

ESE 2019

UPSC ENGINEERING SERVICES EXAMINATION

Main Examination

*Thoroughly
Revised and
Updated*

19 Years
Previous Solved Papers

Mechanical Engineering

Topicwise **Conventional** Solved Questions

Paper-II

Also useful for
State Engineering Services Examinations



www.madeeasypublications.org



MADE EASY Publications

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016

E-mail: infomep@madeeasy.in

Contact: 011-45124660, 0-8860378007

Visit us at: www.madeeasypublications.org

Mechanical Engineering Topicwise Conventional Solved Questions : Paper-II

© Copyright, by MADE EASY Publications.

All rights are reserved. No part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photo-copying, recording or otherwise), without the prior written permission of the above mentioned publisher of this book.

1st Edition : 2011

2nd Edition : 2012

3rd Edition : 2013

4th Edition : 2014

5th Edition : 2015

6th Edition : 2016

7th Edition : 2017

7th Edition: 2018

MADE EASY PUBLICATIONS has taken due care in collecting the data and providing the solutions, before publishing this book. In spite of this, if any inaccuracy or printing error occurs then MADE EASY PUBLICATIONS owes no responsibility. MADE EASY PUBLICATIONS will be grateful if you could point out any such error. Your suggestions will be appreciated.

Director's Message

During the last few decades of engineering academics, India has witnessed geometric growth in engineering graduates. It is noticeable that the level of engineering knowledge has degraded gradually, while on the other hand competition has increased in each competitive examination including GATE and UPSC examinations. Under such scenario higher level efforts are required to take an edge over other competitors.



B. Singh (Ex. IES)

The objective of MADE EASY books is to introduce a simplified approach to the overall concepts of related stream in a single book with specific presentation. The topic-wise presentation will help the readers to study & practice the concepts and questions simultaneously.

The efforts have been made to provide close and illustrative solutions in lucid style to facilitate understanding and quick tricks are introduced to save time.

Following tips during the study may increase efficiency and may help in order to achieve success.

- Thorough coverage of syllabus of all subjects
- Adopting right source of knowledge, i.e. standard reading text materials
- Develop speed and accuracy in solving questions
- Balanced preparation of Paper-I and Paper-II subjects with focus on key subjects
- Practice online and offline modes of tests
- Appear on self assessment tests
- Good examination management
- Maintain self motivation
- Avoid jumbo and vague approach, which is time consuming in solving the questions
- Good planning and time management of daily routine
- Group study and discussions on a regular basis
- Extra emphasis on solving the questions
- Self introspection to find your weaknesses and strengths
- Analyze the exam pattern to understand the level of questions
- Apply shortcuts and learn standard results and formulae to save time

B. Singh (Ex. IES)

CMD, MADE EASY Group

Conventional Solved Questions of UPSC Engineering Services Examination

1. Mechanisms and Machines..... 1-63	4. Manufacturing Engineering 178-279
1. Simple Mechanisms..... 1	1. Metal Cutting and Machine Tools..... 178
2. Velocity and Acceleration..... 7	2. Metal Forming 199
3. Kinematic and Dynamic Analysis..... 13	3. Powder Metallurgy..... 218
4. Cams and Follower..... 16	4. Casting..... 223
5. Gear and Gear Trains 21	5. Welding 233
6. Flywheel..... 33	6. Non-Traditional Machining Methods 250
7. Balancing..... 36	7. Metrology..... 259
8. Governors..... 49	8. CAD/CAM and Automation..... 267
9. Mechanical Vibrations..... 53	
10. Gyroscope 63	5. Industrial & Maintenance Engg.. 280-333
2. Strength of Materials 64-124	1. Break Even Analysis..... 280
1. Simple Stress-strain & Elastic Constant..... 64	2. Inventory Control 284
2. Strain Energy and Thermal Stresses..... 68	3. Forecasting 292
3. Shear Force & Bending Moment Diagram.... 74	4. PERT/CPM..... 303
4. Bending Stress and Shear Stress in Beams ... 79	5. Linear Programming..... 309
5. Torsion of Shafts..... 91	6. Assignment and Transportation..... 315
6. Principal Stress-strain & Theories of Failure .. 99	7. Queuing Theory 324
7. Deflection of Beams 108	8. Sequencing..... 327
8. Pressure Vessels..... 112	9. Production Planning and Control..... 328
9. Theory of Columns..... 116	10. Line Balancing 329
10. Engineering Mechanics..... 118	11. Miscellaneous 330
3. Design of Machine Elements 125-177	6. Engineering Materials..... 334-352
1. Bearing 125	1. Crystal System..... 334
2. Clutches 134	2. Phase Diagrams..... 338
3. Gear 139	3. Heat Treatment..... 341
4. Bolted, Welded and Riveted Joint..... 143	4. Properties and Application of Ferrous and Non-Ferrous Material..... 346
5. Joint, Shaft, Key and Coupling..... 149	5. Plastic, Ceramic and Composite..... 350
6. Belt, Rope and Chain Drive 161	
7. Power Screw 167	7. Mechatronics and Robotics 353-364
8. Spring..... 172	
9. Fly Wheel..... 176	



