CHAPTER-1

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Repair and rapid geometrical modifications of high-value tools and components are demanding challenges of modern manufacturing technology. Advanced cladding techniques with lasers offer outstanding possibilities for applications in aircraft maintenance as well as mold and die industry. The development of high power lasers cladding has been one of the major research topics. During the last fifteen years basic and applied research led to a profound understanding of the cladding process as well as to a variety of potential application. However, industry was rather reluctant to adopt this technology, mainly due to high investment and running costs. Since high power diode laser and Nd; YAG lasers were developed and introduced to the market which has changed the situation. A main advantage of these lasers is a significant reduction in running and maintenance costs. The next step will be the generation of complete prototype components and the geometric modification of expensive tools. High-power lasers open a completely new dimension in material deposition. The beam quality is extremely high, and this results in both small laser focus diameters (10–100 μm) and very long focal lengths. In addition, the current system technology, laser optics, powder feeders and nozzles, as well as CAD/CAM software, permit an easy and efficient integration of the laser process into manufacturing system [1].

In laser cladding the supply of the additive material is one of the key factors controlling the process. The most advantageous method is powder injection, as it gives good quality clad without severe dilution, porosity and melt depth is easier to control. In this paper efforts are made to design and fabricate an off-axis injection powder feeder for laser cladding to meet the requirement of PILO(KRL) Rawalpindi.

1.2 Aim

Design, fabricate and apply the lateral powder feeder for laser cladding purpose.

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1.3 Powder Feeder Types

So for, different types of feeders have been used in the laser cladding process. However it is hard to say which type of feeder is suitable for this process. Due to the wide range of application of the laser cladding, different powders, with different mesh sizes at various powders feed rates are required for the process. Many research groups, which are developing the laser-cladding apparatus, have designed and manufactured their own powder feeder, which suit their applications. It is impossible to convey every powder with a steady state flow using a single feeder machine. As a result, various types of powder feeders have been developed for laser cladding to provide smooth and steady flow in the required flow rate.

There are many types of powder feeders used in industry. In general, powder feeders can be categorized into the following classes based on different principles of operations. In some powder feeders, a combination of the above methods is used to arrive at a better stability in the powder stream. In all types of powder feeders, a carrier gas should be supplied to transport the desired location. A brief explanation of the available powder feeders is provided in the following sections [34].

1.3.1 Gravity- Based Powder Feeder

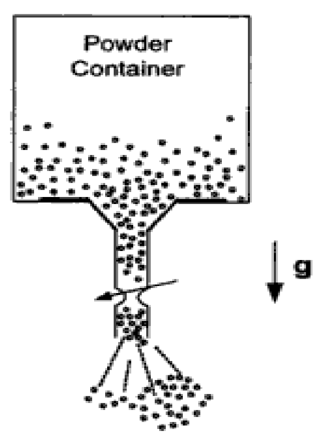


Fig: 1.1 A schematic of gravity based powder feeder [34]

The principle of operation of gravity based powder feeder is similar to a simple sand clock. The powder feeder machine essentially consists of a load Cell based electronic weighing mechanism and an orifice. Due to the weight, the material flows from hopper to the orifice if the powder particles have the requirement flowability. By reducing or increasing the area of the orifice, the amount of powder delivered to the nozzle decreases or increases.

In order to increase the controllability of gravity based powder feeders, different devices such as a metering Wheel can be integrated into the powder feeder. Also, a back pressure can be supplied on the powder funnel to increase the stability of the powder stream, which can be affected by the changes in the height of powders in the funnel. Adding the external component for the measurement of powder is an essential device for obtaining a feed rate with high precision. One of these devices can be a rotating disk with holes around it as shown in the figure below.

The feeder machine consists of a powder container from which powder flow by gravity into a slot on a rotating disk. The powder is transported to a suction unit by a gas stream. The dimensions of the slot and the speed of the disk control the volumetric powder feed rate.

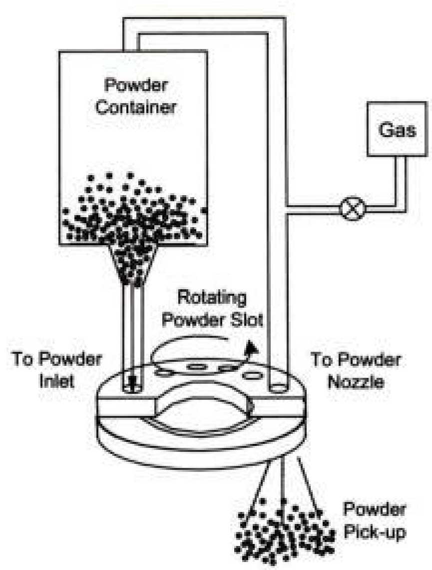


Fig: 1.2 Gravity based powder feeder with a rotating disk [34]

The other idea for integration of a metering wheel into a gravity based powder feeder is shown here. The size of holes around the rotating shaft and the angular velocity of the shaft determine the powder feed rate.

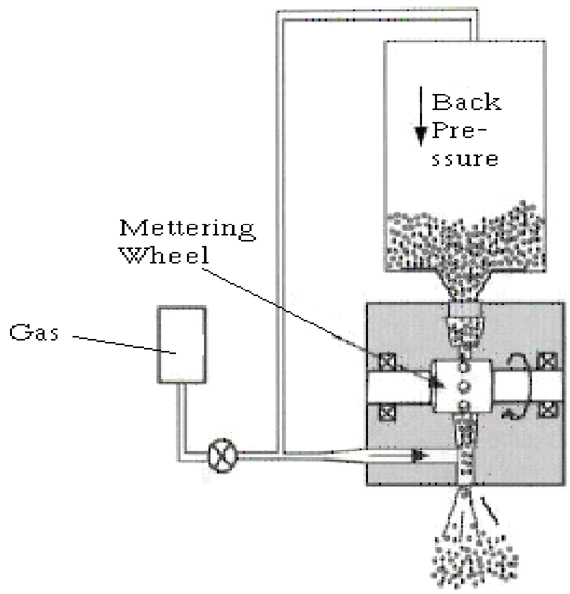


Fig: 1.3 Gravity based feeder with rotating wheel [34]

The other design can be an integration of a lobe gear with the gravity based powder feeder as shown below. This design is not suitable for an application requiring the low powder feed rate.

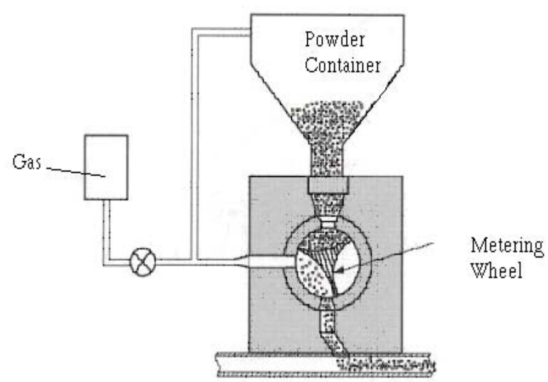


Fig: 1.4 A typical gravity based powder feeder with a lobe gear [34]

1.3.2 Mechanical Wheel Powder Feeder

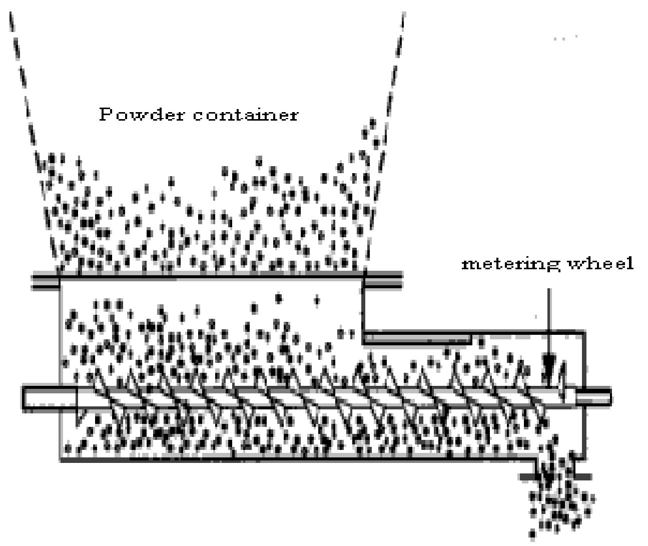


Fig: 1.5 A schematic of mechanical wheel powder feeder [34]

Mechanical wheel powder feeders are also known as screw powder feeders. Mechanical wheel feeders handle a wide range of powder with different mesh sizes. They do not seal against an uncontrolled flow of fine powders and normally operate with zero or low-pressure differential between outlet and inlet. A typical mechanical wheel feeder has a pitch with different diameter ratio or a rotor which can grab powder particles from the storage area. There are many screw configurations that can be used to promote uniform flow with different feed rates. One disadvantage of this type of powder feeder is the interaction of moving parts and abrasive powder particles, which cause rapid wear in the wheel. This can result in variations in coating quality and also increase maintenance costs.

1.3.3 Fluidized- Bed Powder Feeder

A fluidized powder feeder operates based on fluidics principle, which eliminates the need for mechanically moving parts to deliver powder. The fluidics powder feed delivery principle provides a continuous, non-pulsating feed of powder, thereby insuring the user optimum process control and improved coating quality. Another benefit is reduced maintenance and replacement part cost.

The system is designed so that a predetermined quantity of gas is delivered to a closed hopper containing powder. The hopper is constructed so that the gas is passed through a filter located at the bottom of the unit, where it is diffused through the powder, causing the powder to enter into the gas and therefore become fluidized. A powder pickup tube is positioned above the fluidizing gas inlet allowing the fluidized media to be delivered under a shed on the pickup tube through a number of controlled apertures and then to a carrier area where it is propelled by the carrier gas to the feed hose.

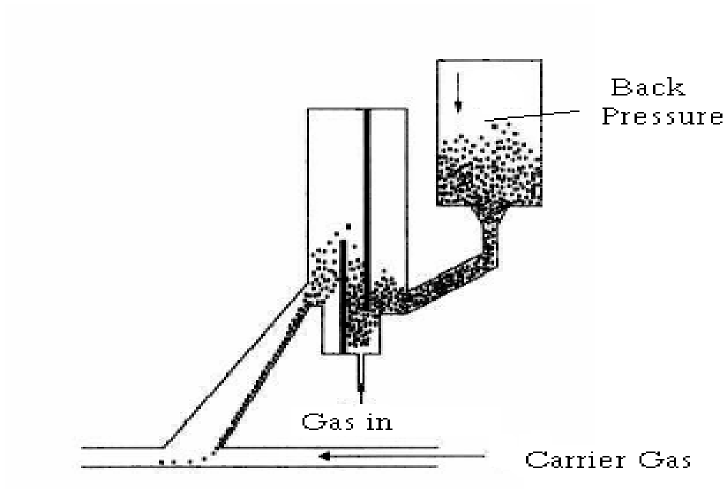


Fig: 1.6 A typical fluidized bed powder feeder [34]

1.3.4 Vibratory Based Powder Feeder

A vibratory feeder, which is also called a vibratory tray feeder or oscillating feeder, consists of a shallow flat bottomed tray. As powder flows from the hopper outlet onto the tray, an external drive vibrates the tray, throwing the powder down to control the feed rate into the process. A vibratory based powder feeder can feed most powder from at least 8 g/min to 2000g/min with ±1% precision.

In order to increase the precision, the vibratory powder feeder can consist of a vibratory tray with a number of plates set on specified angle. Having these plates, the flowing of bulk powder can be controlled.

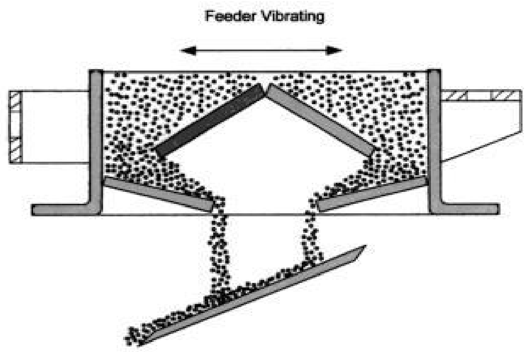


Fig: 1.7 Vibratory type feeder [34]

1.4 Criteria for Feeder Selection

No matter which type of feeder is used (volumetric or gravimetric), it should provide the following:

(1) Reliable and uninterrupted flow of material from some upstream device (typically a bin or hopper).

(2) The desired degree of control of discharge rate over the necessary range.

Often, plant personnel prefer a certain type of feeder because of experience (good or bad), availability of spare parts, or to maintain uniformity for easier maintenance throughout the plant. Such personal preferences can usually be accommodated, since in general, several types of feeders, provided they are designed properly, can be used in most applications.

The major considerations in deciding which type of feeder to be used are the properties of the bulk material being handled and the application. Table 1.1 and table 1. 2 below provide an insight into which of four common types of feeders is best suited to each of these areas.

1.5 Why Screw Powder Feeder

This invention concerns the uniform feeding of irregular and regular shaped powder material at low mass feed rates. There are many occasions on which solid powdered material has to be fed at uniform feed rates. These varying from pharmaceuticals and metal spraying to coal fired boilers and bulk food processing. In consequence numerous powder feeders are available based on a variety of principles, e.g. vibratory feeders, gravity, belt, rotary disc, and screw feeders.

Nearly all these feeders have problems with “bridging” of the powder particularly irregular or fine particles are fed. Screw feeders also suffer from blending, which is the rotation of material along with screw rather than fed. Providing a uniform powder flow particularly at ultra low feed rate is difficult because, whatever, the feeding mechanism, there is a conflicting mechanism for a small aperture to achieve a low feed rate and a critical aperture to prevent “ arching “of the powder coupled with the additional requirement of high rotary/vibratory speeds to eliminate cyclic effect. One object of the present invention is to provide a screw powder feeder which avoids, or at least reduces, screw “blinding” and “bridging” near the screw. The screw may then be rotated at higher speeds which in turn reduce the observable slubbing effects. Another object of the invention is to provide a feeder capable of uniform powder flow at lower feed rates than is possible with existing feeders. A still further object is to reduce the cost of the screw feeder

1.6 Screw Feeders Types.

Screw feeders are devices suitable for handling a wide variety of materials that have good floability characteristics. Screw feeders are well suited for use with bins having elongated outlets. These feeders have an advantage over belts in that there is no return element to spill solids. Since a screw is totally enclosed, it is excellent for use with fine, dusty materials. In addition, its fewer moving parts mean that it requires less maintenance than a belt feeder. Screw feeders come in a variety of types, with the most common using a single helicoidal or sectional flight screw shaft, which is a fabricated weldment. The key to proper screw design is to provide an increase in capacity in the feed direction [45]. This is particularly important when the screw is used under a hopper with an elongated outlet. One common way to accomplish this is by using a design as shown below [42]:

1.6.1 <u>Conical Shaft Screw</u>

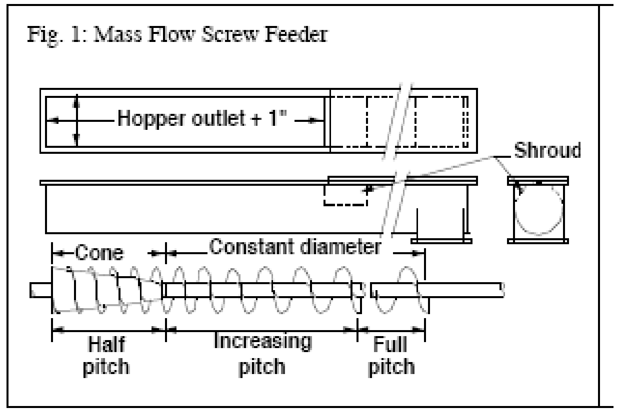
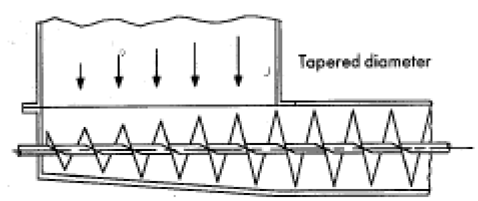


Fig: 1.8 Conical shaft screw [42]

Uniform discharge through the hopper outlet opening is accomplished through a combination of increasing pitch and decreasing diameter of the conical shaft. Approximate capacities of various size screws are given in table below [42].

