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A GRAPH THEORY APPROACH TO EVALUATE THE INTENSITY OF BARRIERS IN A POWDER METALLURGY PROCESS

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Abstract

Proposed: Today in market, product quality, and cost of products are more challenging factor. Now improving the quality of product by controlling the critical factors. For the cost reduction of product, improve the productive and minimization the waste. Now apply lean manufacturing and minimization the waste. An auto part industry; which manufactures auto part by using sintered powdered metallurgy. It is found after enquiring with the management that production of some auto part is very low and rejection was quite high. Here a case study to investigate the low production of the specific auto-part and High rejection rate will be taken to fix the real cause. The study will suggest the best possible measure to over-come both the problem.

Metrology: This paper based on Graph theory application. In this paper identify the critical factors and subcritical factors. Develop a feasible index of transition (FIT) and rank different industry according to cost and quality. The FIT value obtained from permanent function from enabler digraph.

Finding: Help of this paper; find the particular industry is fit for desire quality and optimum cost.

Practical implication: The FIT value obtained from a permanent function indicates the influence of critical and sub critical factor. Higher the value of FIT engineer judge to control this factor for desire quality.

Originality/value: Classification of critical and subcritical factors and their analysis for a desire quality at optimum cost.

Key word: *Graph theory application, powder metallurgy, Barriers, Implementation, and Identification.*
Paper type: Research.

1 INTRODUCTION

Metal part are made by compacting fine metal powder in suitable dies and sintering, that is heating without melting. This process is known as powder metallurgy (P/M)

Powder metallurgy is very oldest process. It is believed to be the oldest form of metal working. It was used before metals were able to be melted down by high temperatures. The process has been used in one form or another for quite some time. One of the oldest references to the methodology is the iron pillar in Delhi, India. The pillar was made by forging together lumps of sponge iron. The pillar weighted six and one-half tons.

3000BC, Egyptians, to make iron tools. One of its first modern uses in 1900s to make the tungsten filaments for incandescent light bulbs. The availability of a wide range of powder compositions, the ability to produce parts to net dimensions and the economics of the overall operation make this process attractive and useful for many applications.

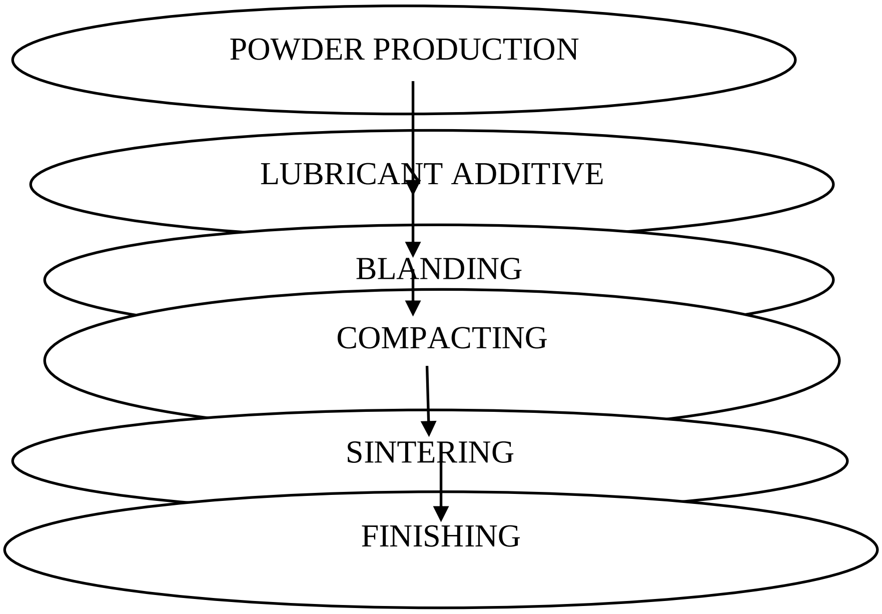
Typical components made by powder metallurgy techniques range from tiny ball for ballpoint pen, to gear, cams bushings, cutting tool filter, and oil-impregnated bearing, to kinds of automotive components such as piston rings; valve guides connecting rods, and hydraulic piston.

2 Literature review

According to (Kei "The approach of PM technology in the environment protection" Hitachi powdered metal report 2009 Japan powder metallurgy association annual report 2010, Kawata Hideaki KunioMaki alloys 2007)major critical and sub critical factors influences the powder metallurgy. Powder production depend upon mechanism, temperature, time, atmosphere, Type of gases used etc. Product depends upon type of lubricant used, Blending process, Compacting process, and pressure, Sintering process (Temperature, time, furnaces atmosphere etc.) and finishing process. Balaji, S.Pvijay, and A.Upadhyaya (2000), suggested that effect on sintering temperature influence the powder metallurgy product. Hryha.E, E.Durdrova and S.Bengtsson suggested that powder compacting influence the powder property and powder metallurgy product. Gmmeson (1959). According to quality of powder depend upon atmospheric condition and control it. Hryha.E, E.Dudrova and S. Bengtsson, According to powder compacting: influence of powder property and powder metallurgy product. M. Kondoh (2002) He suggested that density of powder achieve by compaction process and improve the quality of product. J. Hamillet al (2000) He suggest that atomization process and condition of atomization affect the powder metallurgy product.

Necessary to control these factors for a quality improvement. Now study to Graph theory application applied in various field (Grover et al., 2006; Rao and Gandhi, 2002; Wani and Gandhi, 1999, Op Mishra.et.ai 2014, Tilakraj.et.al 2010, Rajesh attei.et.al 2014) Rajesh attri .et.al used To Develop the relative scale of barriers in the implementation of total productive maintenance (TPM). Tilak raj et al 2010 used in "Evaluating the feasibility of transition to FMS". Op mishra.et.al 2012 apply in "supply chain management" Grover et al. (2006) used this technique "To develop a relative scale environment of an industry". Rao and Gandhi (2002) used the digraph and matrix approach in "The failure cause analysis of machine tools") Develop FIT index and help of this index more challenge factor came into the picture and control this factor applying different technique. such that improve the quality, reduction of cost and minimization the waste.