4

Manufacturing Engineering

Revised Syllabus of ESE : *Metal casting-Metal forming, Metal Joining, Machining and machine tool operations, Limits, fits and tolerances, Metrology and inspection, computer Integrated manufacturing, FMS.*

1. Metal Cutting and Machine Tools

Q.1 Discuss in brief the flank and crater tool wear mechanisms.

In a certain machining operation with a cutting speed of 50 m/min, tool life of 45 minutes was observed. When the cutting speed was increased to 100 m/min, the tool life decreased to 10 minutes. Estimate the cutting speed for maximum productivity, if tool change time is 2 minutes. [10 marks : 2001]

Solution:

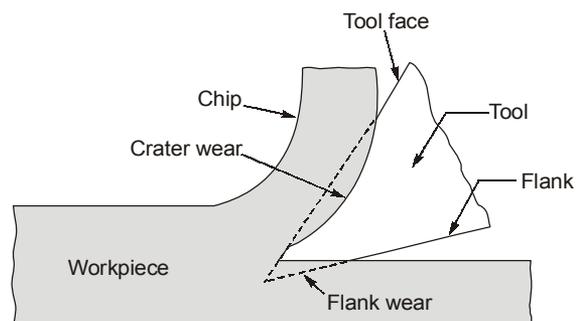
Face wear (Crater wear):

- On the face of the tool there is a direct contact of tool with the chip. Wear takes the form of cavity or crater, which has its origin above the cutting edge. With time, cavity goes on widening. This is prominent in ductile materials. The crater occurs on the rake face of the tool at the point of impingement of the chip with tool and does not actually reach the cutting edge but ends near the nose and on the periphery which serves as the focal points of development of crack and extends to the cutting edge causing a rapid rupture. It leads to weakening of tool, increase in cutting temperature, friction and cutting forces. The tool life due to crater wear can be determined by fixing the ratio of width of crater to its depth.

Flank wear (Edge wear):

- This wear is also called “wearland”. Work and tool are in contact at cutting edge only. Usually wear first appears on the clearance face of the tool in the form of a wear land, and is mainly the result of friction and abrasion.
- Adhesion is also a factor because welding of the tool to the work material causes a built-up edge which is torn away, taking particles of the tool material with it. Thermal cracking, due to thermal shock, is also a cause of breakdown of small particles, leading to flank or edge wear.
- Flank wear starts at cutting edge and then starts widening along the clearance face. It is independent of cutting conditions and tool/work materials.

Crater wear is prominent in ductile metals, but the flank wear becomes predominant in materials having brittle and flaky chip and discontinuous chip. It is important even in ductile materials if surface finish is the main criteria.



- While all other modes of tool failure can be effectively reduced by changing speed, feed or depth of cut, the flank wear is a progressive form of deterioration which will ultimately result in failure inspite of best precautions.

Given data: $V_1 = 50$ m/min; $T_1 = 45$ min; $V_2 = 100$ m/min; $T_2 = 10$ m/min

$$VT^n = \text{constant} = C$$

$$V_1 T_1^n = V_2 T_2^n$$

$$50(45)^n = 100(10)^n$$

$$4.5^n = 2$$

$$n = 0.46; \quad \therefore C = 50(45)^{0.46} = 288.04$$

Optimum speed for max. productivity: Max. productivity means minimum time of production.

\therefore Production time

$T =$ tool change time + cutting time

$$= \left(\frac{L}{f} \frac{\pi D}{1000 V} \right) \times \frac{T_c}{\text{tool life}} + \left(\frac{L}{f} \right) \times \frac{\pi D}{1000 \cdot V} = \frac{\pi DL}{1000f} \left[\frac{1}{V} + \frac{1}{V} \frac{T_c}{\text{tool life}} \right]$$

$$= \frac{\pi DL}{1000f} \left[\frac{1}{V} + \frac{T_c}{V \left(\frac{C}{V} \right)^{\frac{1}{n}}} \right] \quad \left[\because VT^n = C \right]$$

$$T = \frac{\pi DL}{1000f} \left[\frac{1}{V} + \frac{T_c}{C^{1/n}} \cdot V^{\left(\frac{1}{n} - 1 \right)} \right] \quad \left[T = \left(\frac{C}{V} \right)^{\frac{1}{n}} \right]$$