1.6.2 <u>Tapered diameter screw</u>



<u>Fig: 1.9 Tapered diameter screw [46]</u>

It is not recommended for most materials because the narrow back end is prone to having arches over it, besides it is difficult to properly fabricate the screw [46].

1.6.3 Tapered shaft and variable pitch

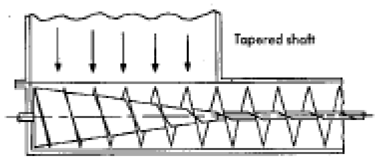


Fig: 1.10 Tapered shaft and variable pitch [46]

Poor fabrication tolerances are a frequent problem the consequence is high power consumption and poor flow. Also, it is a quite expensive configuration [46].

1.6.4 Variable pitch

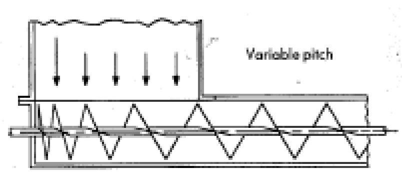


Fig: 1.11 Variable pitch [46]

The minimum pitch must be not less than one half the screw diameter the maximum pitch approximately one screw diameter .

1.6.5 Constant pitch

A constant pitch in the feed section is different from the constant one in the conveying section is a very cheap and common solution. Typically:

P= 2/3* D in the feed section, P=D in the conveying section [46].

1.6.6 Combination of b) – c) –d)

1.7 Design Guidelines For Screw Feeder

A number of guidelines useful in designing screw feeders for optimum performance have been developed over the years. A non proper design and selection of this device, which is present in large part of industrial processes, could mean poor performances, excessive power, and severe wear of plant and degradation of the conveyed material. In the past the performance of screw feeders has been based either on a semi-empirical approach (C.E.M.A.-like procedure) or on experimental studies using dynamic similarity to predict the performance of geometrically similar screws [42].

1.7.1 Flow, Speed and dimensions.

Calculation of the nominal flow can be done once the screw geometry, its rotation speed and the filling coefficient are known. The flow rate of a screw conveyer or feeder depends on a number of interlinked factors, like: [46]

(1) Geometry of the screw.

(2) Rotation speed.

(3) Flowability of the material.

(4) Geometry of the feed hopper and tube.

The risk of backflow increases with the inclination. There are several methods to increase screw capacity with length and to reduce the necessary starting torque [46].

1.7.2 <u>Tolerance</u>

Pitch tolerance is specified to the manufacturer and is being met.

In order to minimize problems with pitch tolerance, a good rule of thumb, when using mass flow screws having a tapered shaft and a variable pitch, is to limit the length of the screw under the hoper outlet to no more than about six times the screw diameter. Stepped shaft diameter mass flow screw can have lengths under the hopper outlet of up to 12 times the screw diameter [42].

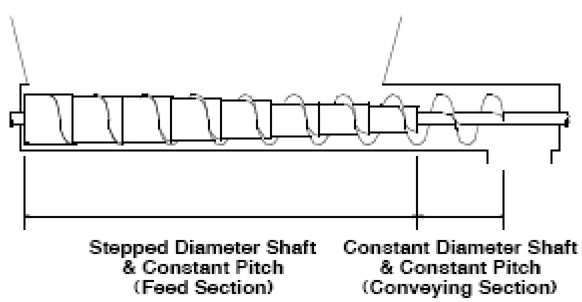


Fig: 1.12 Stepped shaft Diameter Mass Flow Screw [42]

1.7.3 Use a U-shaped trough.

This provides control of the flow pattern in the hopper, which is usually not possible with a V-shaped trough because the latter's shallow sides tend to hold up material.

1.7.4 Limit on Hopper outlet

Use a bolted flanged connection and size the hopper outlet width equal to the screw diameter. (Note: This dimension must be large enough to prevent arching of the material over the hopper outlet.) With screws designed to CEMA (Conveyor Equipment Manufacturers Association) specifications, the inside dimension of a U-shaped trough is one inch larger than the screw diameter. Therefore, sizing the hopper outlet width equal to the screw diameter allows a nominal half-inch increase in the inside dimension of the trough. This minimizes the possibility of a ledge, which could hold up material in the hopper at this point [42].

1.7.5 Speed of screw

Keep screw speed between roughly 2 and 40 rpm. Below 2 rpm, the discharge from the end of a screw is irregular, and the cost of the reducer becomes excessive. Above 40 rpm, screw efficiency decreases, causing increases in the power required to operate the screw, abrasive wear on the screw flights, and particle attrition [42].

1.7.6 Position of bearings

Use only end bearings to support the screw. Internal hanger bearings are troublesome because a mass flow screw feeder operates between 90% and 100% full. Thus, a hanger bearing becomes immersed in material and wears out quickly. It also provides an impediment to material discharge and thereby upsets the mass flow pattern desired in the hopper section. Using only end bearings avoids these problems, but the length of the screw becomes limited by deflection of the screw between the end bearings. As a practical matter, screw lengths are typically limited to approximately 12 ft. unless an extra-strong shaft is used to support the screw.

1.7.7 Material

Use rugged materials of fabrication. Stainless steel and carbon steel are typically used for most industrial applications.

1.7.8 Surfaces

Choose a smooth surface finish on the screw flights, the surface finish on the trough should be rough. Extend screw flights no more than one inch over the discharge opening [42].

1.8 GEOMETRY OF THE SCREW

Powder feeders can be based on various working principles as discussed in the previous chapter. In flowability of powder different powder feeders are required for each type of powder. For example, the required powder feed rate for thermal spraying can be relatively large, whereas the required powder feed rate for prototype by laser cladding is relatively small. Therefore, a powder feeder machine needs to be carefully controlled in order to ensure that a stable powder stream with a desired feed rate is generated.

Selection of a suitable powder feeder is a vital factor for a successful laser cladding process. A powder feeder should provide a continuous and uniform powder stream with high accuracy in terms of flow rate at a desired feed rate. It is crucial to control the feed rate in real time with minimum time constant. Also in a laser cladding process, particular attention has been given to minimizing pulsations and agglomeration and the powder feeders in the market can not provide a low time constant (e.g.,0.5seconds) and low powder feed rate at high precision (e.g.,0.1g/min) which are two important parameters in the laser cladding technology. For this reason special powder feeders with different control strategies have been designed and introduced.

Also, researchers are developing feeders for ultra fine powders to arrive at a continuous stream with low feed rate. These powder feeders are vibration based or pressure assisted feeders, which can even be used in direct wire deposition.

Feeders differ from conveyors in that the latter are only capable of transporting material, not modulating the rate of flow. Dischargers are also not feeders. Such devices are sometimes used to encourage material to flow from a bin, but they cannot control the rate at which materials flows. This requires a feeder [34].

1.9 SCREW DESIGN PARAMETERS

Dispensing any material onto a substrate has two basic requirements:

(1) Applying the material to the exact location required.

(2) Dispensing a dot of exact volume.

The amount of material dispensed depends upon the following:

(1) Pitch of threads. The quantity of material dispensed decreases in decrease in pitch [35].

(2) Depth of cut. The quantity of material dispensed increases with an increase in depth of cut [35].

(3) Type of threads.

(4) Length of screw.

(5) The number of starts.

(6) Angle of rotation of the screw.

As a result, it is extremely important to understand the screw parameters, the screw-nozzle combination and the operating conditions that maximize production [35].

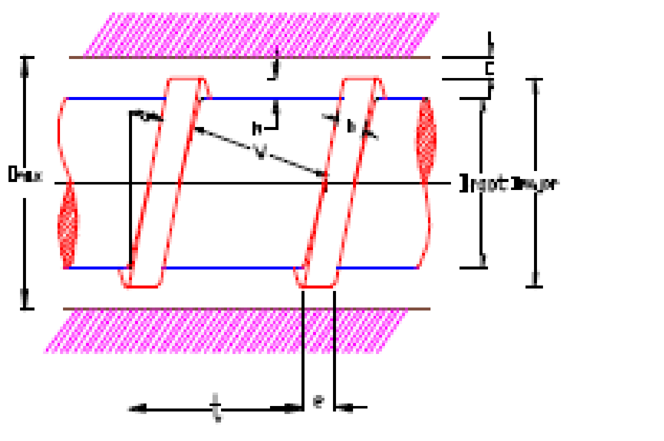


Fig: 1.13 Screw design parameters [35]

1.10 Pitch of Thread (t)

This is defined as the distance between two consecutive threads [36]. A low value of pitch, i.e., small value of thread/inch, reduces the effective surface area of contact. This reduced surface area of contact causes a reduction in pressure build-up as compared to a screw with a greater number of threads/inch. A high pitch causes excessive material to be fed between the threads than the nozzle can handle and, hence, increase the backpressure. This, in turn, reduces the amount of material dispensed as it counteracts the pressure developed to dispense it.

1.11 Depth of Cut

The amount of material dispensed is directly proportional to the depth of cut, up to a certain point, depending upon the nozzle ID. For a given nozzle ID there is an optimum value for the depth of cut to minimize back-pressure. Hence, to maximize the amount of material dispensed through a nozzle, it is necessary to determine the optimum depth of cut of a screw [35].

1.12 Type of Thread

Square threads have sharper edges as compared to angled threads such as the British Standard Whitworth. The square threads can possibly cause excessive shearing and, hence, increase separation [35].

1.13 Number of Starts

The number of starts determines the distance moved by the material in one rotation of the screw. For a single threaded screw, the distance moved by the material in one rotation is equal to the pitch of the screw; whereas, for a double threaded screw, the distance moved by the material in one rotation is twice the pitch. Hence, the quantity of material dispensed by a double threaded screw is greater than a single threaded screw for the same amount of turn [35].

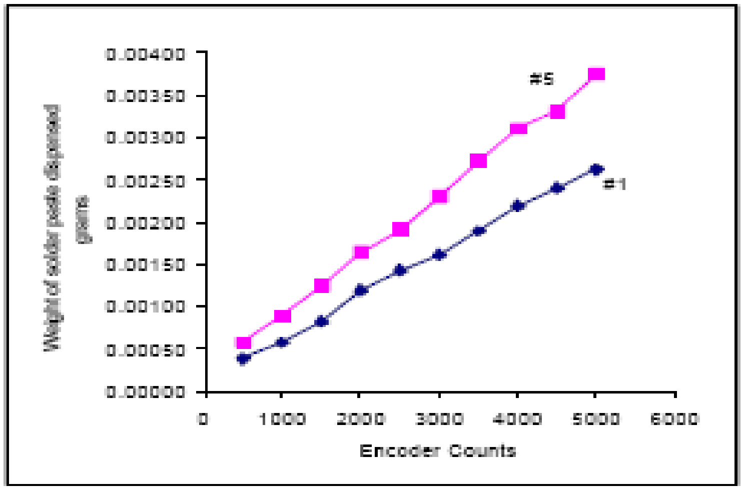


Fig: 1.14 Effect of no of starts on weight dispensed.[35]

1.14 <u>Comparison of single start/double start and depth of cut</u>

To analyze the effect of the above-mentioned parameters, eight screws with variation in the depth of cut, and number of starts were designed. For the first four screws, the depth of cut is increased keeping the same number of starts (see Table 3.1). For the next four screws, the number of starts is doubled with the same values of depth of cut. The pitch of the screws is constant.

Table: 1.1 Variation in dimensions of the screws

Code	Number of Starts	Depth of cut (mils)
1	Single	10
2	Single	15
3	Single	20
4	Single	30
5	Double	10
6	Double	15
7	Double	20
8	Double	30

For unrestricted flow, (i.e. without a nozzle) the weight of material dispensed increases with an increase in the depth of cut and angle of rotation; Figure 3.3 validates the conjecture.

In performing the same type of experiment with a 16-mil nozzle ID, interesting results are obtained (see Figure 3.4). While Screw #2 and Screw #3 performed differently under unrestricted flow, Figure 3.4 indicates that, with this restriction, an increase in depth of cut does not significantly increase the quantity of dispensed material. This trend seems to also be manifested in the comparison of Screws #6 and #7. Another interesting result concerns the comparison between Screws #6, #7, and #8 (the double start screws) in Figure 3.4. Since Screw #8 has the largest depth of cut, one may expect that it would dispense the largest quantity of solder paste. While this is evidenced for unrestricted flow, it is not the case with a 16-mil nozzle restriction. In fact, Screw #8 at the higher encoder counts dispensed a smaller quantity of solder paste than Screws #6 and #7.