3. Operations involve in making powder metallurgy parts:



3.1 Methods of powder production:

The powder metallurgy process begins with metal powders. Metal powders are discrete particles of solid metals and range in sizes from a fraction of a micron on up the scale to those that normally pass through a 20-mesh screen. It is carried out control atmosphere below the melting temperature (75*melting temperature). The size of powder also depends upon mechanism and process. The powders are producing by the following methods:

Mechanical
Chemical
Physical Processes;

3.1.1 Mechanical Process:

These methods are dividing into the following categories:

- Atomization
- Pulverization

- **Atomization**: In this process where molten metal is disintegrated into particles by pouring it into a jet stream of air, inert gas, water spray, and steam. The

Jet streams are made by forcing the disintegrating mediums under high pressure through a nozzle or an orifice. The jet streams direct high energy particles the molten metal in to particles. mindful control of the metal stream spray medium or preventive atmosphere, and pressure of the atomizing medium is important. The material is then dried and processed by any other process as the manufacturer deems necessary to produce his specific product. In some special cases, the atomization process is used as an intermediate method before the reduction processes are used, and elemental powders can be produced by the atomization process under controlled conditions. A few powder manufacturers use this process for producing defect free iron powder. The atomizing process has been perfected into a versatile tool for the large-scale production of non-ferrous powders, and ferrous alloys. This process is used where other processes cannot useful to produce the desired alloy or metal powder. The process is practically the only victories method for producing pre-alloyed and certain refractory metal powders.

It is unique process is to manufacture aluminium-alloy powder for dispersion-strengthen materials. Pre-alloyed steel, tool steel, and stainless-steel powders are manufactured by atomizing molten metal in a Jet stream. Alloy steel powders that are atomized in a steam jet or water spray are dried and screened. The powders are heat treated in controlled atmospheres to reduce surface scales, control carbon content, and remove quench hardening defects. In stainless steel powders to vanquish the surface oxidation by the addition of silicon to the alloy. The addition of silicon also tends to produce dendrite type powders, which improve compacting, or pressing the powder from this process is usually spherical or round in shape and can be porous or dense.

- **Pulverization** : It is usually done by crushing, machining, grinding, or a combination of the above process for the production of metal powders. This process, “Gem Fluid Energy Mills are used to pulverize hard "brittle, abrasive, soft and agglomerate materials. The simplicity of design of this unit give controlled adaptability to a variety of process conditions. Gem Mills will dry grind to low and sub-micron particle size. Generally employing compressed air, Gem Mills may be operated with inert gas such as argon and nitrogen, or with superheated steam. The maintenance factor is very low. Controlled atmospheres, has also proved to be one of the most reliable processes for producing powders of such reactive metals as titanium, and non-ferrous powders. Grinding or ball zirconium, and specially beryllium as well as other refractory and ferrous milling is used to manufacture very fine and ultrafine powders

3.1.2 Chemical Processes.

Powder Production by the chemical processes are divided into the following categories:

- Reduction Process
- Decomposition Process

In the Reduction Process, a chemical compound, usually an oxide, in reduced to elemental powders. In some other cases, these powders are obtained from a halide or other salt solution of the basic metal. Metal powders manufacturing from the following states by the reduction process:

- Solid State
- Gaseous State
- Aqueous State

An example of the solid-state method the reduction of iron oxide with carbon, and the gaseous state technique the reduction of titanium from titanium vapour with molten magnesium, and the aqueous technique the reduction of a metal from its ammonia cal salt solution with hydrogen under pressure.

- **Reduction:** In this process for manufacturing iron powders from the solid state are important methods for producing commercial grade powders. The raw materials used for producing the powders are high grade iron ore and mill scale, a key product of steel manufacture. A specific iron powder produced from the solid- state reduction method, this is a commercial product and it is known as sponge iron. The powder gets its name from its peculiar physical characteristics grade of powder is consumed in greater quantities for the fabrication of p/M parts than any other ferrous powder or powder metal for that matter. The method, in general, for producing sponge iron powders involves the heating of a mixture of high-grade ferrous materials (usually in the form of oxides) mixed with crushed coke. The mixture is heated to a temperature of approx. 2000^{0}C. Oxygen is removed from the oxide by combining with carbon in the coke to form gas compounds of carbon monoxide (CO) and carbon dioxide (CO2) which are drawn off and the iron oxide is reduce to form iron particles. The granules are removed by mechanical means (magnetically) from the impurities and then pulverized to desired particle size. In most cases the powder has to be further reduce and annealed in a last production step because the iron granules contain small percentages of impurities such as carbon and oxygen. The resulting sponge powders are practically defect free elemental material but a very small percentage of impurities (which are not considered harmful) still contain. Considerable amounts of copper powder are produced by the reduction of copper oxide with an exothermic gas (methane or propane) which is partially combusted* The copper oxide is reduce at low temperatures in continuous furnaces. Some refractory metals such as tungsten and molybdenum are reducing from oxides.

- **Decomposition:** In this method by which metal powders are manufactured by the decomposition of chemical compounds. Two processes are worth mentioning and they are the decomposition of hydrides and the decomposition of carbonyls. The decomposition of hydrides is used to manufacturealmost refractory metals such as titanium, tantalum, zirconium, hafnium, vanadium, columbium, thorium, and uranium. These metals are changes into hydrides by heating them in the form of sponge, chips or trimmings in hydrogen at authorize temperatures and pressures. The hydrides produced are quite brittle, so that ball milled into powders of desired size. The powder hydrides are then de- hydride to obtain elemental powder

3.1.3 Physical Process:
The electrochemical or electro-deposition process is used to manufacture metal powders. These kinds of powder are known as electrolytic powders. The electrochemical process is more important for manufacturing copper powders than any other process. It is also used to manufacture iron powders. Powder production of this process is same as electroplating. Instead of plating the cathode a powdery or porous metal is deposited at the cathode. For manufacture electrolytic copper powder, a lead cathode for collecting the deposit is normally used. The anode, usually made of refined pure copper and a sulphate electrolyte is used to complete the processing system. The deposit on the cathode falls to the bottom side of the tank and it is brushed off the cathode and collects in the bottom of the tank. It is removed, filtered, washed, and finally reduced and annealed as required condition. This processing result in a semi-cake, such that pulverized into powder of desired size.
For manufacturing electrolytic iron powder, a stainless-steel cathode is used and the anode is usually made of iron or low carbon steel. The electrolyte used is an acid solution. The ferrous powdery deposit collected on the cathode is porous, brittle and contains impurities of hydrogen and oxygen. The iron powders go through similar processing steps used for copper then it having reduce and annealed to receive a soft electrolytic powder. The iron powders manufacture are highly pure and good compressibility characteristics for compacting process. Higher green and sintered densities can be attained from the ferrous powders manufacture from this method. Electrolytic iron powders are higher in cost than ferrous powders produced by the reduction process and consequently is not used as widely or is as popular as sponge iron for the fabrication of P/M parts. The powder metallurgy is anbest choice for very high dense ferrous structural components.