For max. production $\left(\frac{dT}{dV} \right) = 0$

$$\left(\frac{dT}{dV} \right) = \frac{\pi DL}{1000f} \left[-\frac{1}{V^2} + \frac{T_c}{C^{1/n}} \left(\frac{1}{n} - 1 \right) \cdot V^{\frac{1}{n} - 2} \right] = 0$$

$$\therefore \frac{\pi DL}{1000f \cdot V^2} \left[\frac{T_c}{C^{1/n}} \left(\frac{1}{n} - 1 \right) V^{\frac{1}{n}} - 1 \right] = 0$$

$$V^{1/n} = \frac{C^{1/n}}{T_c \left(\frac{1}{n} - 1 \right)} \quad (T_c = \text{tool changing time})$$

$$V = \frac{C}{\left[T_c \left(\frac{1}{n} - 1 \right) \right]^n} = \frac{288.04}{\left[2 \times \left(\frac{1}{0.46} - 1 \right) \right]^{0.46}} = 194.5 \text{ m/min}$$

Q.2 How does a cutting tool fail?

[10 marks : 2002]

Solution:

Some of the possible tool failure criteria are

- Tool wear
- Chipping or fine cracks developing at the cutting edge
- Wear land size
- Crater depth, width or other parameters
- Volume or weight of material worn off the tool
- Total destruction of the tool

- Failure of tool implies when the tool ceases to function satisfactorily. Among the various failures are: tool point gets blunt, gets fractured, foreign materials from work gets welded onto it, or the microstructure changes thus reducing the hardness from the optimum value. Failure could be caused due to the following reasons.
- **Temperature Failure:** During machining at high speeds, very high temperature exists at tool chip interface. When temperature exceeds the critical limit, the tool point gets softened. Due to this high temperature, localised phase transformation occurs. This gives rise to high residual stresses due to which cracks appear in the tool point and in such a state, it is more prone to failure. In some cases tool point might even melt. This type of failure occurs quite rapidly, and is frequently accompanied by sparking and is easily recognised. Thermal cracking occurs when there is a sudden temperature gradient due to intermittent cutting. Thermal shock combined with mechanical impact lead to failure.
- **Rupture of Tool Point:** At slow speeds, built up edge is formed on the tool. When it grows too much, it is unstable and breaks away with the underside of the chip, taking away a small portion of tool with it.
- Tool are generally hard. A large degree of brittleness is associated with hardness especially in case of carbide and diamond tipped tools. Whenever the cutting forces exceed the critical limit, small portions of the cutting edge begin to chip off, or the entire tip may break away in some cases.
- The high forces, which produce this type of failure are not generally associated with steady state cutting but rather with variations in the cutting process or when cutting with excessive vibration (Chatter).

Q.3 In a drilling operation under a given condition, the tool life was found to decrease from 20 min to 5 min due to increase in drill speed from 200 rpm to 400 rpm. What will be the tool life of that drill under the same condition if the drill speed is 300 rpm?

[15 marks : 2002]

Solution:

$$\therefore T_1 = 20 \text{ min at } N_1 = 200 \text{ rpm}$$

$$T_2 = 5 \text{ min at } N_2 = 400 \text{ rpm}$$

But Taylor's tool life equation for drilling

$$N_1 T_1^n = N_2 T_2^n = \text{constant} \quad \dots(i)$$

$$\therefore 200(20)^n = 400(5)^n$$

$$4^n = 2$$

$$\therefore n = 0.5$$

$$\therefore \text{Tool life at } N_3 = 300 \text{ rpm}$$

$$\therefore N_1 T_1^n = N_3 T_3^n$$

$$200(20)^{0.5} = 300.T_3^{0.5}$$

$$T_3 = 20 \left(\frac{200}{300} \right)^2 = 8.89 \text{ min.}$$

Q.4 The thickness of a rectangular brass plate of length L_w and width B_w has to be reduced by t mm in one pass by a helical fluted plain or slab milling cutter of length $l_c (> B_w)$, diameter D_c and number of teeth, Z_c at cutting velocity, V_c m/min and feed, S_0 mm/tooth. How will you determine the time that will be required to accomplish the aforesaid work? All other dimensions are in mm.