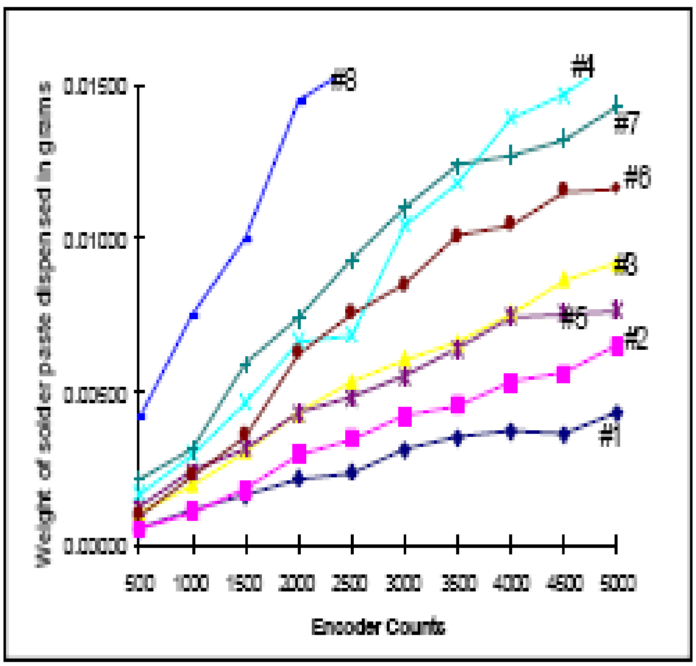


Fig: 1.15 Effect of depth of cut on weight of material dispensed for unrestricted flow[35]

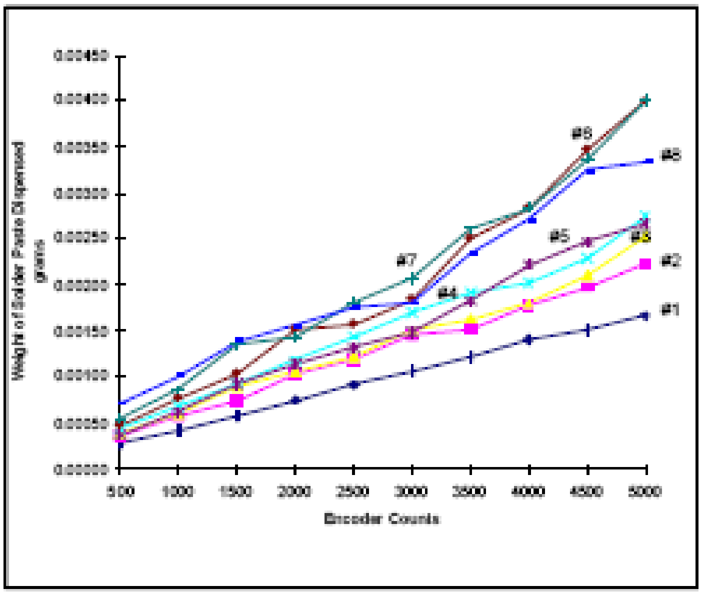


Fig : 1.16 Effect of depth of cut on weight of Material dispensed with a 16 mil ID [35]

1.15 FLOWABILITY OF THE MATERIAL

Powder properties and screw conveyor design influence the flow properties of a screw conveyor. Studies shows that different powder properties like particle size, bulk density and particle shape have a large influence on screw capacity. Coarse powders will flow into the screw easier than fine powders. The screw capacity will also be higher if a dense powder is used. Particle with a round shape have lower internal friction that results in a greater screw capacity. It was also shown that the Hausner ratio, assessed from tapped and apparent density and angle of repose are effective methods to determine the free-flowing properties of the powder. The aim is to identify different powder properties and screw design that influences the flow properties of the screw conveyor. Different powder properties can be used to identify if powder is free flowing or not [31].

1.16 <u>Typical Fine Powder Flow Problems</u>

Many bulk solids exhibit one or more of the following problems.

(1) No flow due to arching or ratholing.

(2) Particle segregation.

(3) Limited live or useable capacity (usually the result of a ratholing problem)

(4) Degradation (spoilage, caking, oxidation) which is usually the result of a first-in-last-out flow pattern.

(5) Structural failure of bins due to loads being applied to them which they were not designed to withstands.

1.17 Particle shape

Particle shape has a large influence on flow properties. A group of spheres has minimum inter-particle contact and generally optimal flow properties, whereas a group of flakes have a very high surface-to-volume ratio and poorer flow properties [33].

1.18 Size of Powder Particle

The screw capacity is greater for coarse powders than for fine due to the differences in floability. Fine particles have large specific surface area and are more cohesive than coarse particles. If the powder is more cohesive, it is not free flowing. A coarse powder will be freer flowing than a finer powder and will thus flow more easily into the screw.

It implies that use of powders with low internal friction (round powder-Fe6,8Si) will result in greater screw capacity than obtained with powders with higher internal friction.

The clearance and the free length of intake have a large influence on screw capacity. No correlation was found between conveying length and conveyor capacity.

The higher the surface area to volume ratio, the more propensity a powder particle has to cling to another particle rather than to fall away under the influence of gravity, reducing the ability of the powder to flow.

1.19 Hausner ratio

The Hausner ratio is a number that is correlated to the flowability of a powder or granular material. It is calculated by the formula,

$$H = \sigma_{T/}\sigma_{B}$$

Where, δ_B = freely settled bulk density of the powder,

δ_T = tapped bulk density of the powder.

The Hausner ratio is not an absolute property of a material; its value can vary depending on the methodology used to determine it. A Hausner ratio greater than 1.25 is considered to be an indication of poor flowability. [56].

1.20 Bulk Density (Apparent density)

Bulk density was determined by filling the powder through a standardized funnel into a small cup, leveling-off the surplus powder on top of the cup and dividing the weight of powder contained in the cup by the cup volume [32].

Bulk density is one of the most important parameter for screw capacity since the screw has a fixed volume. The higher the bulk density of a powder the more mass of the powder can be introduced into the screw. It means that powders with large bulk density will have a largest screw capacity than obtained with powders with a low bulk density.

1.21 Angle of Repose

For measuring the drainage of powder angle of repose is used. The angle of repose, also referred to as angle of friction, is an engineering property of granular materials. The angle of repose is the maximum angle of a stable slope determined by friction, cohesion and the shapes of the particles. When bulk granular materials are poured onto a horizontal surface, a conical pile will form. The internal angle between the surface of the pile and the horizontal surface is known as the angle of repose and is related to the density, surface area, and coefficient of friction of the material. Material with a low angle of repose forms flatter piles than material with a high angle of repose. In other words, the angle of repose is the angle a pile forms with the ground [55].

Fig: 1.17 Angle of repose [55]

Iron powders have different angles of repose, see table 4.2. A comparison between angle of repose and screw capacity, figure 4.2 for different iron powders shows that powders with low angle of repose get a higher screw capacity than powders with a high angle of repose. It was expected because powders with a low angle of repose flow more easily into the screw [33].

Table: 1.2 Angle of repose as an indication
Of powder flow properties [31]

Angle of repose	Type of flow
Less than 20	Excellent
20----30	Good
30 ---- 34	Passable
Greater than 40	Very poor

Figure 1.18 shows how mass flow depends on screw velocity for different iron powders.

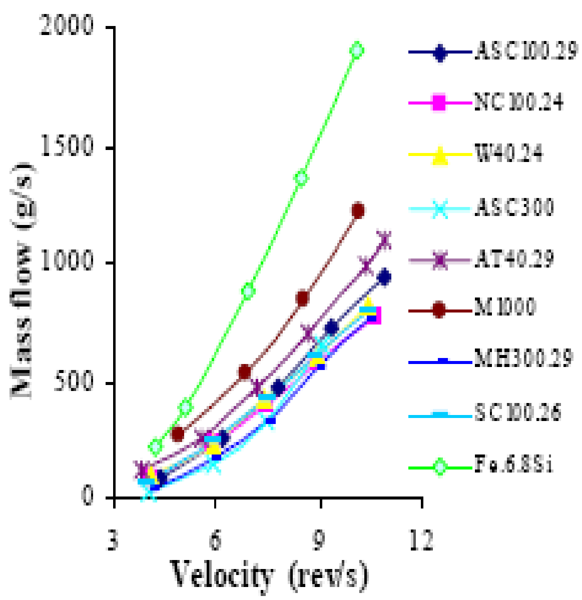


Fig: 1.18 Mass flow for some different iron powder [33]

1.22 Fundamentals of Laser

There is nothing mysterious about a laser. It is just another type of light source with unique properties that make it a unique light source, but these properties can be understood without knowledge of complicated mathematical technique. A laser is a device that amplifies light and produces a highly directional, high intensity beam that most often has a very pure frequency or wavelength. It comes in sizes ranging from approximately one tenth of the diameter of a human hair to the size of a very large building, in powers ranging from 10^{19} to 10^{20} Watts, and in wavelengths ranging from microwave to the soft X- ray spectral regions with corresponding frequencies from 10^{11} to 10^{17} Hz. Laser have pulse energies as high as 10^{4}J and pulse duration as short as 5×10^{-15} seconds. They can easily drill holes in the most strong of materials and can weld detached retina within the human eye. They perform heat treatment of high strength materials, such as the piston of our automobile engines, and provide a special surgical knife for many types of medical procedures. What a remarkable range of characteristics for a device that is only its fifth decade of existence.

The word laser is an acronym for Light Amplification by simulated Emission of Radiation. The laser makes use of processes that increase or amplify light signals after those signals have been generated by other means. These processes include stimulated emission, a natural effect that was deduced by considerations relating to thermodynamics equilibrium, and optical feed back (present in most lasers) that is usually provided by mirrors.

Thus in its simplest form, a lasers consists of a gain or amplifying medium (where stimulated emission occurs), and a set of mirrors to feed the light back into the amplifier for continued growth of the developing beam.

There are three different types of lasers,i.e, Co_2, Nd-Yag and diode lasers.

1.23 What is laser cladding

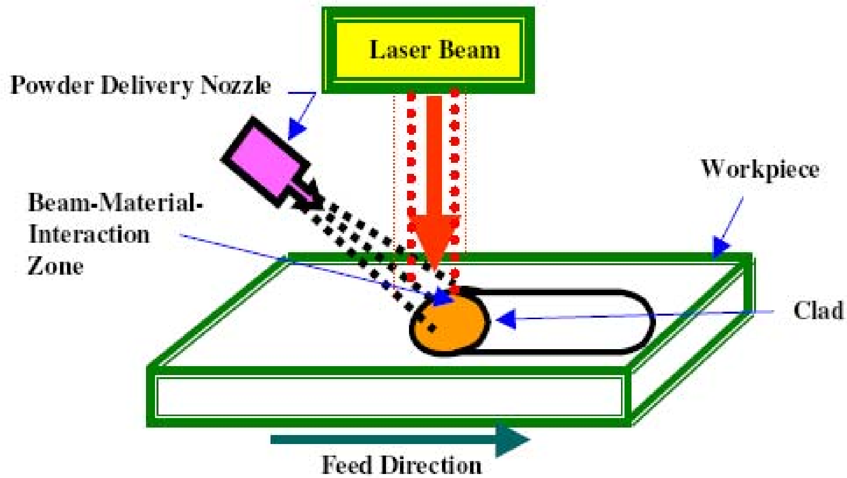


Fig 1.19: Typical Laser cladding

Laser cladding is an advanced material processing technology that has potential to deposit various materials locally on highly non-planar and complex surface. It can be used to refurbish or improve corrosion, wear and other surface related properties of components. Laser cladding is performed to improve the surface properties using an ordinary cheap base material for the surface that is not being exposed to high loads.

Laser cladding is considered as strategic technique, since it can yield surface layers that, compared to other hard facing techniques, have superior properties in terms of pureness, homogeneity hardness, bonding and microstructure. [2].

Laser cladding consists of three main functions. First is the phenomenon of cladding itself, the second is the development of tools that facilitate the use of laser cladding. The third part consists of development of practical applications. Some aspects of these will be discussed in brief while main effort of this thesis remains on the fabrication of mechanical powder feeder [2]. Some typical applications of laser coatings are:

- Shafts, rods and seals.
- Valve parts, sliding valves and discs.
- Exhaust valves in engines.
- Cylinders and rolls.
- Pump components.

- Turbine components.
- Wear plates.
- Sealing joints and joint surfaces.
- Tools, blades.
- Moulds.

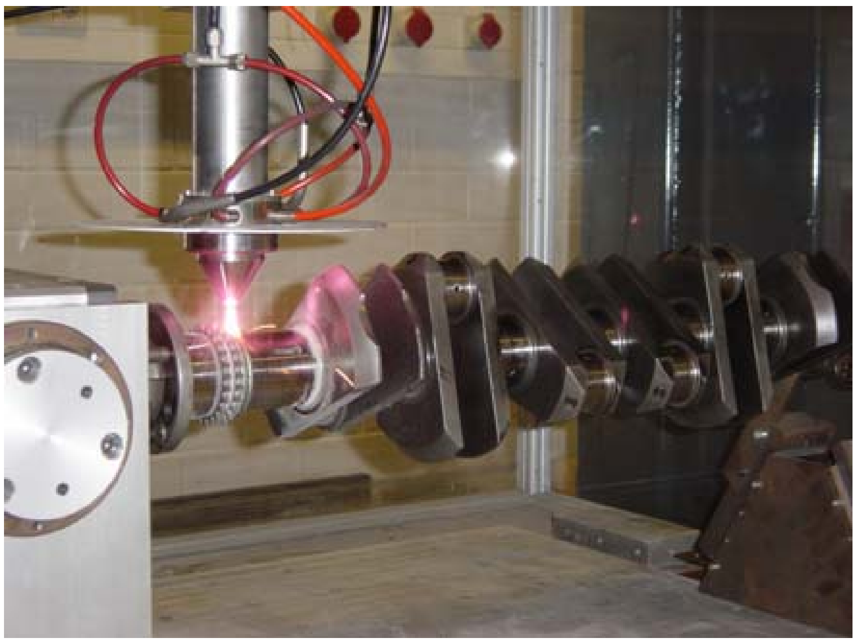


Fig : 1.20 Repair of car engine crankshafts

Fig : 1.21 Engine valve

The deposited materials can be transferred to the substrate by several methods. These are:

(1) Powder injection.

(2) Pre-placed powder on the substrate.

(3) Wire feeding.

1.24 <u>Laser cladding methods</u>

Two material application principles can be distinguished. The two stage (pre-placed) technique and the one stage technique. These two methods are both used in practice. The coating material is predominantly supplied in the form of powder particles.

1.24.1 <u>Two stages process</u>

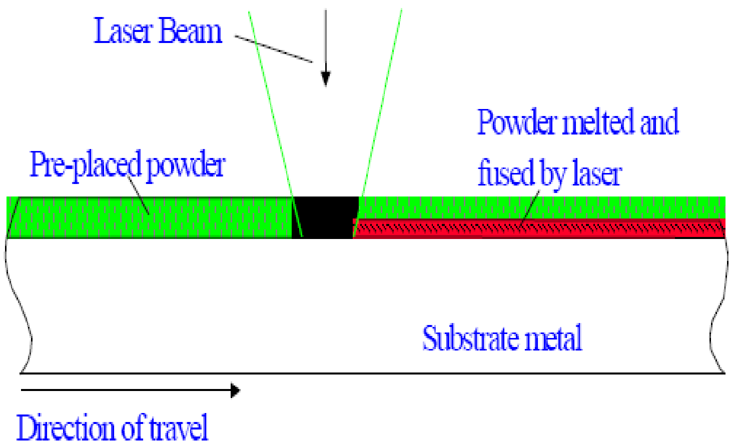


Fig 1.22 : Pre-placed powder technique Method

The two stage methods are particularly useful for parts that can be treated in one single track. It is of course possible to apply several adjacent tracks, but this will result in an increased dilution. Before the first clad track is produced, the entire area is covered by the pre-placed material. A part of the coating is molten by the laser beam. After passing of the beam, the molten material contracts due to surface tension. Hence, the substrate area directly next to the produced clad layer is not covered with pre-placed material anymore. When the next track is made, the non covered part of the substrate is directly irradiated by the laser beam. Deeper melting of the substrate will occur in this area.

