following categories:

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