[10 marks : 2002]

Solution:

$$\text{The length of a rectangular brass plate} = L_w$$

$$\text{Width} = B_w$$

$$\text{The length of a slab milling cutter} = l_c (> B_w)$$

The diameter of a slab milling cutter = D_c

Thickness to be reduced in one pass = t

Number of teeth = Z_c

Cutting velocity = V_c m/min

Feed = S_0 mm/tooth

Feed per cutter revolution = $S_0 \times Z_c$

= $S_0 Z_c$ mm/rev

Let, Take number of revolutions per minute = N

We know that, $V = \frac{\pi D_c}{1000} \Rightarrow V_c = \frac{\pi D_c}{1000}$

Number of rotations, $\Rightarrow N = \frac{V_c \times 1000}{\pi D_c}$

{ $\therefore V_c \rightarrow$ m/min, $N \rightarrow$ rev./min. take, L_w, D_c in mm i.e., D_c mm = $\left(\frac{D_c}{1000}\right)$ m }

Distance travelled in 1 min. = $S_0 Z_c \times N = S_0 Z_c \times \frac{V_c \times 1000}{\pi D_c}$ mm

\therefore Time taken to travel a distance (L_w) mm

$$= \frac{L_w}{S_0 Z_c \times \frac{V_c \times 1000}{\pi D_c}} = \frac{\pi D_c L_w}{(S_0 Z_c) \times (1000 V_c)}$$

Q.5 During turning a carbon steel rod of 160 mm diameter by a carbide tool of geometry, $0^\circ, 0^\circ, 10^\circ, 8^\circ, 15^\circ, 75^\circ, 0$ (mm) at speed of 400 rpm, feed of 0.32 mm/rev. and 4.0 mm depth of cut, the following observations were made :

Tangential component of the cutting force, $P_z = 1200$ N.

Axial component of the cutting force, $P_x = 800$ N

Chip thickness (after cut), $t_2 = 0.8$ mm

For the above machining condition determine the values of

- Friction force F and normal force N acting at the chip-tool interface.
- Yield shear strength of the work material under this machining condition.
- Cutting power consumption in kW.

[20 marks : 2003]

Solution:

- Since the second last value in the tool signature is very high and the side cutting edge angle as per ASA can not be so high. So, ORS tool signatures are given in the above problem. So approach angle = 75° ; $D = 160$ mm

$$N = 400 \text{ rpm}$$

$$f = 0.32 \text{ mm/rev.}$$

$$d = 4 \text{ mm}$$

$$F_C = 1200 \text{ N}$$

$$F_F = 800 \text{ N}$$

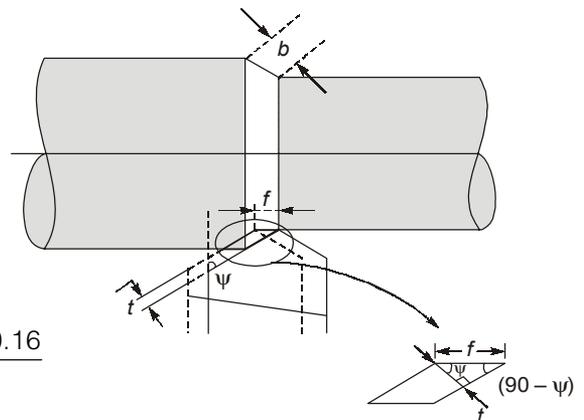
$$t_2 = t_c = 0.8 \text{ mm}$$

Find: (i) F, N (ii) τ_s (iii) P_C

$$\alpha = 0$$

$$V = \frac{\pi DN}{60} = \frac{\pi \times 400 \times 0.16}{60}$$

$$V = 3.35 \text{ m/s}$$



$$\begin{aligned}
 F_R &= F_T \sin \psi \\
 F_F &= F_T \cos \psi \\
 \psi &= 90^\circ - 75^\circ = 15^\circ \\
 800 &= F_T \cos 15^\circ \\
 F_T &= 828.22 \text{ N} \\
 F &= F_T \cos \alpha + F_C \sin \alpha \\
 \Rightarrow F &= 828.22 \text{ N} \\
 N &= F_C \cos \alpha - F_T \sin \alpha \\
 N &= 1200 \text{ N}
 \end{aligned}$$

$$2. \quad \frac{F_S}{\left(\frac{b \cdot t}{\sin \phi}\right)} = \tau_s ; \quad \tan \phi = \frac{\cos \alpha}{\frac{t_c}{t} - \sin \alpha}$$

$$\text{As } \alpha = 0 \text{ then } \tan \phi = \frac{t}{t_c}$$

$$t = f \cos \psi = 0.31 \text{ mm} ; \quad b = \frac{d}{\cos \psi} = 4.14 \text{ mm}$$

$$\tan \phi = \frac{0.31}{0.8}$$

\Rightarrow

$$\phi = 21.18^\circ$$

$$F_S = F_C \cos \phi - F_T \sin \phi = 1200 \cos 21.18^\circ - 828.22 \sin 21.18^\circ$$

$$F_S = 819.7 \text{ N}$$

$$\tau_s = \frac{819.7 \sin 21.18^\circ}{0.31 \times 4.14} = 230.76 \text{ MPa}$$

$$3. \quad P = F_C V = 1200 \times 3.35 = 4020 \text{ W}$$

Q.6 Name the processes by which external screw threads can be produced (both manually using tools and in machines). [10 marks : 2003]