1.24.2 <u>One Stage Process.</u>

The one stage process starts with the formation of a melt pool in the substrate. Simultaneously, coating material is fed into this pool and melts; a strong fusion bond between coating material and substrate is achieved immediately.

(1) <u>Injected Powder Method</u>

Powder efficiency of lateral is more than co-axial. It has the following advantages.

- Well-defined treated region.
- Low dilution.
- Good fusion bond.
- It is easy to blend powder with a

- Desired composition.
- High reproducibility.
- Used for several adjacent tracks.
- Melt depth is easier to control.
- Porosity is less likely to occur.

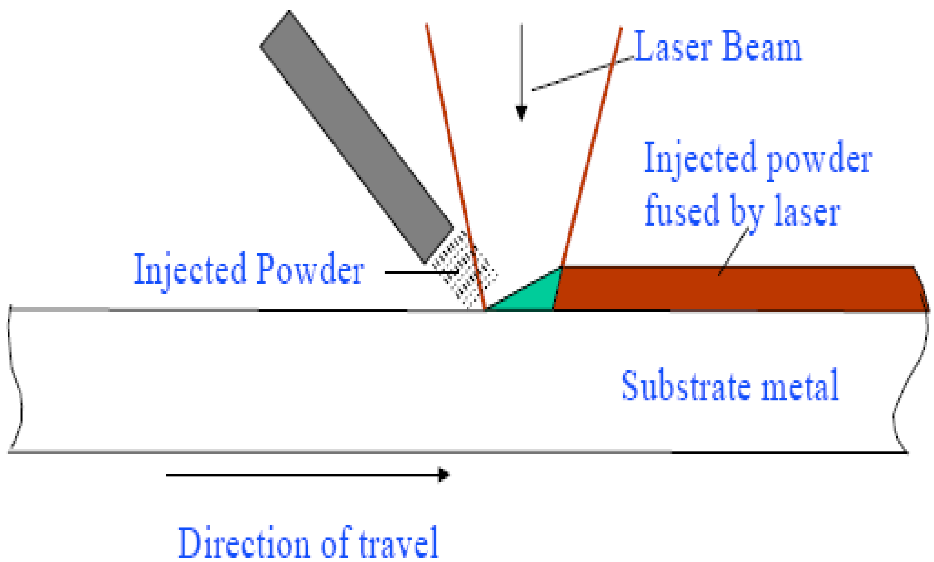


Fig:1.23 : Injected powder technique Method

(2) <u>Wire Feed Method</u>

In laser cladding with fire feed technique the clad material in the form of wire is fed into the interaction area under the laser and is fused to the substrate. The advantages of this technique include its relatively clean working environment, and the clad material is fully used.

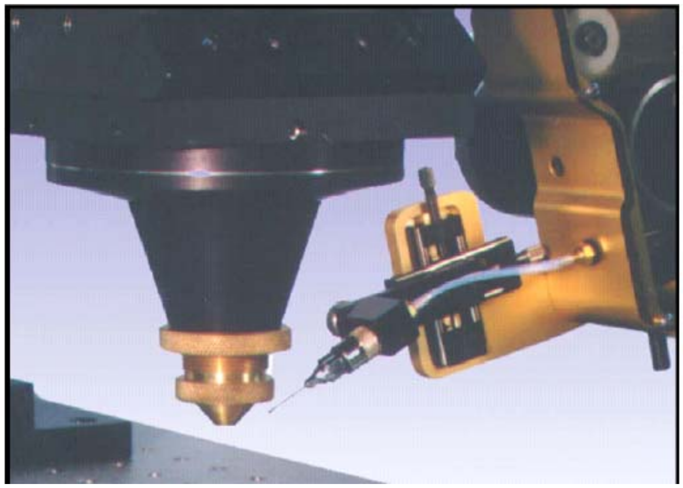


Fig 1.24: Wire Feed Method

1.25 Advantages of Laser Cladding

Following are the main advantages of laser cladding.

- 100% metallic adhesion, no chance of coating coming loose.
- Both simple and special, high quality coatings are available.
- Very local application.
- Small total heat contribution, no deformation.
- Contact free, no forces are exerted on the work item.
- Process depth is well defined.
- Environmentally friendly process.
- Superior properties.
- No porosity.
- Homogenous distribution of the elements.
- Excellent control of the layer thickness.
- Controlled minimum mixing.
- Less part distortion.
- Narrow heat affected zone.

1.26 Energy Distribution During CO2 Laser Cladding

By theoretical calculation and experimental work it has been possible to identify how much of the original laser energy contributes to the laser process and how much is lost to the surrounding environment by reflection, radiation, convection etc. while using the blown powder cladding process.

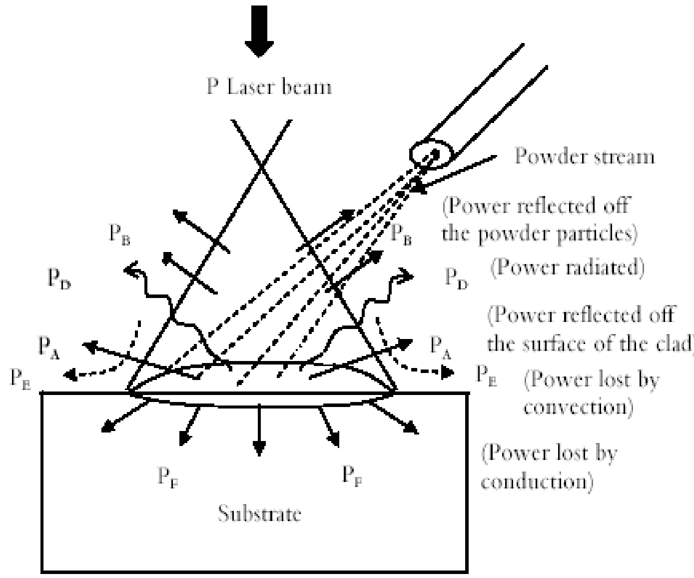


Figure: 1.25 : The redistribution of laser power during the cladding process

An energy balance for laser cladding can be expressed as follows:

$$P_{tot} = P_C + P_L \text{…………… (1)}$$

Where:

P_{tot}= The output power of the laser

P_C= The power utilized in melting the cladding material and welding it to the surface of the substrate

P_L= The power lost by reflection, radiation, convection etc.

P_C in eqn (1) can be expanded as follows:

$$P_C = P_p + P_s \text{ ………………… (2)}$$

Where:

P_p = the power utilized in melting the cladding powder.

P_s= the power utilized in melting the surface of the substrate in order to achieve a clad/substrate weld.

P_L in eqn (1) can be expanded as:

$$P_L = P_A + P_B + P_D + P_E + P_F + P_G \text{……………….. (3)}$$

Where:

P_A= Power reflected off the surface of the clad zone.

P_B = Power reflected off the powder particles as they approach the weld pool.

P_D= Power lost by radiation from the cladding zone.

P_E= Power lost by convection from the cladding zone.

P_F= Power lost by conduction from the clad zone to the substrate.

P_G= Power absorbed by the powder particles which do not enter the cladding melt pool.

Fig 1.7 gives a visual representation of eqn 3.These losses are to some extent necessary. Any influence which could minimize terms in eqn 3 would increase the efficiency of the cladding process.

The aim of commercial cladding is to cover the surface of one metal with another at the lowest cost. Clad depths are usually stipulated and the biggest cost element of the process is laser time.

Therefore the simple aim of commercial cladding can be expressed as follows:

- To cover metal A with a known thickness of metal B at the fastest possible rate with a high quality interfacial bond.

Returning to eqn2 it is clear that the process can be speeded up if there is an increase in the laser power available for melting the cladding material P_p.

The requirement here would be to melt enough powder to achieve the correct clad thickness at a faster linear speed. Also an increase in P_s must not be employed to melt the substrate to a greater depth.

To summarise:

- The efficiency of laser cladding could be improved by minimizing any of the losses in eqn3. This would lead to an increase in P_c and the process could be accelerated to produce the same clad depth with a minimal depth of substrate melting.

1.27 <u>Specific energy delivered to the interaction zone</u>

The layer thickness increases with the powder feed rate. Similarly, an increase in laser power increases the deposit thickness as shown. With increasing traverse speed, the layer thickness decreases.

The observed phenomenon can be related to the specific energy being delivered to the interaction zone, which is defined as follows:

SE = LP/ (BD)(TS) …………………………

where SE is the Specific Energy, LP is the Laser Power, BD is the Beam Diameter and TS is the Traverse Speed. A higher specific energy would lead to a greater amount of powder being fused and hence a thicker layer of material [57].

1.28 Dilution

Hardness is inversely proportional to dilution. The dilution of the clad layer into the substrate depends on several factors:

- The thermal conductivity of the substrate material.
- Initial temperature of the substrate.
- Powder flow rate.
- The interaction time of the powder in the beam and laser power.
- Power value of laser. For large value the melting of substrate is more and hence more dilution.

1.29 Defect in laser cladding

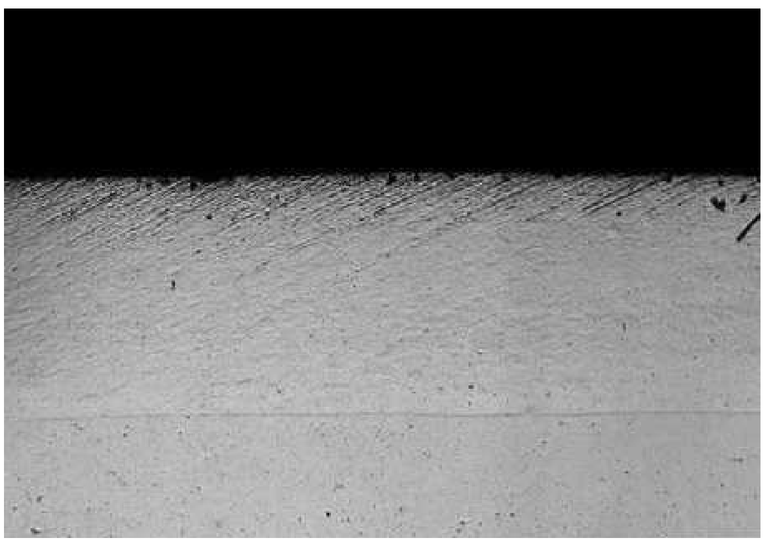


Fig : 1.26 : Defect free clad

Fig : 1.27 : Crack in the clad layer

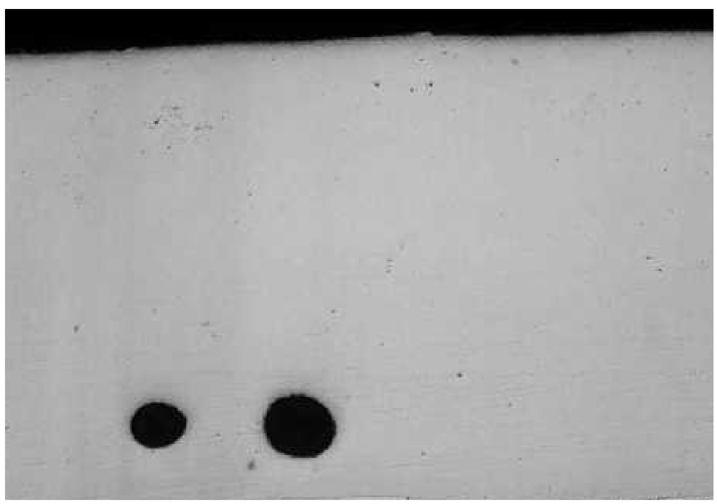


Fig : 1.28 : Porosity in the clad layer

Chapter- 2

Experimental Procedure

2.1 Design No -1

In the first design a plate was placed above the screw in the hopper. A hole of 12mm diameter was made in the plate toward the inlet (Driven side). The outlet was made in the bottom of feeder toward the opposite end. The gas pressure was given in the exit pipe just below the outlet opening. The feed rate was not consistent and flow of powder was in jerks in this design. Design Parameters kept for this design are:

a. Dia of screw = 12 mm
b. Length of Screw = 150 mm
c. Pitch = 1 and then tested for 2 mm
d. Depth of cut = 0.2 and then 0.5 mm
e. No of starts = Single and then double.

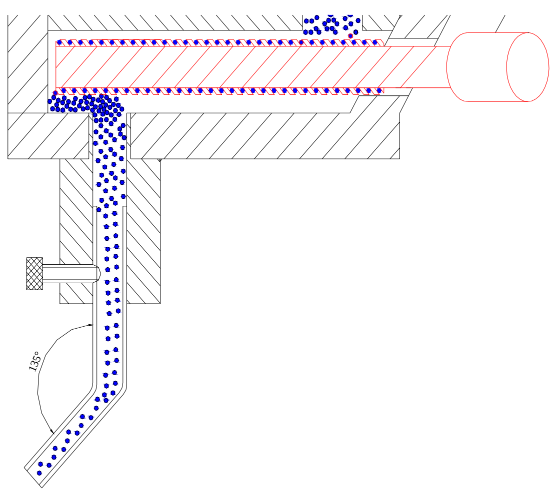


Fig: 2.1 Design NO 1

2.2 Design No -2

It was felt in the above design that the inconsistency of flow could be because of improper flow towards the inlet hole. The flow was directed towards the inlet by making slope, at an angle of 30^0, in the hopper. Even with this modification the flow was in pulses. The same design parameters were repeated.

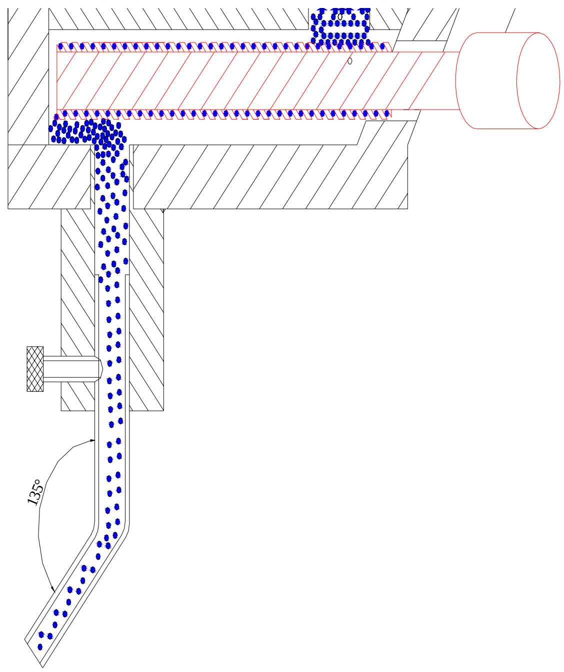


Fig: 2.2 Design No 2

2.3 Design No-3

In this design the powder was fed at the other end of the feeder. The screw was protruded in the channel on the opposite side. The gas pressure was given just above the top of chamber where the powder is being fed. Even with this design the consistency of powder feeding was not obtained.