3.2 Additives Lubricant:
It acts as a binder, it is mixing of different metal powder by the help of lubrication. Lubrication having attractive property to mixed the different metal powder with the help of adhesives force of attraction. It help to reduce the friction between partial and dies. Additive-lubricant has a special property given below.

- ➢ High melting point and low freezing point wide range of temperature.

- High viscosity
- Thermal stability
- Corrosion prevention
- High resistance to oxidation
- Corrosion inhibitors

It can be added to the mixture of the powder particles to increase the green strength during the powder compaction process. Lubricant has important function in powder metallurgy.

3.3 Powder Blending

A single powder does not full fill the desire property such that mixing of different mechanical, physical, chemical, and different boiling point metal powder mixed together Mixing must be proceed in control atmospheric condition to avoid oxidation, avoid contamination or deterioration. Blending has a several purpose given below.

Different size and shape powder particle are mixing uniformly.

It having facilitates to mixing of different powder particle to impart wide range of physical and mechanical property.

3.4 Powder Compaction

Aim of compaction process to apply the pressure such that bound formation between the metal powder with the help of cohesiveness. This term is green compaction.

In this operation, high pressures applied upon the powder in the die cavity, through two or more vertically moving plungers, from top and bottom compacting the particle.When apply the pressure, the powder particle close together, their irregularInterlock some diffusion mechanism take place their surface. After this process, sufficient strength to handling without damages the product.

After the compaction the following effects given below:

- Reducing the void
- Increasing the density
- Increasing the green strength
- Shape of part achieve
- Increase the compressing strength

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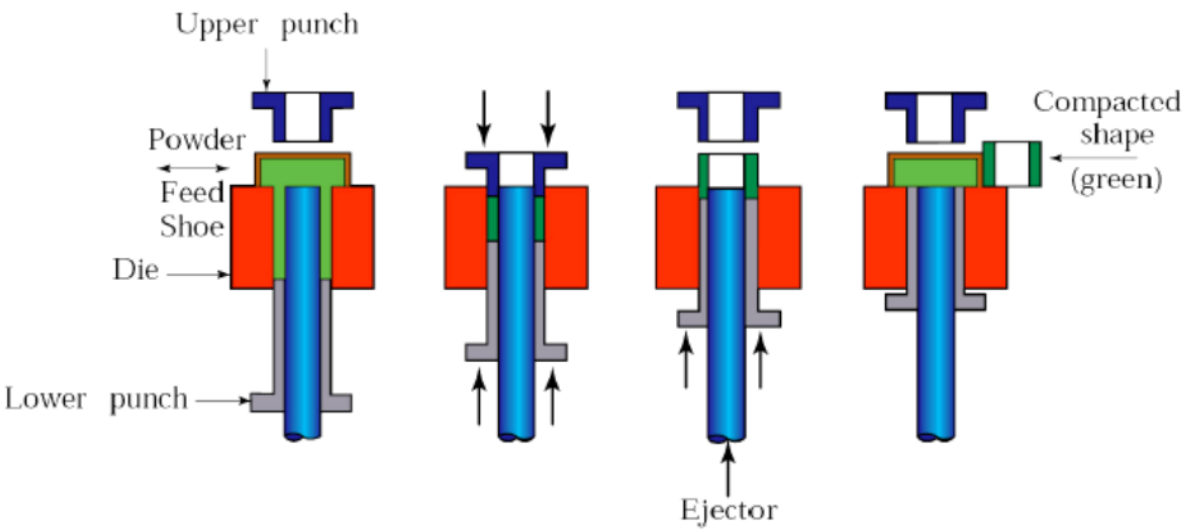

Fig 1.Compaction process

3.5 Sintering

After the compaction heating operation is perform to specific temperature (below the melting point) in control atmosphere (is inert gas, or vacuum for some specific part). In this process bound formation between the powder particles by some mechanism such that increase the strength of final part.

Strength and nature of bound formation depend upon the diffusion mechanism, plastic flow of metal particle, evaporation of volatile material.

In sintering operation, have three critical factors.

- Temperature
- Time
- Furnaces atmosphere

Bound formation of particles this way:

1. Melting of minor constituents of the powder particles
2. Diffusion between the powder particles
3. Mechanical bonding

After the sintering following property enhanced

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- Density increase
- Increase the connect area between the particle
- Strength increase
- Mechanical property increase
- Physical property increase

3.6 Finishing Operation

After the sintering operation improve the surface finish and quality, dimensional accuracy, mechanical and physical properties and appearance secondary operation performs according to required.

- Re-pressing
- Coining and sizing
- Forging
- Impregnation
- Inflation
- Heat treatment
- Machining
- Grinding
- Plaiting

Table 1 Enabler list

S no	Enabler category	Sub Enabler category	source
1	Powder production(P_1)	1 Control atmosphere (p_{11}) 2Temperature (p_{12}) 3Size (p_{13}) 4Mechanism (P_{14}) 5 Shape factors (p_{16})	K. taeuchi (2000) A.UPADHYAYA(2007) Expert opinion Expert opinion Expert opinion
2	Additive Lubricant (P_2)	1Chemical composition (p_{21}) 2Viscosity (p_{22}) 3Density (p_{23}) 4Heat capacity (p_{24}) 5Temperature (p_{25})	Expert opinion S. Bengtsson (2008 Expert opinion Expert opinion I cremer(2000)
3	Blending (P_3)	1Physical property (p_{31}) 2Mechanical property (p_{32}) 3 Particle size (p_{33}) 4 Chemical composition (p_{34}) 5 Shape factor (p_{35})	Orban R L (2004) Orban R L (2004) Expert opinion Expert opinion Expert opinion
4	Powder Compaction(P_4)	1 density(p_{41}) 2 Pressure (p_{42}) 3 Particle size (p_{43}) 4 Temperature (p_{44})	S. Bengtsson (2008) Heider Yasser(2018) Expert opinion I cremer(2000)
5	Sintering (P_5)	1Temperature(p_{51}) 2 Time (p_{52}) 3 Furnaces atmosphere(p_{53}) 4 Diffusion mechanism (p_{54})	I cremer(2000) Torralba (2004) Torralba (2004 TAEUCHI (2000)
6	Finishing operation (P_6)	1 Heat treatment (p_{61}) 2 Impregnation (p_{62}) 3 Infiltration (p_{63}) 4 Machining (p_{64}) 5 Grinding (p_{65}) 6 Plating (p_{66})	Verma.et.al(2017) Expert opinion Expert opinion Expert opinion Expert opinion Expert opinion