Solution:

The process by which external screw threads can be produced are:

1. Casting: (i) Sand casting (ii) Die casting (iii) Permanent mould casting (iv) Plastic moulding (v) Shell moulding (vi) Low-wax casting
2. Rolling
3. Chasing: (i) Single-point tool (ii) Multiple-point tool
4. Die and tap cut
5. Milling
6. Grinding

Q.7 (i) What are the detrimental effects of the high cutting temperature on the machined product and the cutting tool? (ii) How can such cutting temperature be reduced without sacrificing productivity? [6 + 4 = 10 marks : 2003]

Solution:

(i) Detrimental effects of the high cutting temperature on the

(a) Machined product:

- Welding of chips to the work piece
- Dimensional errors due to stresses generated
- Low surface finish

(b) On the cutting tool:

- Welding of chips to tool
- Excessive tool wear and its affects on the life of a tool
- Overheated at isolated points and localized phase transformation can occur.
- Softening of the surface of the tool and frequently very small cracks will be formed, that results in surface transformation.

(ii) Such cutting temperature can be reduced by using cutting fluids without sacrificing productivity:

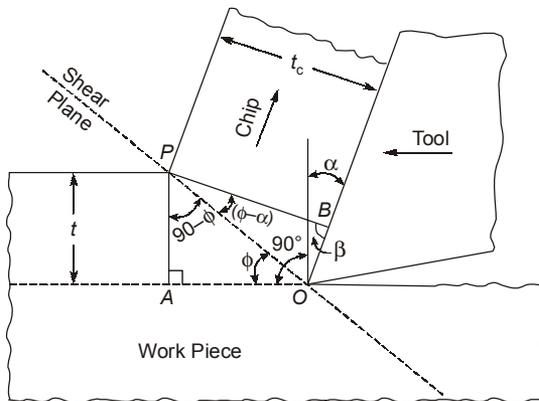
Q.8 What are the velocities which come into existence when a metal is cut orthogonally? Show these velocities graphically on a velocity diagram and determine the mathematical relationship in terms of shear and rake angles. [15 marks : 2004]

Solution:

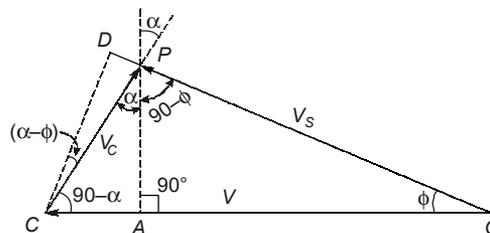
When a wedge shaped tool is pressed against the workpiece, chip is produced by deformation of material ahead of cutting edge because of shearing action taking place in a zone (Treated as single plane) known as shear plane. Shear plane separates the deformed and underformed material.

When the tool moves with the velocities V against the work, it shears the metal along the shear plane PO . The depth of cut t which is actually the feed in turning operation changes into the chip thickness t_c . This experiences two velocity components V_c and V_s (Velocity of the chip relative to the tool, and velocity of the chip relative to the workpiece along the shear plane). The former is acting along the tool face and the latter along the shear plane. **V - Cutting velocity, V_s - Shear velocity, V_c - chip velocity.**

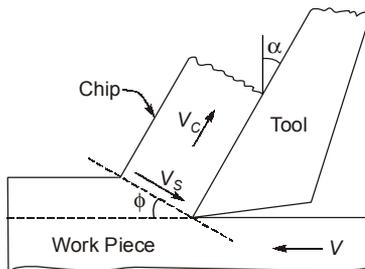
In accordance with the principle of kinematics, these three velocity vectors form a closed velocity triangle POC as shown in below figure. It may be noted that the vector sum of cutting velocity V and the chip velocity V_c is equal to the shear velocity vector V_s .