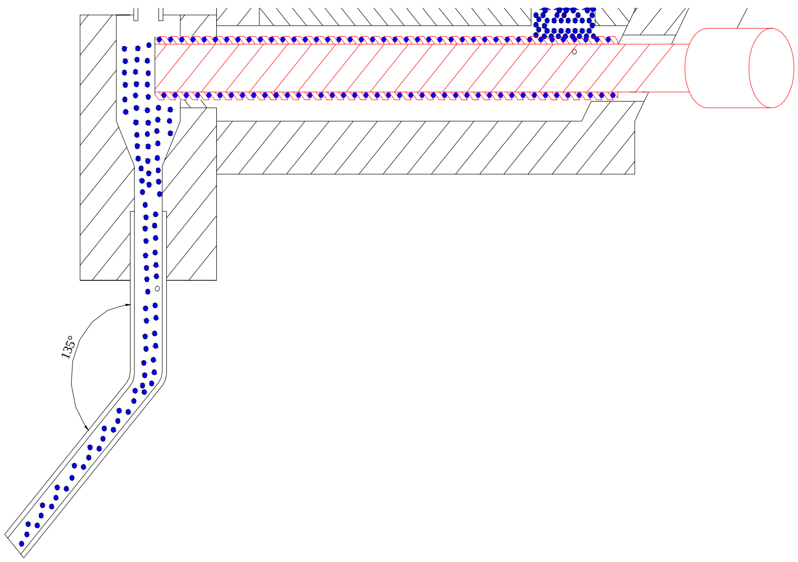


Fig 2.3 Design No 3

2.4 Design No-4

In this design the gas pressure line was protruded below the screw, thus creating a non turbulent region. The metered quantity of powder is then entrained into the gas flow as it falls toward the base of the chamber. A low uniform flow rate is achieved by suitably balancing the gas pressure inside the hopper against the gas pressure in the chamber. This is achieved by pressurizing the hopper through a pressure regulator connected in a pressure equalizing line which branches from the delivery line at a T-junction upstream of the chamber. The powder flow is also controlled independently of the conveying gas flow by varying the screw rotation speed.

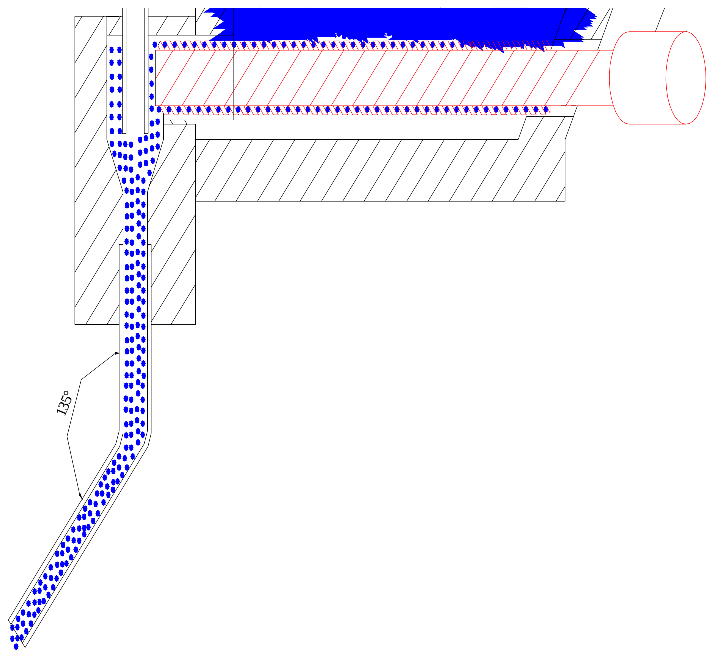


Fig: 2.4 Design No 4

2.5 Main parts of the Project

It consists of the following parts.

2.5.1 **Screw:**

Following two materials were used for screw:

(1) Stainless Steel

(2) Aluminum

2.5.2 **Gravity Feed Hopper**

(1) Mass flow type.

(2) Outlet is rectangular.

(3) Gas supply is given sufficient enough to break down the static arching of the powder at the outlet aperture.

(4) Funnel effect is given, to facilitate the flow on the screw.

2.5.3 **Motor.**

(1) A simple DC motor has a coil of wire that can rotate in a magnetic field. The current in the coil is supplied via two brushes that make moving contact with a split ring. The coil lies in a steady magnetic field. The forces exerted on the current-carrying wires create a torque on the coil.

(2) 12 volts dc motor

2.5.4 **Transformer**

A transformer is an electrical device that takes electricity of one voltage and changes it into another voltage. You'll see transformers at the top of utility poles and even changing the voltage in a toy train set. Basically, a transformer changes electricity from high to low voltage using two properties of electricity. A step down transformer is used here which reduces 220 volts to 12 volts.

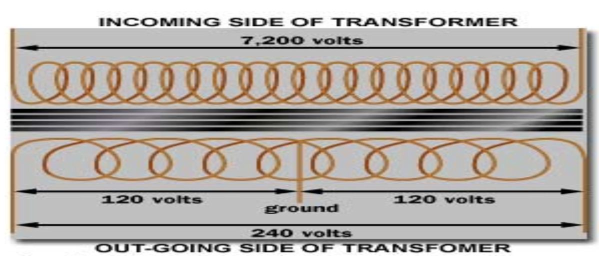


Fig: 2.5 Transformer basic structure

2.5.5 Potentiometer

A potentiometer is a manually adjustable resistor. The way this device works is relatively simple. One terminal of the potentiometer is connected to a power source. Another is hooked up to ground (a point with no voltage or resistance and which serves as a neutral reference point), while the third terminal runs across a strip of resistive material. This resistive strip generally has a low resistance at one end, its resistance gradually increases to a maximum resistance at the other end. The third terminal serves as the connection between the power source and ground, and is usually interfaced to the user by means of a knob or lever. The user can adjust the position of the third terminal along the resistive strip in order to manually increase or decrease resistance. By controlling resistance, a potentiometer can determine how much current flow through a circuit.

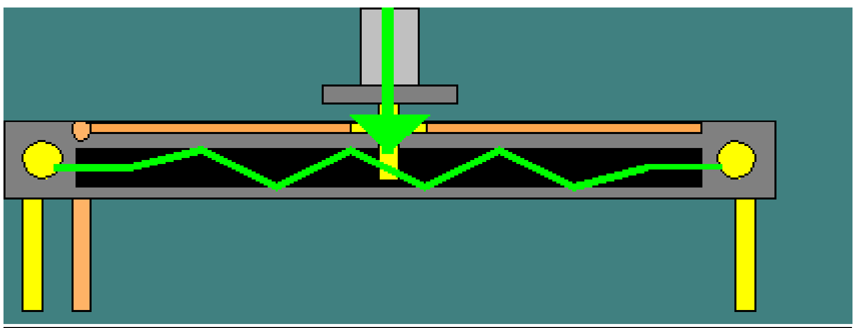


Fig:2.6 Schematic diagram of potentiometer

2.5.6 Capacitors.

Two capacitors have been used in the design.

A capacitor consists of two plates separated by an insulating medium known as a dielectric. A capacitor is a device, which stores an electrostatic charge.

2.6 Final Design

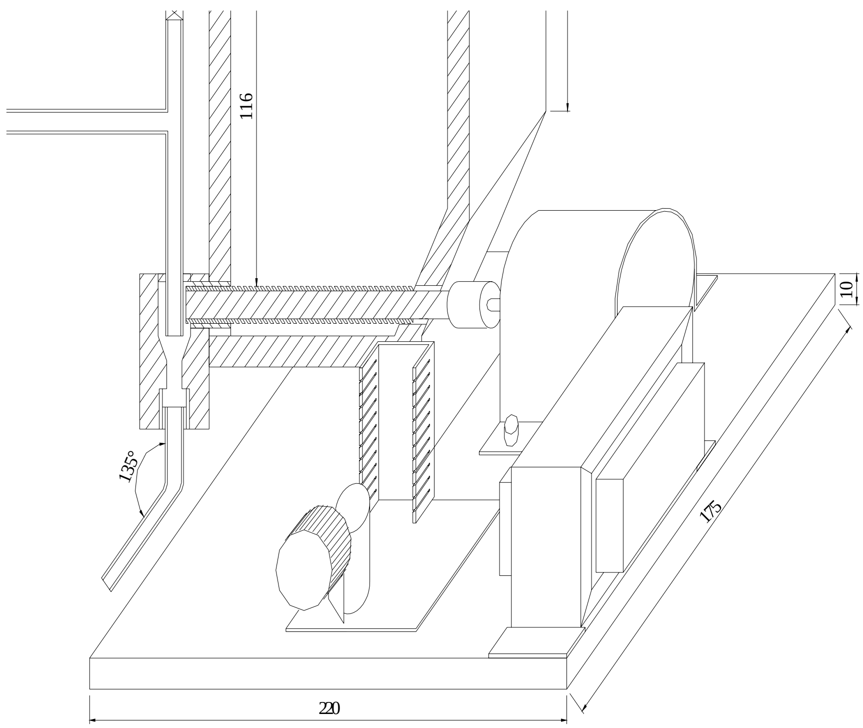


Fig : 2.7 Final Design

The objective of this thesis is to fabricate a powder feeder feeding at different rate. The feeder include a gravity feed hopper and the feeding of powder, which do not flow smoothly under gravity, is assisted by discharging a gas into the powder in the hopper. The quantity of gas should be just sufficient to break down static arching of the powder.

The resulting dynamic arch collapses thus producing a uniform gravity flow on to the rotary screw which then conveys the powder into the discharge port.

The powder is fed by the screw into the chamber. The pressure in the chamber being varied against the applied pressure to control the feed rate for a given screw speed. In this manner ultra-low feed rates can be achieved while still maintaining a uniform flow. The applied pressure is controlled by controlling the gas pressure in the gravity feed hopper. A relatively low hopper pressure increases" slip" by reducing friction between the powder particles and the screw surface and /or by inducing a backward flow of gas into the hopper.

The powder discharged by the screw is preferably picked up in the chamber by a gas stream, the powder being discharged into an aerodynamically tranquil zone of the chamber before being entrained in the gas stream. The same gas supply may be used to pressurize the hopper through a valve located in a pressure equalizing branch line disposed upstream of the chamber.

Referring to the drawings, gravity feed hopper feeds powder to the screw through a hole. The screw is spaced just above the floor of the hopper and extends to the other side. A seal bearing is placed at the inlet end of screw. Powder discharged by screw into chamber is picked up by a flow of gas delivered to the chamber through a delivery line. The metered quantity of powder is discharged into the chamber in a non-turbulent region above the outlet of the delivery line, and is then entrained into the gas flow as it falls toward the base of the chamber. A low uniform flow rate is achieved by suitably balancing the gas pressure inside the hopper against the gas pressure in the chamber. This is achieved by pressurizing the hopper through a pressure regulator connected in a pressure equalizing line which branches from the delivery line at a T-junction upstream of the chamber. The powder flow is also controlled independently of the conveying gas flow by varying the screw rotation speed.

Object of the present invention is also to provide a screw powder feeder which avoids, or at least reduces, screw "blinding" and "bridging" near the screw. The screw may then be rotated at higher a speed which in turn reduces the observable slubbing effects. Another object of the invention is to provide a feeder capable of uniform powder flow at lower feed rates than is possible with existing feeders.

Chapter - 3

Results and discussion

3.1 Parametric Studies of powder feeder

After completing the design process there was a need to test the feeder that whether the design is fulfilling the requirement of consistent, controlled and low feed rate. For this purpose the powder feeder was studied for the following two processes, before being applied for actual cladding operations.

3.2 Feed Rate Vs Gas Pressure

The feeder was operated at a constant 150 rpm while varying gas pressure obtaining different feed rate. Data obtained shows that the feed rate increases while increasing the gas pressure in the outlet chamber. The gas pressure inside the hopper was kept constant.

Table: 3.1 Feed Rate Vs Gas Pressure

S/NO	Gas pressure	Feed Rate
1	1	0.2
2	2	0.22
3	3	o.25
4	4	0.27
5	5	0.3
6	6	o.35
7	7	0.37

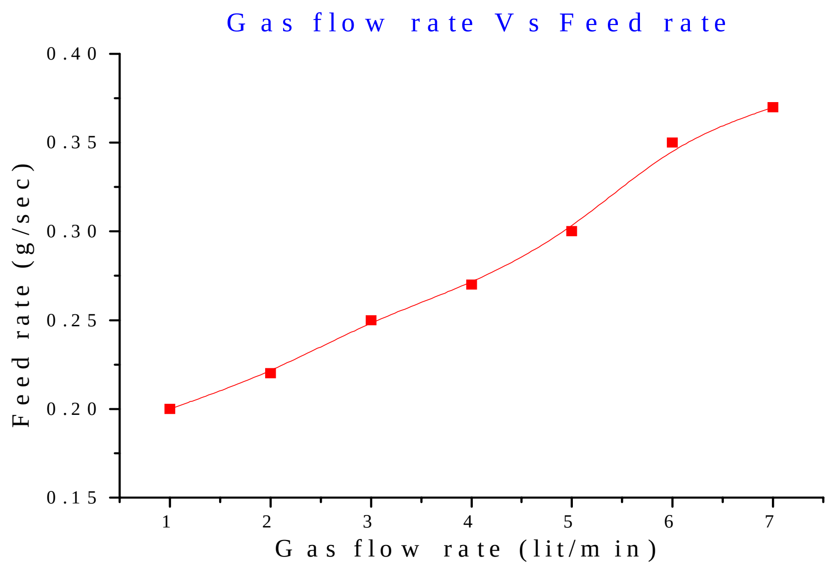


Fig: 3.1 Feed Rate Vs Gas Pressure

3.3 Feed rate Vs Screw speed

The powder feeder was operated at a constant gas flow rate of 5 lit / min while varying the speed of screw to obtain different feed rate required for different clad height.

Table: 3.2 Feed rate Vs Screw speed

S/NO	Speed of screw	Powder feed rate
1	75	0.12
2	100	0.16
3	150	0..25
4	300	0.5

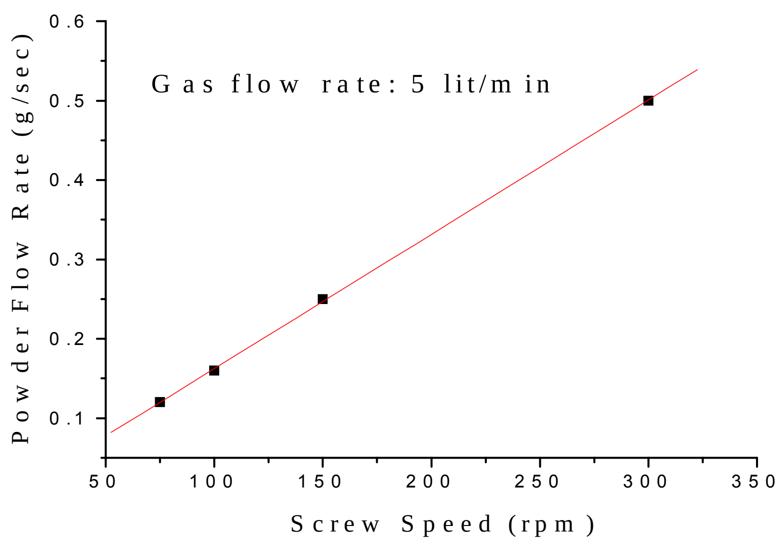


Fig 3.2: Feed rate Vs Screw speed

3.4 Experiments

The process consists of a laser, a Powder Feeder and control system for Nitrogen. The interaction zone between the laser beam, powder jet and substrate determining the coating characteristics. The powder feed system is the heart of process. The base material or substrate is placed or clamped into special CNC jigs.