4.1 Graph-theoretic approach

GTA connect the inter relationship between the different variables. It provides the synthesise score for entire system. It gives the directional relationship and inter dependences between the attributes. GTA technique represent the digraph, matrix and permeant function. It gives the pictorial representation of attributes or barrier. In this technique barrier represent the digraph, with the help of digraph convert matrix, matrix give the mathematical model. This theory is applicable very wide range. Eg Engineering, manufacturing, transportation, Automation, physical, social, biological science, Inventory management, and another field. The application of GTA used in various paper (Grover et al., 2006; Rao and Gandhi, 2002; Wani and Gandhi, 1999, Op Mishra.et.ai 2014, Tilakraj.et.al 2010, Rajesh attei.et.al 2014) Rajesh attri.et.al used "To Evaluate the intensity of barriers in the implementation of total productive maintenance (TPM)". Tilak raj.et.al 2010 used in "Evaluating the feasibility of transition to FMS". Op mishra.et.al 2012 apply in "supply chain management" Grover et al. (2006) used this technique "To develop a mathematical model of TQM environment of an industry". Rao and Gandhi (2002) used the digraph and matrix approach in "The failure cause analysis of machine tools".

Main objective of this paper finds the intensity of barrier and implementation of this effect. The intensity of barrier depends upon interaction among the barriers. In this paper identify the six categories of barrier and sub barriers. Those barriers are used to evaluate the intensity of barrier in P/M computing index.

Intensity of barriers =(IOB)pm= f (Barriers)

4.2 P/M enabler digraph

Digraph represent the signification of barrier and their interdependences with the help of node and edge. In this digraph (Pi) represent the node and (p_{ij}) represent the edges. Pi represents the inheritance of P/M barriers and pij represent the degree of dependences of the j_{th} P/M barriers on i_{th} barriers.

The interdependencies between the barriers are stab list with of engineer and expert. In this paper six categories of barriers, powder production (P_1), Lubricant additive(P_2), Blending(P_3), Powder Compaction(P_4), Sintering (P_5), Finishing(P_6). In this digraph consists of two sets (P_1 P_2 P_3 P_4……….) and (p_1 p_2 p_3……). (P_1 P_2 P_3….) are called vertices and (p_1 p_2 p_3……….) are called edge.

In each edge p_{ij} is define with an order of (P_iP_j) of vertices. The number of node equal to number of enabler. If a node i has relative importance over the node j than arrow from node i to node j. It denoted by p_{ij}. In this digraph, six major categories are mansion.

The P/M barriers' digraph

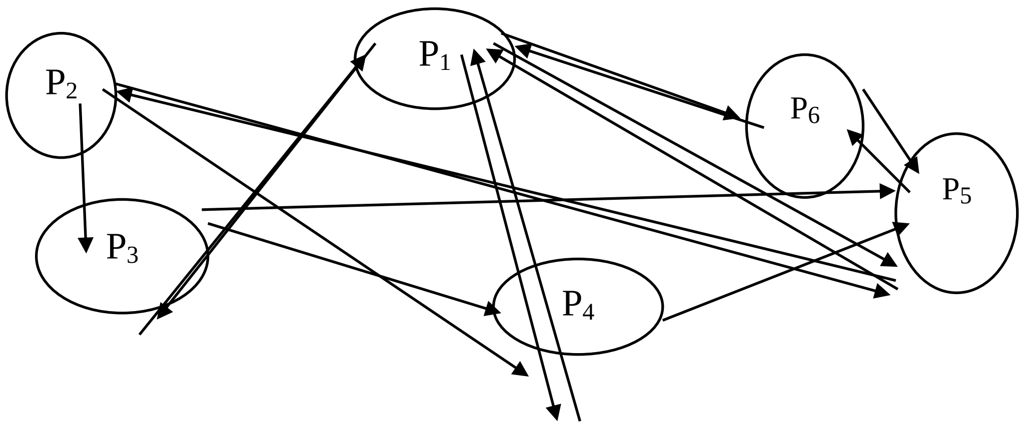


Figure 2 The P/M barriers' digraph

4.3 Matrix representation of P/M enablers

Digraph a pictorial representation but computing analysis, mathematical representation is necessary, such that pictorial to mathematical conversation. It converts in matrix format such that analysis is convenient.

The representation of matrix based on the suggestion of Deo (1999)

F=(P_{ij}) where P_{ij} represent interaction of i^{th} enabler to j^{th} enabler. Here p_{ij} = p_{ij} because enablers are directional. P_{ij} =0 it means enablers are not interact with each other.

Table 2 Per meant function Matrix representation

.

$$\begin{bmatrix} P_{11} P_{12} P_{13} & .. & .. & P_{1n} \\ P_{21} P_{22} P_{23} & .. & .. & P_{2n} \\ P_{31} P_{32} P_{33} & .. & .. & P_{3n} \\ .. \quad .... & .. & .. & ... \\ ... \quad ... & .. & .. & ... \\ P_{n1} P_{n2} P_{n3} & .. & .. & P_{nn} \end{bmatrix}$$

Table 3

In this matrix P_1 P_2 P_3 P_4 P_5 P_6 represent the major process and pij represent the interdependency of element i to j.

$$F = \begin{array}{c} \\ P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \\ P_6 \end{array} \begin{array}{c} \begin{matrix} P_1 & P_2 & P_3 & P_4 & P_5 & P_6 \end{matrix} \\ \begin{bmatrix} P_1 & 0 & P_{13} & P_{14} & P_{15} & P_{16} \\ 0 & P_2 & P_{23} & P_{24} & P_{25} & 0 \\ P_{31} & 0 & P_{33} & P_{34} & P_{35} & 0 \\ P_{41} & 0 & 0 & P_{44} & P_{45} & P_{46} \\ P_{51} & P_{52} & 0 & 0 & P_{55} & P_{56} \\ P_{61} & 0 & 0 & P_{64} & 0 & P_{66} \end{bmatrix} \end{array}$$

4.4 Permanent representation of P/M enabler matrix.

Digraph is a pictorial representation but computing analysis, it converts into mathematical format, such that convert in matrix. In matrix format analysis is easy and convenient. According Deo (1999),

F = (P_{ij}) Where p_{ij} representation the interaction of i^{th} enabler to j^{th}enabler. Here p_{ij}=pji because enablers are directional. P_{ij}= 0 It means enabler are not interact with each other. The digraph and matrix not a unique nature because alter the node than alter the matrix. Hence develop a unique representation which is independent of node. It is a powerful tool to analysis the function. In this function does not contain negative sine.