(a) Geometry of chip formation



(b) Cutting velocities triangle
{ ϕ - shear angle ; α - rake angle}



(c)

From cutting velocity triangle, in ΔOPC using sin's rule.

$$\frac{V_c}{\sin \phi} = \frac{V_s}{\sin(90 - \alpha)} = \frac{V}{\sin(90 - (\phi - \alpha))}$$

$$\therefore V \sin \phi = V_c \cos (\phi - \alpha), \text{ and } V_c = \frac{\sin \phi}{\cos(\phi - \alpha)} V$$

$$\therefore V_s = \frac{\cos \alpha}{\cos(\phi - \alpha)} V$$

The relationship between chip thickness ratio (r) and the shear angle can be obtained from the figure(a). This chip thickness ratio is defined as the ratio of the depth of cut (t) to the chip thickness (t_c). It may be noted that in fig.(a), PB which is perpendicular to tool chip interface represents t_c , i.e. chip thickness.

From the right-angle triangle PAO in fig. (a), $PO = (t/\sin \phi)$ and from the right-angle triangle PBO , $PO = t_c/\sin(\phi - \alpha)$. Comparing these two equations we have chip thickness ratio

$$r = \frac{t}{t_c} = \frac{\sin \phi}{\cos(\phi - \alpha)} = \frac{\sin \phi}{\cos \phi \cos \alpha + \sin \phi \sin \alpha}$$

$$\text{or } \frac{r \cos \phi \cos \alpha}{\sin \phi} + \frac{r \sin \phi \sin \alpha}{\sin \phi} = 1$$

$$\text{or } r \cos \alpha = (1 - r \sin \alpha) \tan \phi$$

($1/r$ is termed as chip reduction coefficient or chip compression factor and is denoted by K) and shear angle ϕ is given by the equation given below

$$\tan \phi = \frac{r \cos \alpha}{1 - r \sin \alpha}$$

Q.9 Distinguish between a jig and fixture, with the help of diagrams for at least five each.

[10 marks : 2004]

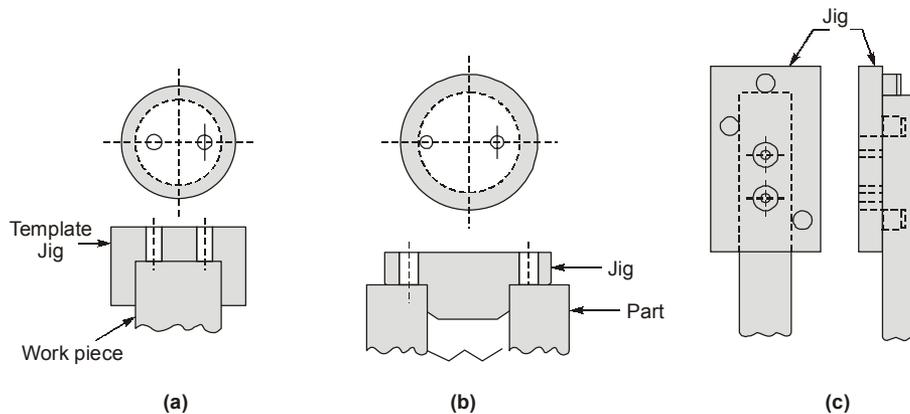
Solution:

Jig: It is described as a plate, or metal box, structure or a device usually made of steel onto or into which components can be clamped or fastened or located and held in positive manner in identical position one after the other for specific operation in such a way that it will guide one or more cutting tools to be same position or any number of similar components which may be used upon it.

Fixture: It is described as a structure for locating, holding and supporting a component or work piece securely in a definite position for a specific operation but it does not guide the cutting tool.

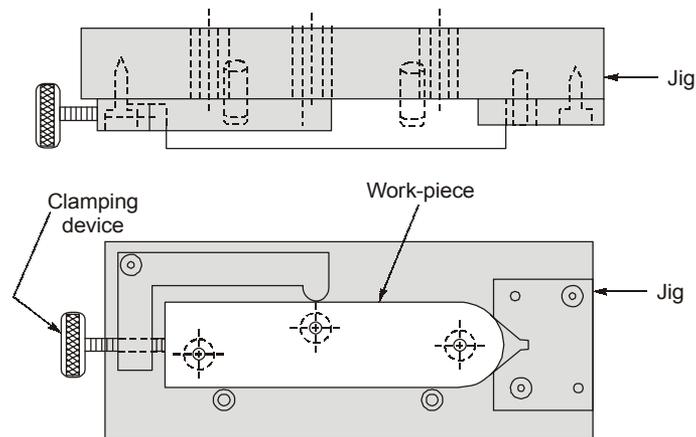
Types of Jigs:

- (i) **Template jigs:** are the simplest type used more for accuracy than speed. This type of jig fits over, on, or into the work and is not usually clamped, (Refer below Fig). If bushings are not used, then the whole jig plate is normally hardened.