The laser beam is directed onto the surface of the substrate and a melt pool is created. A Jet of particles arrive from the powder feeder, fastened to the laser, in this area. As the leading edge of the substrate is no more solid the powder particles will not ricochet off and stick to the surface of the substrate and cladding occur. This is because the leading edge becomes molten forming a sound fusion bond.

3.5 Material

The alloy material used in this experiment is Iron- Manganese alloy (Fe-Mn). The alloy was used in three different proportions.

a. 10% Mn and 90% Fe.

b. 15% Mn and 85% Fe.

c. 20% Mn and 80% Fe.

The powder used as the cladding/coating material has a size of 40 um.

3.6 Parametric Studies

3.6.1 Effect of laser power on clad height and width

Experiments were performed on the following parameters.

(1) Powder feed rate = 10 g/min

(2) Scan speed = 50 mm /min

It can be seen that the clad height and width increases with increasing the laser power.

Table 3.3 : Effect of laser power on clad height

Powder feed rate = 0.16 g/sec		
Scan Speed = 50 mm/min		
S/No	**Laser Power (Kw)**	**Clad Height**
1	1.2	1.00
2	1.3	1.32
3	1.45	1.7
4	1.5	2.14

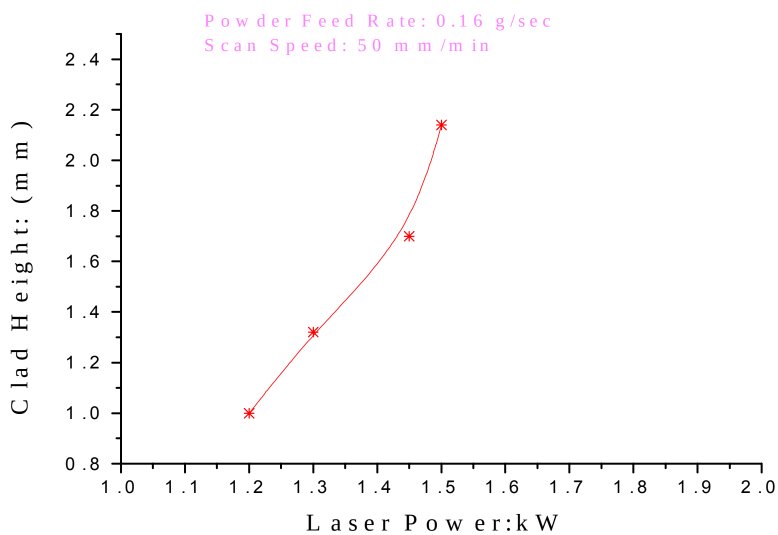


Fig: 3.3 Effect of laser power on clad height

Table 3.4 : Effect of laser power on clad width

Powder feed rate = 0.16 g/sec		
Scan Speed = 50 mm/min		
S/No	**Laser Power (Kw)**	**Clad width**
1	1.2	5.1
2	1.3	5.4
3	1.45	5.8
4	1.5	6.00

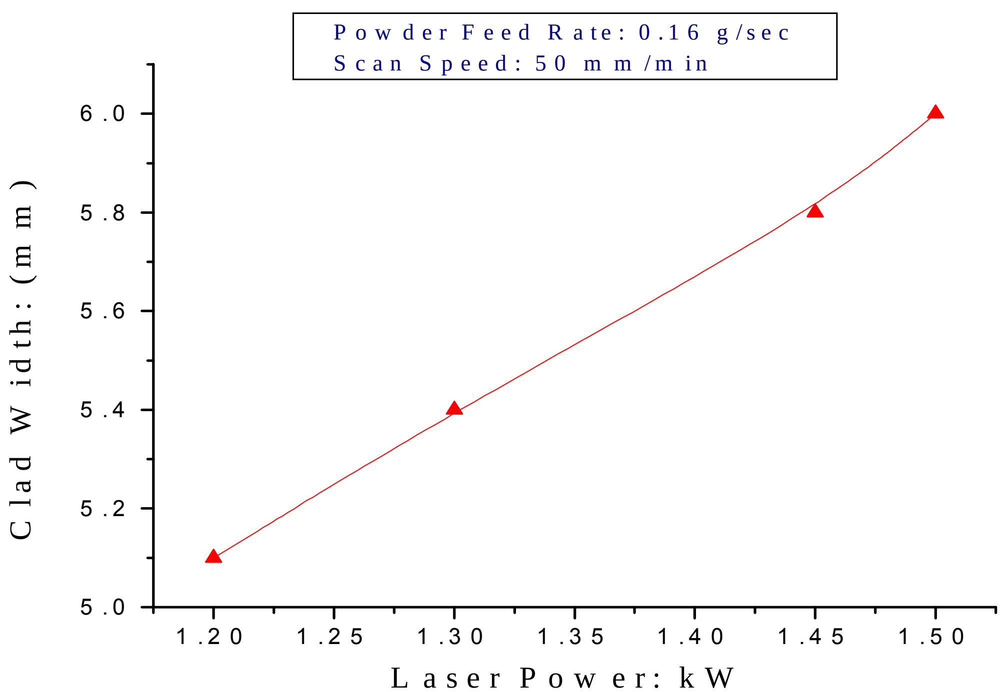


Fig 3.4: Effect of laser power on clad width

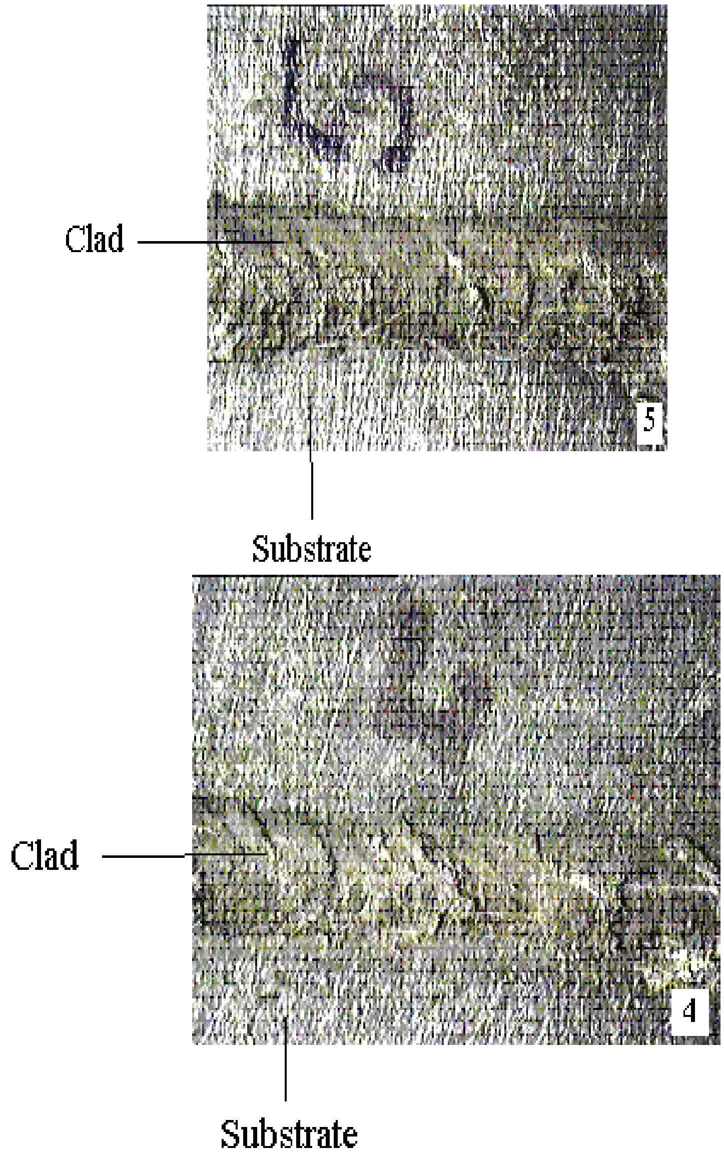


Fig : 3.5 Clad sample

3.6.2 <u>Effect of powder feed rate on clad height and width</u>

The clad height and clad width increases with increasing the powder feed rate. Different parameters are shown below in the table.

Table 3.5 : Effect of powder feed rate on clad height

Laser Power = 1100 W		
Scan Speed = 50 mm/min		
S/No	**Powder Feed Rate (g/sec)**	**Clad Height**
1	0.12	1
2	0.16	1.21
3	0.37	1.8
4	0.5	2.4

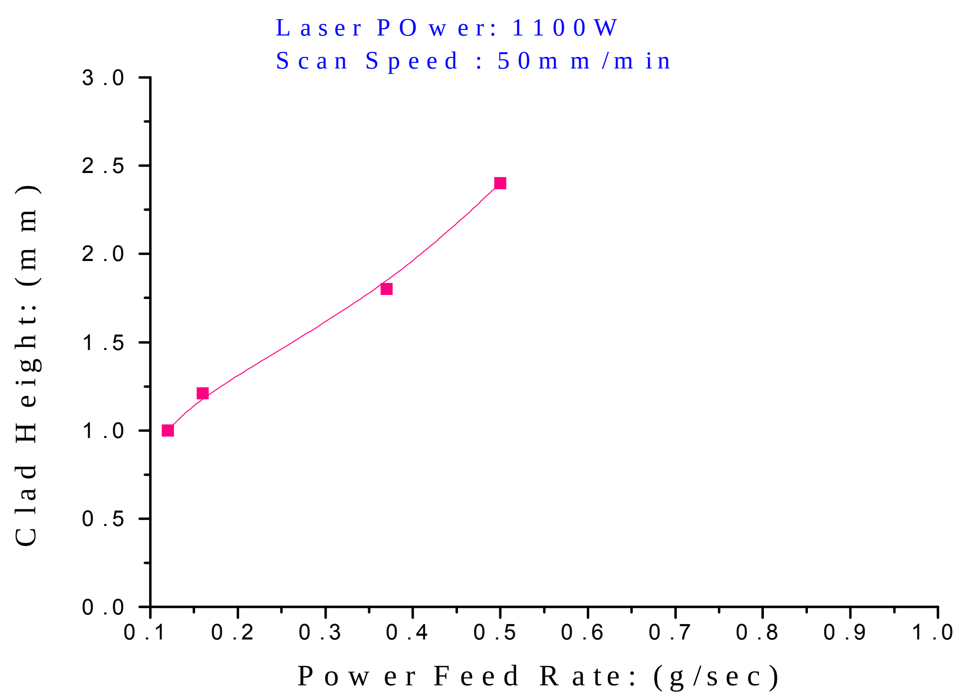


Fig 3.6: Effect of powder feed rate on clad height

Table 3.6: Effect of powder feed rate on clad width

Laser Power = 1100 W		
Scan Speed = 50 mm/min		
S/No	**Powder Feed Rate (g/sec)**	**Clad Width**
1	0.12	4.1
2	0.1.6	4.5
3	0.37	4.9
4	0.5	5.1

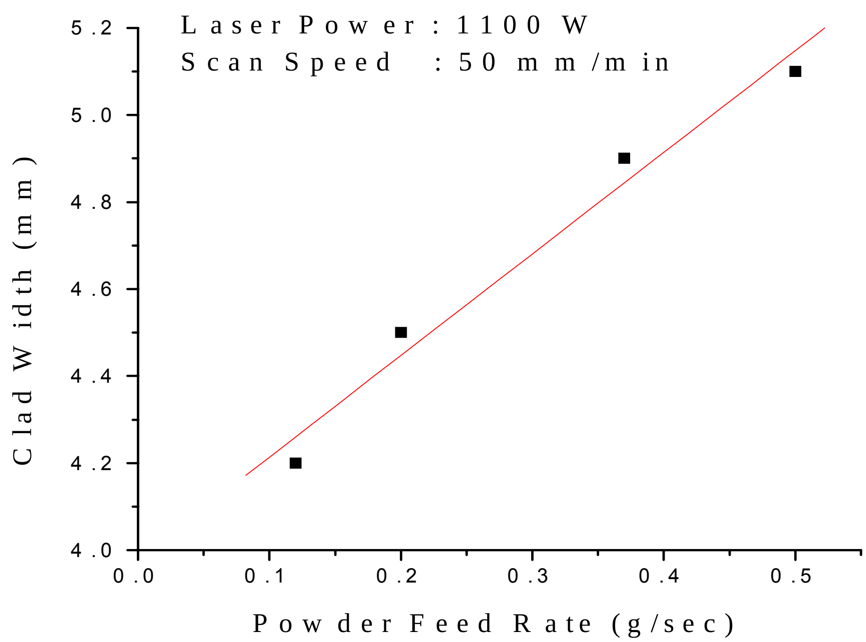


Fig 3.7 Effect of powder feed rate on clad width

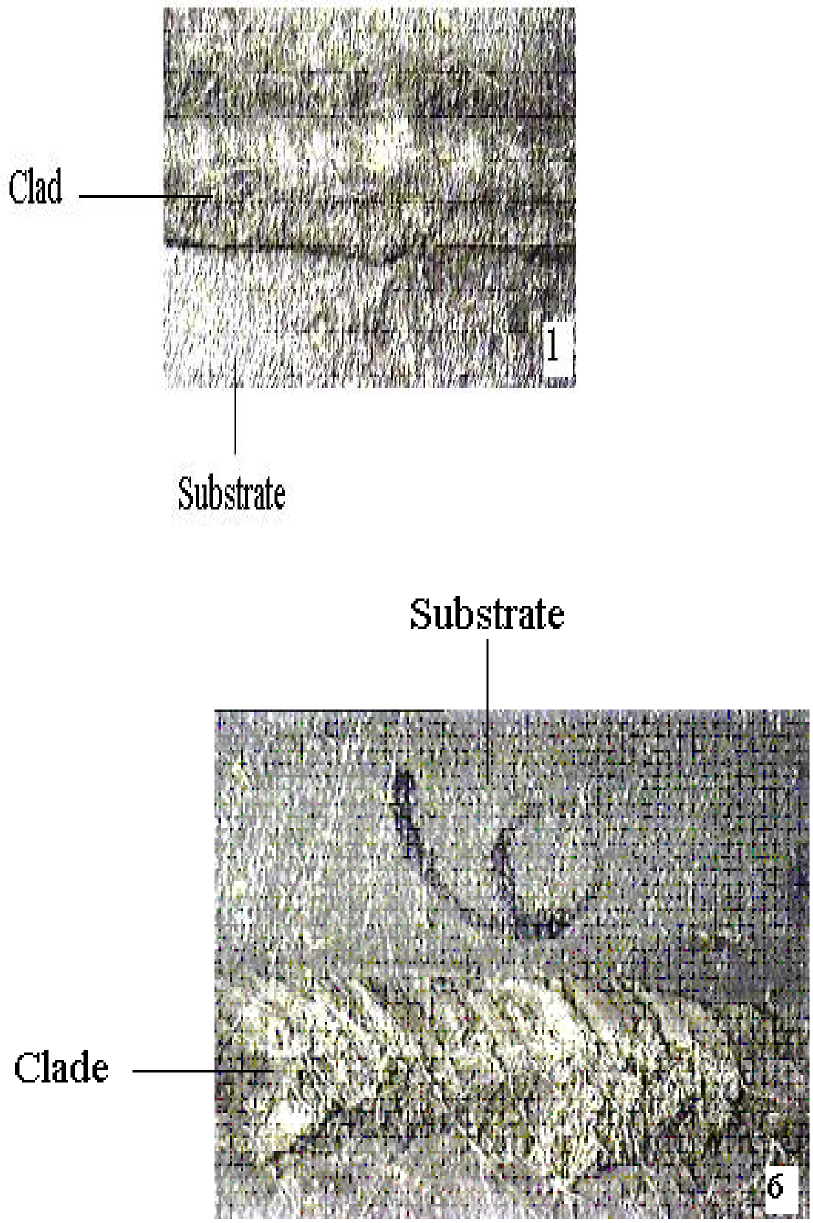


Fig : 3.8 Clad samples

3.6.3 Effect of scan speed on clad height and clad width

Table: 3.7 Effect of scan speed on clad height

Laser Power = 1100 W		
Powder Feed rate = 0.16g/sec		
S/No	**Scan Speed (mm/min)**	**Clad Width (mm)**
1	20	7.4
2	30	6.5
3	40	6.2
4	50	6