Pre F* $=\prod_{i=1}^{6} Pi+$
$\sum_{ijklm}(pijpji)PkPlPmPn+$
$\sum_{ijklm}(pijpjkpki + pikpkjpji)PlPmPn+($
$\sum_{ijklmn}(pijpji)(pklplk)PmPn+$
$\sum_{ijklm}(pijpjkpklpli + pilplkpkjpji)\ PmPn)+$

$\sum_{ijklmn}(pijpji)(pklplmpmk + pkmpmlplk)Pn+$
$\sum_{ijklmn(}pijpjkpklplmpmi + pimpmlplkpkjpji)Pn$
$+$
$\sum_{ijklmn}(pijpji)(pklplnpmnpnk + pknpnmpmlplk)$
$+\sum_{ijklmn}(pijpjkpki)(plmpmnpml)+$
$\sum_{ijklmn}(pijpji)(pklplk)(pmnpnm)+$
$\sum_{ijklmn}(pijpjkpklplmpmnpni + pinpnmpmlplkpkjpji))$

It is a mathematical expression in symbolic form.

1.In the first group represents six major enabler $P_1P_2P_3P_4P_5P_6$areinteract among them self.

2.In second group no, self-loop in the digraph.

3.In 3rd group represents two elements inter dependences loop ($P_{ij}P_{ji}$) and P/M enabler remaining four unconnected elements.

4.In fourth group, Represents the product of three elements interdependences loop ($P_{ij}P_{jk}P_{ki}$ or $P_{ik}P_{kj}P_{ji}$) and remaining three uncounted elements.

5.In fifth group contain two sub group, In first subgroup contain ($P_{ij}P_{ji}$ or $P_{kl}P_{lk}$) and second subgroup the product of four element interdependences loop ($P_{ij}P_{jk}P_{kl}P_{li}$ or $P_{il}P_{lk}P_{kj}P_{ji}$) and P_mP_n .

6.In the six subgroups contain two subgroups, in first subgroup is the product of ($P_{ij}P_{ji}$) and ($P_{kl}P_{lm}P_{mk}$ or $P_{km}P_{ml}P_{lk}$) and enabler P_N. Second subgroup is product of in of four element interdependences loop ($P_{ij}P_{jk}P_{kl}P_{lm}P_{mi}$ or $P_{im}P_{ml}P_{lk}P_{kj}P_{ji}$) and P_n .

7.In seventh group consist of four subgroups, In first subgroup, product of two elements ($P_{ij}P_{ij}$) and four elements ($P_{kl}P_{lm}P_{mn}P_{nk}$) . In second subgroup the product of three elements ($P_{ij}P_{jk}P_{ki}$)and($P_{lm}P_{mn}P_{nl}$). In 3rd subgroup, the product of three interdependencies loops of two element each ($P_{ij}P_{ji}$ $P_{kl}P_{lk}$ and P_{mn} p_{nm}). In four subgroups contain six elements interdependences loop ($P_{ij}P_{jk}$ $p_{kl}P_{lm}P_{mn}P_{ni}$).

Pre F* = $P_1P_2P_3P_4P_4P_5P_6$ $+((p_{13}p_{31})P_2P_3P_4P_5P_{6+}(p_{14}p_{41})P_2P_3P_5P_6+(p_{15}p_{51})P_2P_3P_4P_6+(p_{16}p_{61})P_2P_3P_4P_5)+((p_{13}p_{34}p_{41})P_2P_5P_6+(p_{14}p_{15}p_{51})P_2P_3P_6+(p_{15}p_{56}p_{61})P_2P_3P_4+(p_{16}p_{64}p_{41})P_2P_3P_5+(p_{24}p_{45}p_{52})P_1P_3P_6+(p_{41}p_{16}p_{64})P_2P_3P_5+(p_{24}p_{45}p_{52})P_1P_3P_6+(p_{41}p_{16}p_{64})P_2P_3P_5)+((p_{13}p_{31})(p_{25}p_{52})P_4P_6+(p_{46}p_{64})(p_{13}p_{31})P_2P_5+(p_{46}p_{64})(p_{25}p_{52})P_1P_3+(p_{52}p_{25})(p_{16}p_{61})P_3P_4)+(p_{12}p_{23}p_{34}p_{45}p_{56}p_{61})P_5P_6+(p_{13}p_{34}p_{41})P_5P_6+(p_{13}p_{34}p_{45}p_{51})P_2P_6+(p_{14}p_{45}p_{56}p_{61})P_2P_3)+(p_{12}p_{23}p_{34}p_{45}p_{56}p_{61}))$

4.5 Feasibility index transition for P/M

Intensity of P/M barriers determine the relative strength for all the identified barriers. The intensity of barrier depends upon their nature and interaction among the barrier.

(IOB)p/m = f(Barriers)

= f (powder production (P_1) Lubricant additive (P_2) Blending (P_3)

Compacting (P_4),Sintering (P_5),Finishing (P_6).

= Permanentfunction of P/M barriers matrix

Different factor affects barriers identified (enablers). He intensity of these factors and their interferences can be determined with the help of data available on a manufacturing or organisation and manufacturing expert person. If the quantitive value is not available than develop a scale (1 -10) and assign the value with the help of expert. Now for assign value of sub enabler(pij) with the help of expert, but it cannot be measured directly, so develop a scale (1-5) and assign the qualitative value of interdependences of sub-enabler.