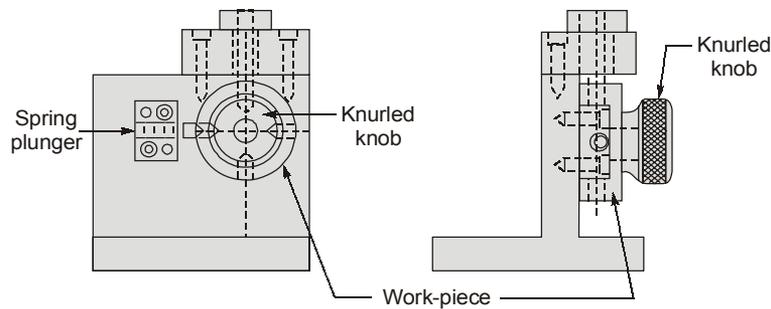
Template Jigs

- (ii) **Plate jigs:** are similar to templates excepting that these have built-in clamps to hold the work, shown in the figure below:



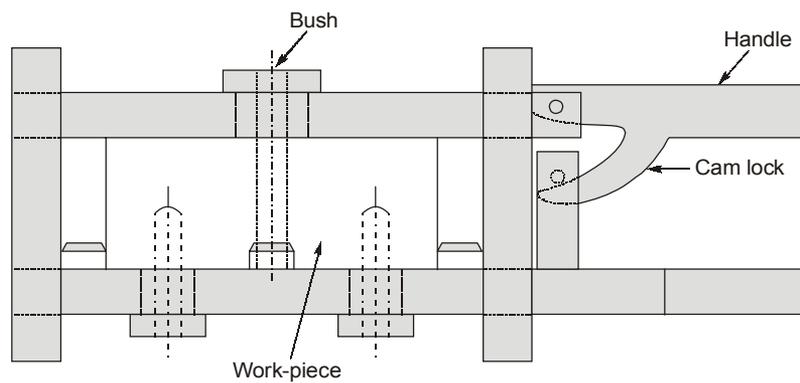
Modified angle Plate Jig

- (iii) **Angle-plate jigs:** These are used to hold parts which are to be drilled at right angles or some other angles to their mounting locators.
- (iv) **Indexing jigs:** These are used to accurately space holes or other machined areas around a part. Indexing is achieved by using a reference plate and a plunger.



Indexing Jig

- (v) **Leaf jig :** These are small box type jigs with a hinged leaf to permit easy loading and unloading of part. Normally, these do not completely surround the part.



Leaf Jig

Types of Fixture:

- (i) **Plate fixture:** It is the simplest form of popular fixture due to its adaptability. The basic fixture is made from a flat plate which has a variety of clamps and locators to hold and locate the part. It is useful for most machining operations.

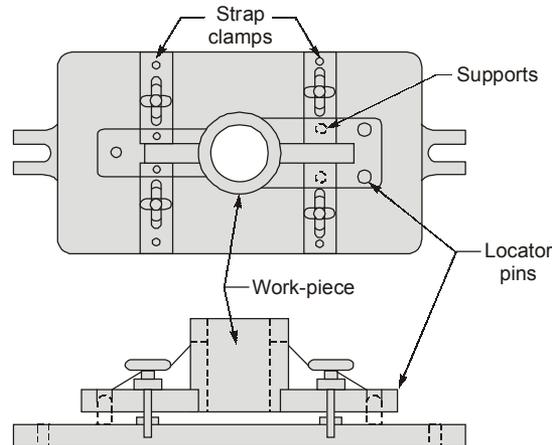
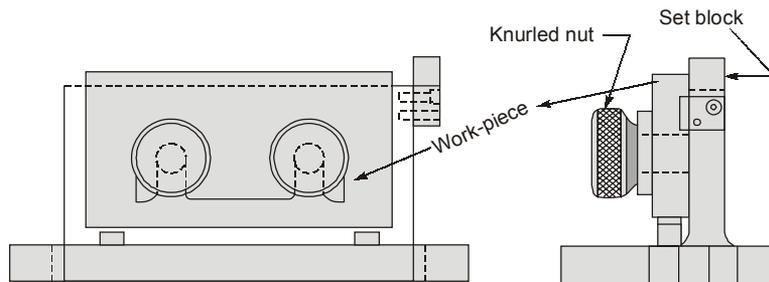


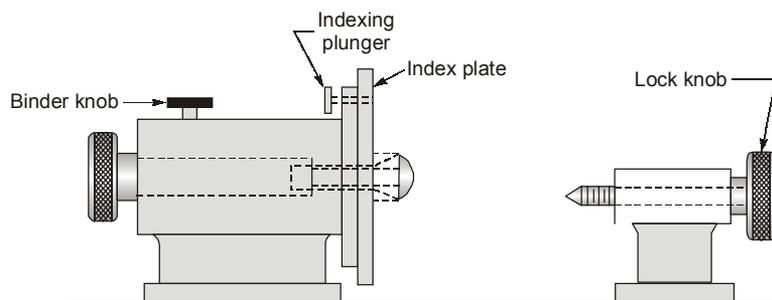
Plate fixture

- (ii) **Angle plate fixture:** This is used when the part is to be machined at right angle to its locator. Angle-plate fixtures are normally made at 90 degrees, but other angles are also possible.