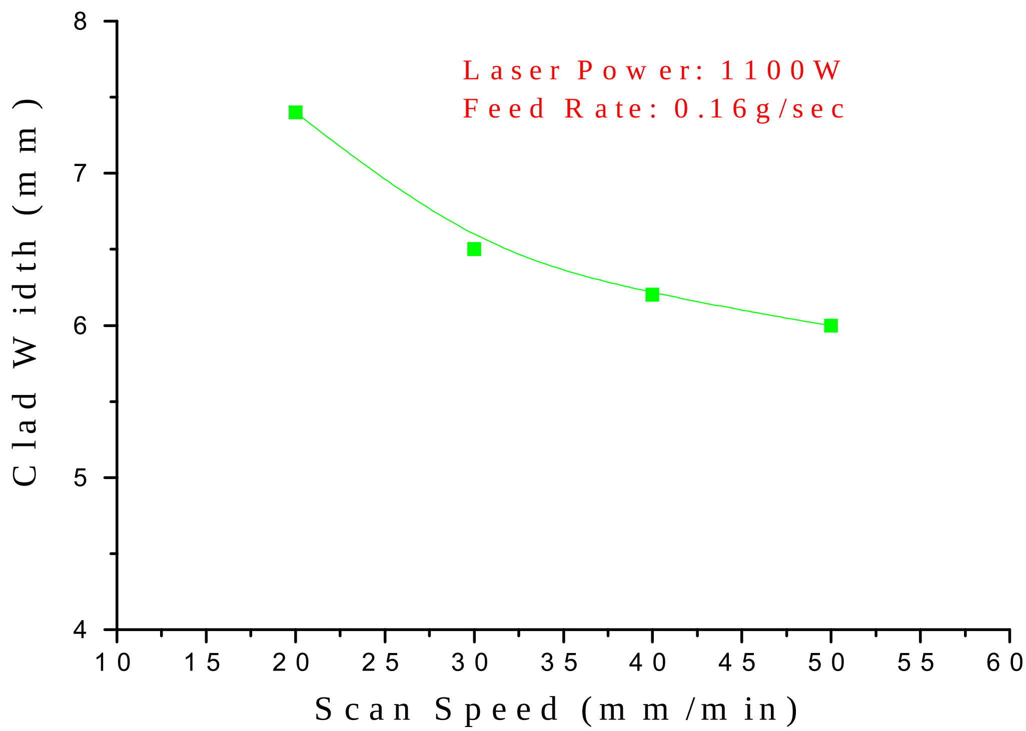


Fig: 3.9 Effect of scan speed on clad height

Table 3.8 :Effect of scan speed on clad width

Laser Power = 1100 W		
Powder Feed rate = 0.16g/sec		
S/No	**Scan Speed (mm/min)**	**Clad Height (mm)**
1	20	2.1
2	30	1.25
3	40	1.2
4	50	1.0

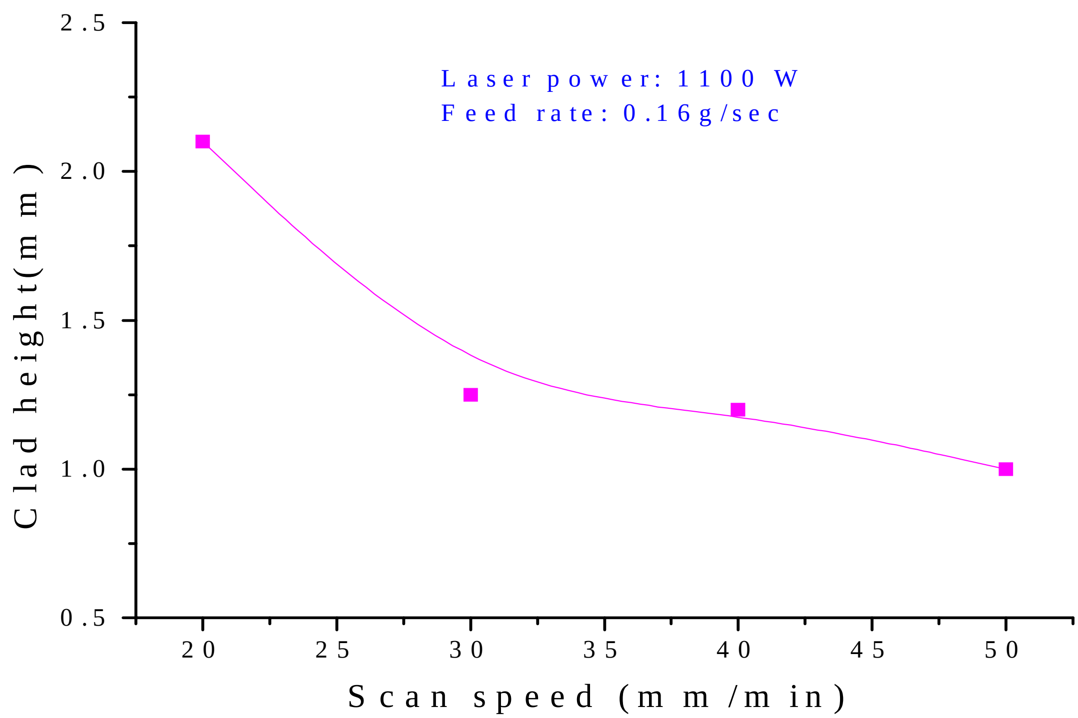
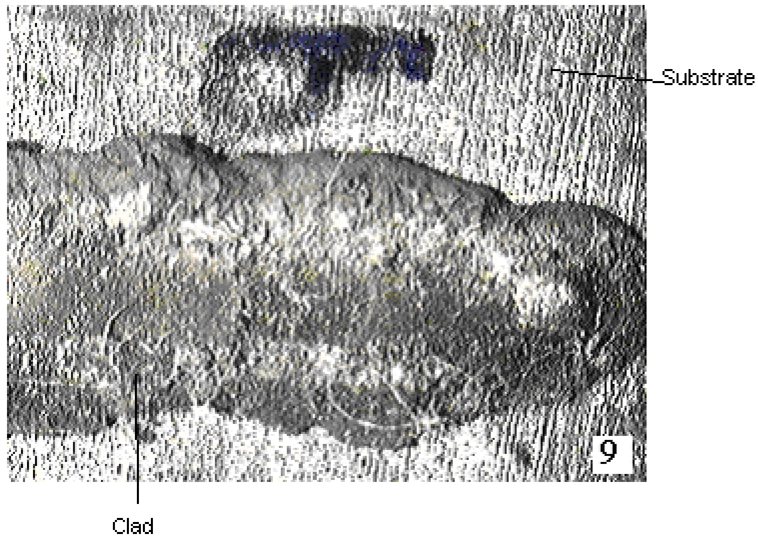
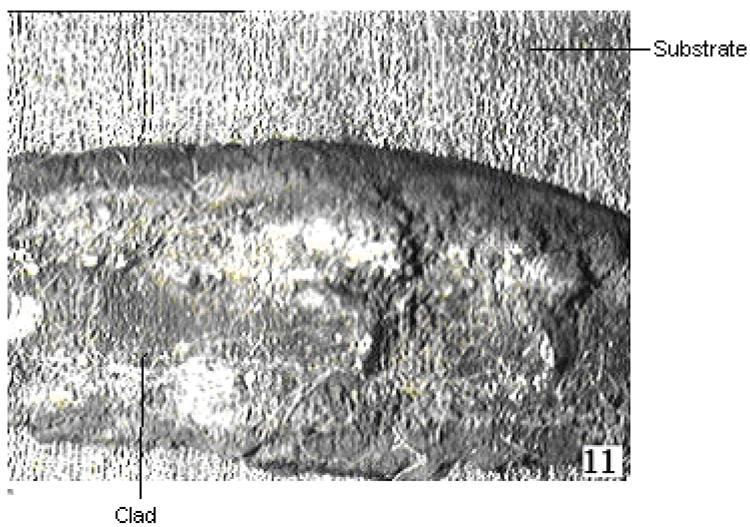


Fig: 3.10 Effect of scan speed on clad width


Substrate
Clad
9


Substrate
Clad
11

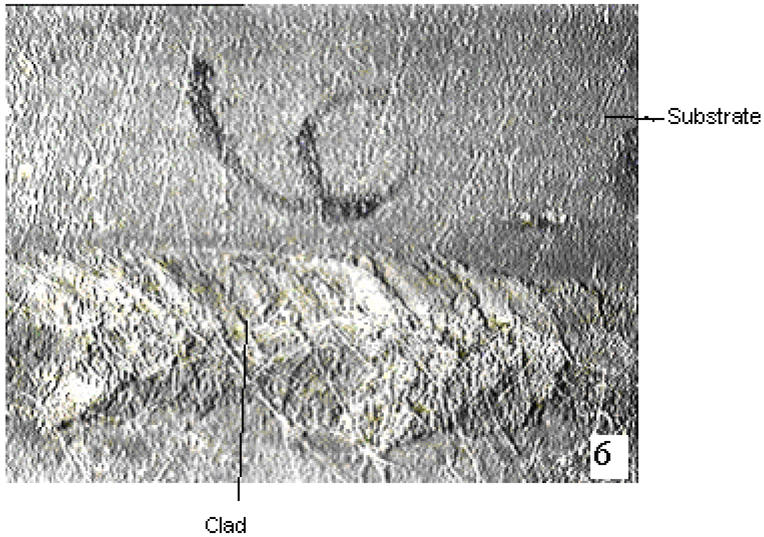
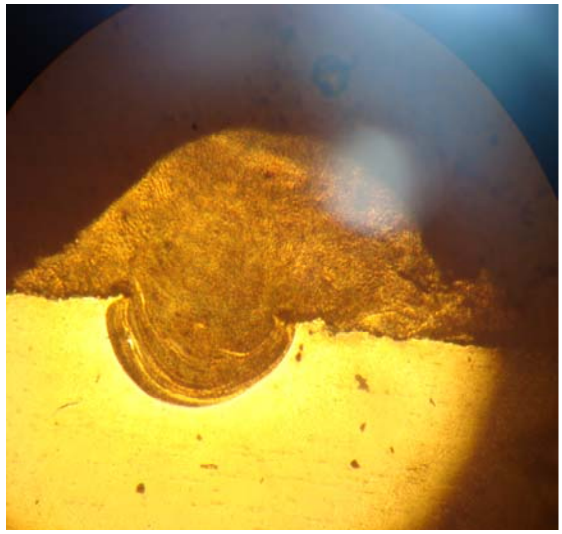


Fig : 3.11 Clad sample

3.7 <u>Microstructure: X 50</u>



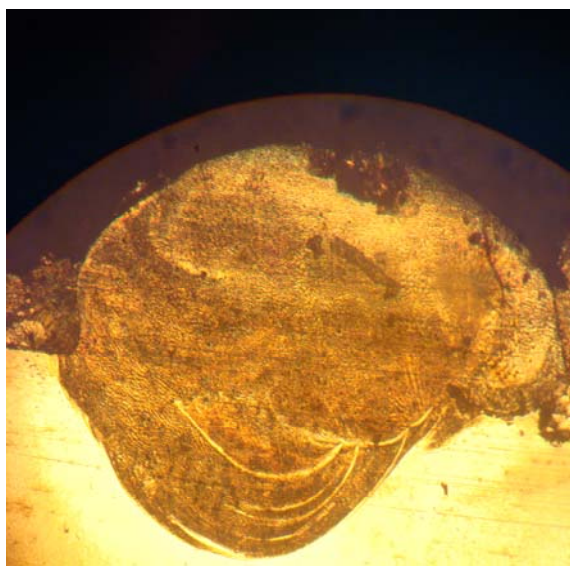
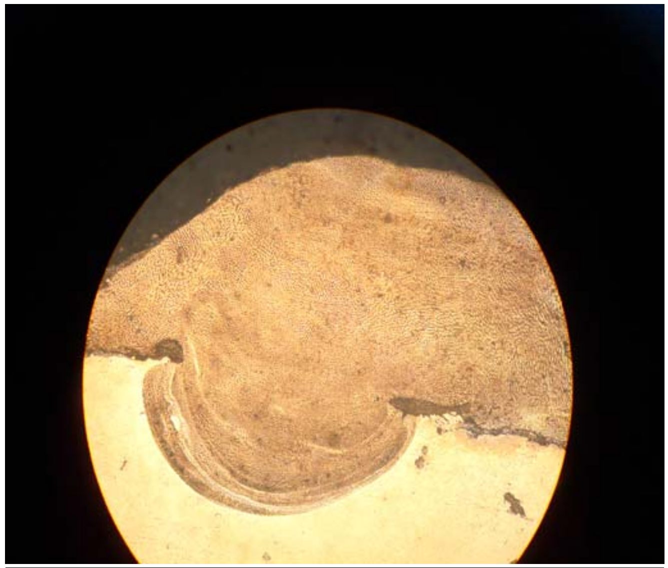