Table 4 Index

S NO	Qualitative measurement	Assigned value
1	Exceptionally low	1
2	Extremely low	2
3	Very low	3
4	Below average	4
5	Average	5
6	Above average	6
7	High	7
8	Very high	8
9	Extremely high	9
10	Exceptionally high	10

Table 5 The values of interdependence barriers index

S.NO.	Qualitative measure of interdependence of barriers	Assigned value (p_{ij})

1	Very weak	1
2	Weak	2
3	Medium	3
4	Strong	4
5	Very strong	5

4.6 Comparison

Compression of different organisation on the basis of intensity of barrier in P/M i.e. IOBp/m. Two organization similar on the basis of barrier point of view and digraph. P/M barrier digraphs are similar than matrix is similar. That means the number of terms and value in each grouping must be same. Based on this criterion P/M barriers identification set for an industry is written as,

$$/A_1/\ A_2/A_3/A_4/A_{51}+A_{52}/A_{61}+A_{62S}/$$

Xi = Represent the total number of terms of i^{th} group.

Xij =Represent the total number of terms of j^{th} sub-group of thepermeant functionof P/M enablers.

Calculation of X_i and X_{ij}

Substituting of the value of Pi and P_{ij} in grouping and sub grouping in the per meant function. If no sub grouping than P_{ij} = pi (Total number of terms in i^{th} group).The compression of two organisation, on the basis of coefficient of similarity/ dissimilarity. Which are lies between 0 to 1. If coefficient similarity is 0 than both industries have dissimilar. If coefficient similarity is 1 than both industries have similar. Coefficient of dissimilarity also lies between 0 to 1. If coefficient dissimilarity is 0 than both industries have similar. If coefficient dissimilarity is 1 than both industries have dissimilar. Coefficient of dissimilarity emulated these formulas.

$$C_d = \frac{1}{R}\sum_{ij} X_{ij}$$

Where

R = maximum of $\sum A_{IJ}$ AND $\sum[A_{IJ'}$

A_{ij} and $A_{ij'}$ denote the value of the terms for the permanent function of the two organization which are compared,

$X_{ij} = |A_{ij} - A_{ij'}|$

Coefficient of similarity is calculated as follows:

$$C_s = 1 - C_d$$

Help of theses equations comparing of two organizations according to P/M enablers.

5.Methodology

1.Identify the various process (Enablers) in powder metallurgy.

2.Develop their digraph and relate their dependences.

3.Identify their various subfactor (sub enablers) Those factors having production depends.

4.Develop the digraph, all enabler and sub enablers.

5.Develop the matrix, all enabler and sub enablers.

6.Calculate the permanent function for enabler and sub enabler.

7. Develop the matrix n*n with diagonal element P_i and diagonal off element P_{ij}.

8.Calculate the value of permeant function using the matrix.

9.FIT value of different origination arranges ascending order.

10. Calculate the identification set for each organisation.

11.Calculate the coefficient of similarity and dissimilarity.

12.Record and document these result for feature use.

6.1 Data Analysis

According to this mythology, visited to an auto part industry which manufactures auto part by using sintered powdered metallurgy. It is found after enquiring with the management that production of some auto part is very low and rejection was quite high. Now the conversation the management and expert person collect data. Identify six enablers and 30 sub enablers. Now Graph theory application is applying.

1. Identify six enablers in table 1.
2. A digraph develops in fig 2 for six major enablers.
3. Sub enabler are identified in table 1
4. Develop the digraph each category enabler's fig 3-8.
5 Total 30 sub enablers are discus with export (as per two scale (1-10) and(1 - 5)
6 The permanent function of each category is calculated

Per F* = $P_1\ P_2\ P_3\ P_4\ P_5+ ((p_{12}p_{21})P_3P_4P_5+(p_{13}p_{31})P_2P_4P_5+(p_{15}p_{51})P_2P_3P_4+(p_{25}p_{52})P_1P_3P_4+(p_{24}p_{42})P_1P_3P_5+(p_{25}p_{52})P_1P_3P_4+(p_{31}p_{13})P_2P_4P_5+(p_{32}p_{23})P_1P_4P_5+(p_{34}p_{43})P_1P_2P_5+(p_{35}p_{53})P_1P_2P_4+(p_{42}p_{24})P_1P_3P_5+(p_{45}p_{54})P_1P_2P_3+(p_{52}p_{25})P_1P_3P_4+(p_{53}p_{35})P_1P_2P_4P_5+(p_{54}p_{45})P_1P_2P_{3+}(p_{12}p_{23}p_{31})P_4P_5+(p_{15}p_{13}p_{31})P_2P_4+(p_{13}p_{31})(p_{24}p_{45}p_{52})+(p_{21}p_{12}$

$)(p_{34}p_{45}p_{52})+(p_{31}p_{13})(p_{24}p_{45}p_{51}))+((p_{12}p_{21})(p_{34}p_{45})+(p_{13}p_{31})(p_{24}p_{42})+(p_{13}p_{31})(p_{25}p_{52})+(p_{15}p_{51})(p_{23}p_{32}))$
=120990

Similarly, each category calculated below

Pre F_2=90378, Pre F_3= 16380 Pre F_4= 639204 Pre F_5=13764 Pre F_6=23040

7. P/M matrix develop as per equation 1

P_2=pre F_2=90378. P_3=pre F_3 =16380, P_4=pre F_4=639204, P_5=pre F_5=13764, P_6=preF_6=23040

Table 6

	P_1	P_2	P_3	P_4	P_5	P_6
P_1	1209900	0	0	0	3	0
P2	0	90378	3	2	2	0
F=P_3	1	0	16380	2	3	0
P_4	0	0	0	639204	5	3
P_5	2	2	0	0	13764	3
P_6	0	0	0	2	2	23040

8. The value of permanent function is evaluated 3.63072 $*10^{28}$. This value shows that different enablers and their independence.

The P/M powder production barriers' digraph

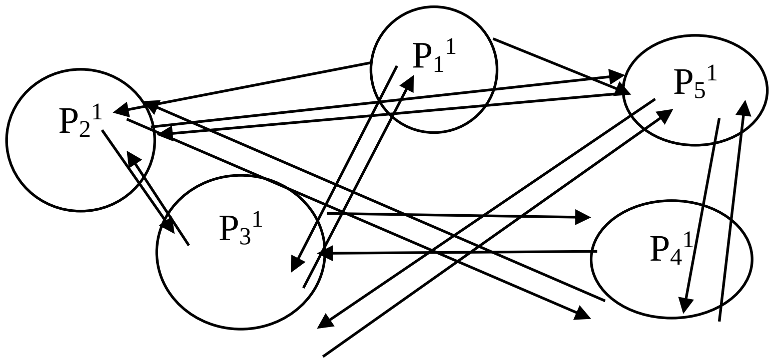


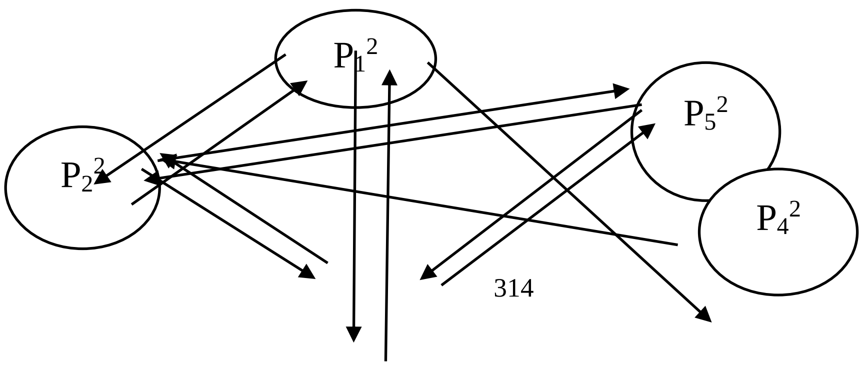
Figure 3The P/M powder production barriers' digraph

Table 7

Matrix representation of the P/M powder production barriers' digraph

$$F_1 = \begin{bmatrix} 8 & 4 & 4 & 0 & 3 \\ 0 & 9 & 5 & 4 & 4 \\ 2 & 5 & 9 & 4 & 4 \\ 0 & 4 & 5 & 7 & 4 \\ 0 & 4 & 4 & 3 & 7 \end{bmatrix}$$

The P/M additive lubricant barriersdigraph.



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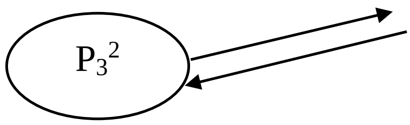
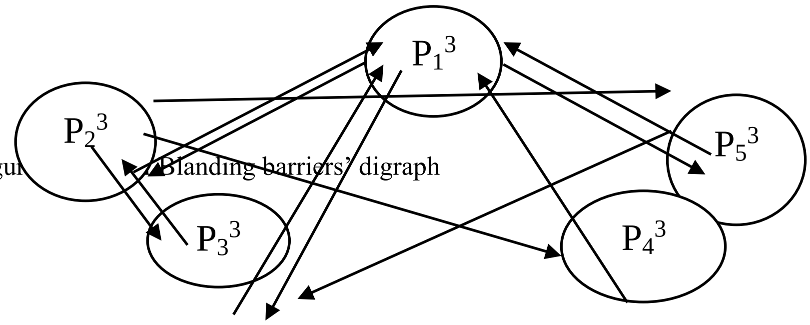


Figure 4 The P/M Additive lubricant barriers' digraph

Table 7 Matrix representation of the P/M Additive lubricant barriers' digraph

$$F_2 = \begin{bmatrix} 7 & 3 & 3 & 3 & 0 \\ 2 & 7 & 4 & 2 & 5 \\ 2 & 4 & 7 & 4 & 4 \\ 2 & 4 & 0 & 8 & 5 \\ 0 & 4 & 4 & 4 & 8 \end{bmatrix}$$

The P/M blending barriers digraph.



Figu Blanding barriers' digraph

Table 8Matrix representation of the P/M blending process barriers' digraph

$$F_3 = \begin{bmatrix} 7 & 3 & 3 & 3 & 3 \\ 4 & 7 & 2 & 0 & 2 \\ 0 & 3 & 7 & 0 & 4 \\ 2 & 2 & 0 & 6 & 0 \\ 2 & 0 & 4 & 0 & 7 \end{bmatrix}$$

The P/M compacting process barriers' digraph

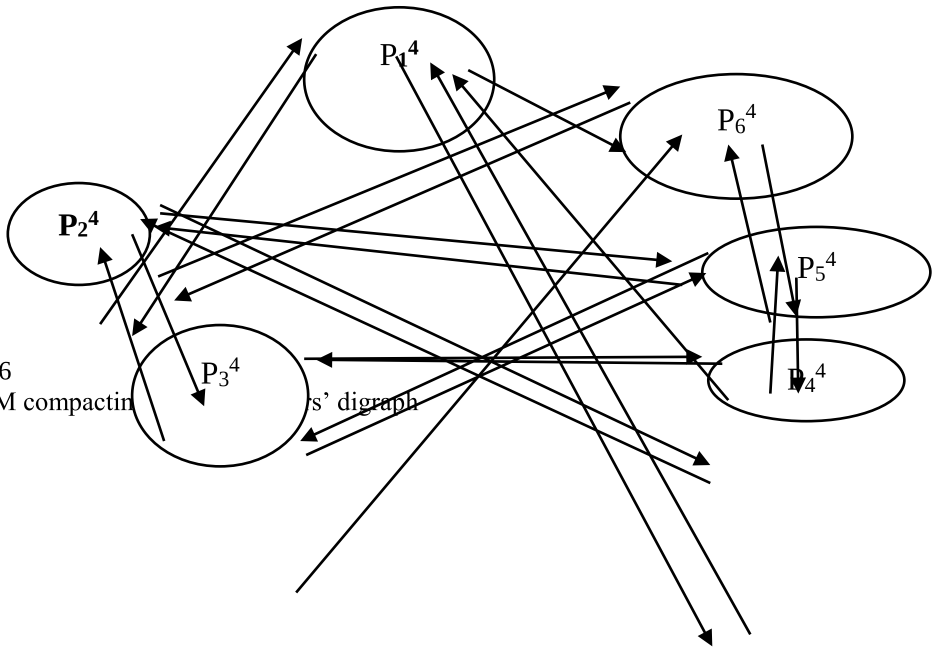


Figure 6
The P/M compactin s' digraph

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Table 9
Matrix representation of the P/M blending process barriers' digraph

$$F_4 = \begin{bmatrix} 850404 \\ 495555 \\ 047454 \\ 350944 \\ 254484 \end{bmatrix}$$