Fig : 3.12 Microstructure X -50

3.8 Microstructure: X100



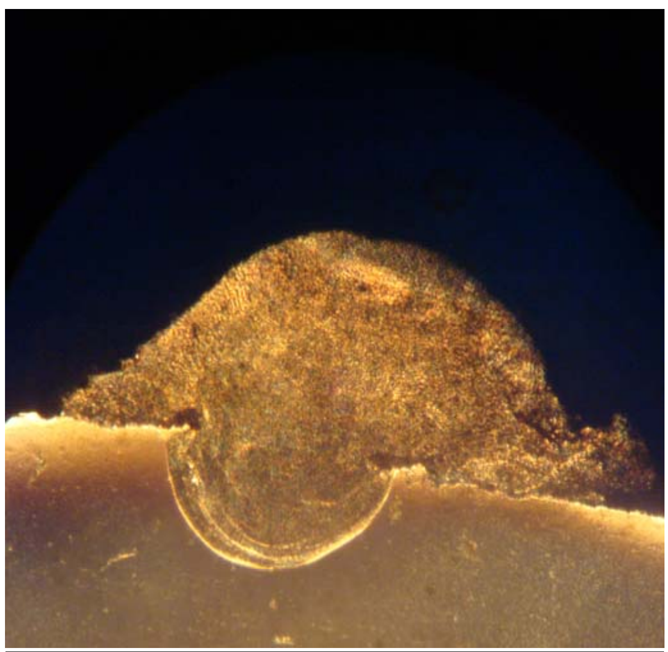


Fig : 3.13 Microstructure X -100

3.9 Microstructure: X 200

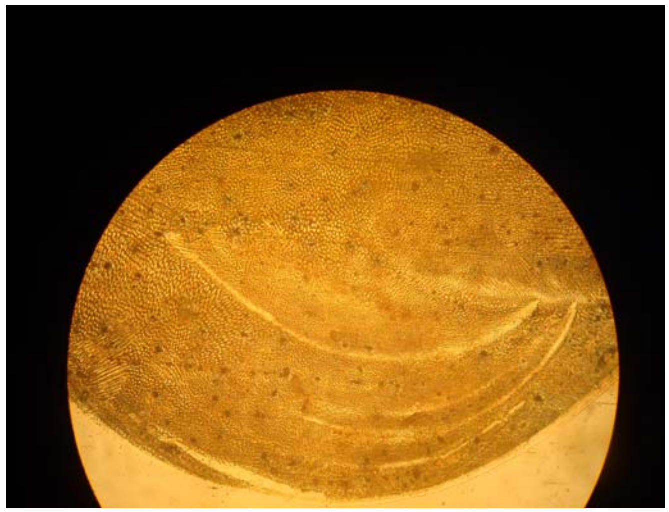


Fig : 3.14 Microstructure X -200

3.10 Microstructure: X 500

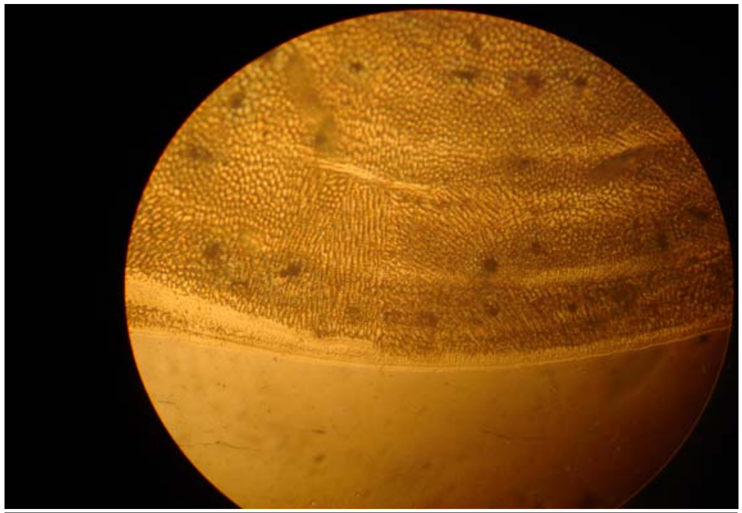
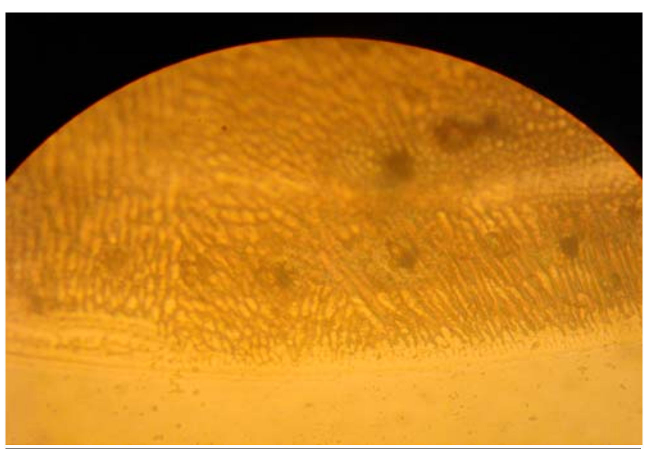


Fig : 3.15 Microstructure X -500

3.11 Microstructure: X 800



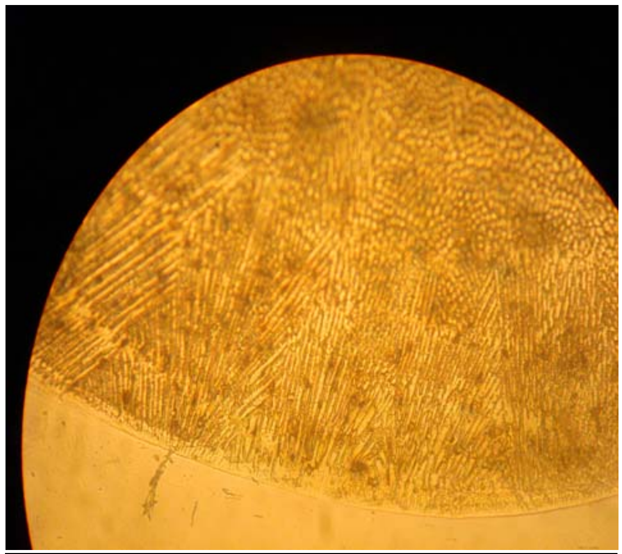


Fig : 3.16 Microstructure X -800

Discussion

This research work was started with the aim to design and fabricate a suitable powder feeder for laser cladding.

Every organization has developed its own powder feeder according to their requirement .There are different concepts available for a powder feeder. These are gravity based, lobe gear, fluidized bed and screw type. These different types of powder feeders have their own advantages and disadvantages. Keeping the requirements like sealing for powder, simple in operation and economical to fabricate. The screw type is the most suitable for our design. All the other types were discarded after studying all the requirements. Among the screw family, there are different configurations like tapered diameter, variable pitch and constant pitch. The constant pitch is the most cheap and easy to fabricate choice .

In the first design the flow of powder was not consistent because of the improper position of gas pressure in the exit line on the one hand and the extraction of powder was carried before the tip of the screw on the other hand. A large number of experiments were carried out but smooth flow could not be achieved. The powder used to accumulate in the screw area and the flow get chocked. In this design the powder just slipped along the screw and does not feed. The hole area become devoid of powder and flow of powder toward the screw is stopped. Different parameters like pitch, depth of cut, no of start shape of thread and length of screw were tested.

In the second design a plate was placed in the hopper portion at an angle of 45^0 to give direction to the flow of powder. The feed rate was not uniform even with this design.

In the third design the screw length was extruded on the other side in a tube having nozzle in the bottom side and a gas pressure just above the screw end. The powder was dropped in that chamber where it receive the gas pressure on top of the chamber. As the gas pressure is given above the screw some of the pressure makes its way inside the screw chamber thus restricting the flow of powder. The flow is not uniform, rather in jerks.

In the fourth design the plate was removed above the screw and the pressure of N_2 was extended just below the screw where the powder falls from the screw. The angled plate was also removed from the hopper. The powder falls in area where there is no pressure of gas and after some fall by gravity the powder is entrained by the gas pressure. With this design a consistent flow was achieved.

The feeder also showed the problem of “ bridging “ of powder when fine powder is fed. It also suffered from problem of “ blinding “ where the powder material rotates with the screw rather than fed.

The gas in the hopper should be just sufficient to break down static arching of the powder at the outlet thus resulting uniform flow.

It is important to design the feeder and hopper as an integral unit. The feeder is not a discharger therefore, reliable flow out of the hopper is essential for proper feeder operation. If the material has difficult flow properties, use a Mass Flow Vee-shaped hopper section, with vertical or slightly diverging end faces and a slot length of at least three times its width.

A parametric study was carried out comparing powder feed rate with N_2 pressure and screw speed. It was find out that the feed rate increases with increase of gas pressure and speed of screw.

Different cladding samples were obtained varying different parameters like laser power, powder feed rate and scan rate. It was find out that the clad dimensions,i.e, height and width, increases with increase of laser power, powder feed rate and decrease of scan rate and the dimensions decreases with vice versa.

At very slow speed less than 0.1 g/sec the clad dimensions are not uniform.

Good cladding was observed keeping the nozzle angle at 45^0 with the substrate.

The distance of nozzle and substrate also effect the quality of clad. The effective distance should be between 8 – 12 mm.

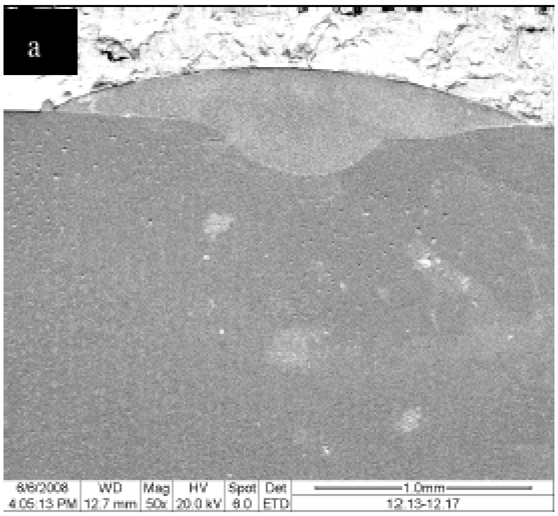
The effect of nozzle diameter was also observed. Increasing the nozzle diameter the feed rate increases. We carried out our experiments using 2mm diameter nozzle.

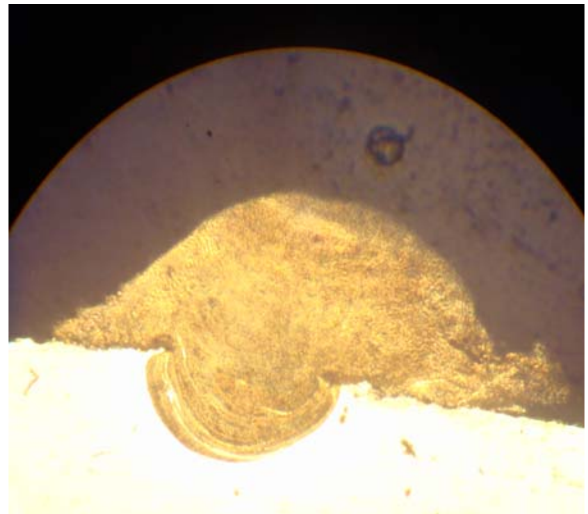
The processing parameters are numerous. These are the laser beam properties and velocity relative to the work piece, the distance between two successive tracks, the geometry of the nozzle used to inject the powder and the injection conditions themselves. These processing parameters are, of course, closely coupled. For instance,

changing the beam width requires the distance between two successive tracksto be corrected.
Numerical results show that the shape of the molten pool, and subsequently the solidification velocity depends strongly upon the parameters of powder injection.
The black specs upon the microstructure are not pores but are particles from the sample mounts which began to decay due to the extreme acidity of the conditions required to etch the sample. They can not be removed without scratching the surface.
The microstructure figures shows an even surface devoid of pores or cracking, with what appears to be high quality homogenous clad. The clad to substrate interfaces again are similar and show a high quality pore and crack free appearance.
In addition there is no evidence of intermetallic compounds forming at the interface. This is optimal because intermetallic compounds would diminish the strength of the clad to substrate bond and also introduce additional compressive stresses to the interface increasing the likelihood of cracking there. The microstructure revealed the grain boundaries and even grain structure of a regular two phase system. The even grain structure suggests that the clad will have uniform properties throughout.
All of which suggests that the clad are of high quality and have the potential to offer the same robust corrosion resistance.
Clad samples with adequate strength can be produced, their corrosion performance remains to be assessed. This will be the subject of further work. The dilution of the clad layer into the substrate depends on several factors, like thermal conductivity of the substrate, initial temperature of substrate, reflectivity of the material, powder flow rate, interaction time of the powder in the beam and laser power.
For low laser power values, no fusion of the substrate occurred and the coating did not adhere to the substrate, while for larger power values the substrate melted increasingly as the power levels increased causing increased dilution.
In general wear resistance increases with increasing hardness. Hardness and surface dependent properties such as wear, corrosion, oxidation and to some extent, fatigue resistance. Surface properties can be improved by modifying only the microstructure or by modifying both the chemical composition and microstructure of the upper layer of the substrate by laser cladding. In general, the exceptional properties of laser cladding

depend critically on the proportions of the alloying elements. Laser cladding is more suitable for processing heat sensitive components.

Comparison of microstructures of Mn alloy in one of the paper and the microstructure of our one of the cladding with magnification X 50. It can be easily compared that the dilution level in both the structure is almost same.





The maximum flow rate of a fine powder through a bin outlet can be several orders of magnitude lower than that of coarser particle material. The primary reason for this limitation is the air pressure gradient that forms naturally at a bin outlet as the air flows up into the hopper section. This pressure gradient acts upward, counter to gravity, thus reducing the rate of discharge. The magnitude of the pressure gradients is very low with coarser particle materials because they are more permeable. In other words, air can easily flow through their voids without resulting much of a pressure drop.

CONCLUSIONS

- Powder feeder is the key element in laser cladding .
- Particle size effect the flow. The flow of fine particles is difficult.
- Air pressure was found necessary, without which the flow was not possible.
- A pressure difference between hopper and flow line is must, without which flow is not possible.
- Different screw materials like stainless steel and aluminum were tested. It was find out that aluminum being light was found useful. However its life is less.
- The design was tested for single start and double starts screw and observed that double start convey more powder.
- Screw with different depth of cut like 1mm, 0.8 mm and 0.6mm were tested and the variations in powder flow were observed. The powder flow increases when the depth is increased.
- Increasing the screw length the powder flow decreases.
- The angle of nozzle drastically effect the clad dimensions and quality. At 45^0 the max efficiency occurs.
- Increasing the nozzle diameter the flow rate increases.
- The laser cladding process has the advantage of lower dilutability in cladding layer, so it can decrease the thickness of cladding layer and cut down cladding material expenses.

FUTURE WORK

- In future sensing and measuring devices like pyrometer and photodiode may be installed to monitor the laser process.
- CAD / CAM may be employed to manufacture intricate shape.
- As the process is experienced based skilled operator be employed.
- Different data tables may be prepared for different parameters for ready references.

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