The P/M sintering process barriers' digraph

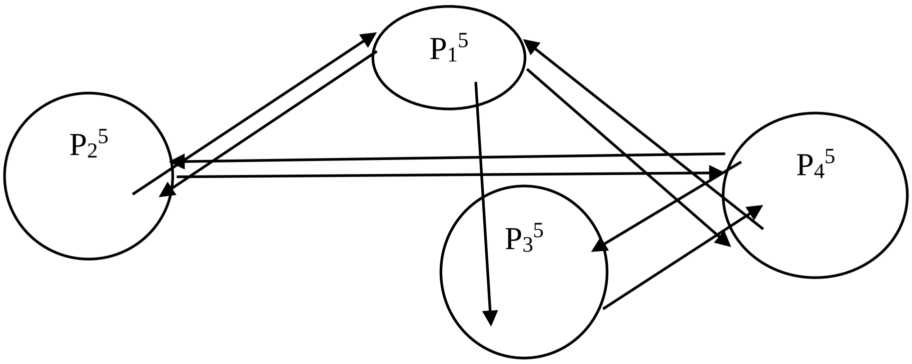

Figure 7 The P/M sintering process barriers' digraph

Table 10 Matrix representation of the P/M compacting process barriers' digraph

$$F_5 = \begin{bmatrix} 9 & 5 & 3 & 4 \\ 5 & 9 & 0 & 4 \\ 4 & 4 & 7 & 4 \\ 5 & 4 & 2 & 8 \end{bmatrix}$$

The P/M finishing process barriers' digraph

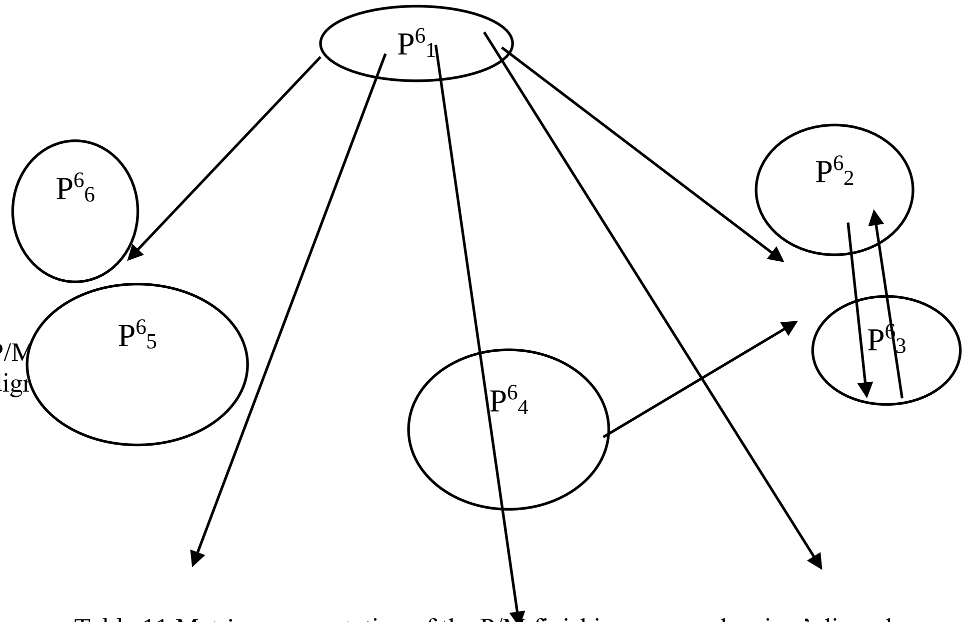

Fig 8The P/M barriers' digr

Table 11 Matrix representation of the P/M finishing process barriers' digraph

$$F_6 = \begin{bmatrix} 833442 \\ 084300 \\ 048000 \\ 000600 \end{bmatrix}$$

6.2 Comparison

In this methodology using the discussed in section 4.6, comparing any two-industry reading their feasibility process. Taking the two industry and collect the data and compression both are how much similar or dissimilar. Now second industry is considering whose data is taken.

P_1, = 12000, P_2, = 90000, P_3' =9000, P_4, =60000, P_5, =13000, P_6, = 10000, and P_{14}, = 2, p_{15}, =3, p_{23}, = 3, p_{25}, = 3, p_{24}, = 5, p_{31}, = 2, p_{34}, = 3, p_{35}, =5, p_{45}, = 3, p_{46},=3, p_{51}, =3 p_{52}, =3 p_{56} =5 p_{61},=2 p_{64},=2 p_{65},=2,

Table 12: Second origination matrix

F, =

	P_1	P_2	P_3	P_4	P_5	P_6
P_1,	120000	0	0	2	3	0
P_2,	0	90000	3	5	3	0
P_3,	2	0	90000	3	5	0
P_4,	0	0	0	300000	3	3
P_5,	3	3	0	0	13000	5
P_6,	2	0	0	0	2	10000

The value of permanent function in 2nd organisation is found to be 3.6708 $*10^{27}$

Hence

$$C_d = \frac{1}{R} \sum_{ij} X_{ij}$$

Where:

R = 3.63072$*10^{28}$and $\sum x_{ij}$ =32.3282$*10^{27}$

C_d = 0.890407

Now find coefficient of similarity

C_s = 1-C_d = 1- 0.890407 =0.109592

This result shows that high co efficient of dissimilarity between the two organisations and very low coefficient of similarity.

7.Discussion

In this present methodology to evaluate the flexibility index on technology transition. This methodology based on the influence of the enablers. Data regarding the available resource in the company and other enablers of P/M have been obtain through a questionnaire floated in the industry33 response obtain from discussion through engineers, technicians and management. Now four experts have same opinion. Use a "GRAPH THEORY APPLICATION" and develop a enablers diagram and sub enablers diagram and then develops a matrix. Now develop a flexibility index and compression with other industry. Found to be very low production and quality. In this paper found to be powder production in optimum temperature, control atmosphere, and pressures are critical factor such that those factors control by different processSuch that improve the density, surface finish, and other parameters.

8.Conclusion:

Powder metallurgy is net shaping forming process, consist of producing metal powders, blending, compacting in dies, sintering to strength, hardness and toughness. Compaction may also be carried out by cold or hot isocratic pressing, for improved properties. Although the size and the weight of its products are limited, the P/M process is capable of producing relatively complex parts economically, in net shape form, to close dimensional tolerances, from a wide variety of metal and alloy powder.

Control of powder shape and quality, of process variables, and of sintering atmospheres are important considerations in product quality. Density, mechanical, and physical properties can be controlled by tooling design by compacting pressure.

Secondary operation improves the surface finish, quality, dimensional accuracy, mechanical and physical properties and appearance operation perform according to required.

To develop the FIT index so that judge that critical factors and controlled it,such that improve the quality and productive

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