Angle-Plate fixture

- (iii) **Vise-jaw fixture:** It is used for machining small parts. The standard vise jaws are replaced with jaws conforming to the shape of the part to be fitted. Their use is limited only by the sizes of the vises available.
- (iv) **Indexing fixture:** It is used for machining parts having evenly spaced machined surfaces.



Indexing fixture

- (v) **Multistation fixture :** It is used for high-speed high volume-production runs in which the machining cycle is continuous. This form of fixture allows the loading and unloading operations to be performed while the machining operations are in progress at different stations.

Q.10 Mild steel is being machined at a cutting speed of 200 m/min with a tool rake angle of 10° . The width of cut and uncut thickness are 2 mm and 0.2 mm respectively. If the average value of coefficient of friction between the tool and the chip is 0.5 and the shear stress of the work material is 400 N/mm². Determine (i) shear angle and (ii) cutting and thrust components of the machining force.

[10 marks : 2005]

Solution:

Cutting speed, $V = 200$ m/min, $\alpha = 10^\circ$, $b = 2$ mm, $t = 0.2$ mm, $\mu = 0.5$, $\tau_s = 400$ N/mm²

Friction angle, $\beta = \tan^{-1}(\mu) = \tan^{-1}(0.5)$

$$\beta = 26.57^\circ$$

(i) Using merchant's first solution to find out shear plane angle

$$2\phi + \beta - \alpha = 90^\circ$$

$$\phi = \frac{90 + 10 - 26.57}{2} = 36.7^\circ$$

$$\text{Shear force, } F_s = \frac{\tau_s \cdot b \cdot t}{\sin \phi} = \frac{400 \times 2 \times 0.2}{\sin(36.7)} = 267.72 \text{ N}$$

$$\therefore F_s = R \cdot \cos(\phi + \beta - \alpha)$$

$$\therefore R = \frac{267.72}{\cos(36.7 + 26.6 - 10)} = 447.983 \text{ N}$$

where R = resultant force of

(i) Cutting force and thrust force or

(ii) Normal and friction force at tool chip interface.

\therefore Cutting force

$$F_c = R \cos(\beta - \alpha) = 447.983 \times \cos(26.57 - 10) = 429.379 \text{ N}$$

$$\text{Thrust force, } F_T = R \sin(\beta - \alpha) = 447.983 \sin(26.57 - 10) = 127.75 \text{ N}$$

Q.11 Explain the grinding process for the following operations:

(i) Roll grinding

(ii) Thread grinding,

and explain speed, feed and depth of cut as applicable to grinding works.

[10 marks : 2005]

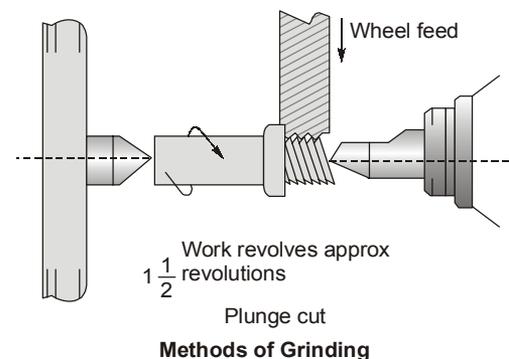
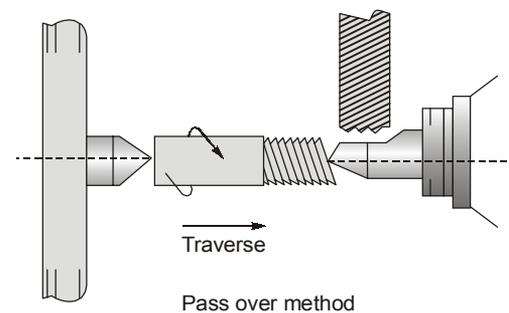
Solution:

(i) **Roll grinding:** Roll grinding is similar to cylindrical grinding with the exception that the grinders used in roll grinding are much heavier, more rigid and so it has more load carrying capacity than the grinders in cylindrical grinding.

The grinding wheel is located in a way similar to the tool post with an independent power, and is driven at high speed suitable for grinding operation. Both the work and grinding wheel rotate counter clockwise. The work that is normally held between centres is rotated at much lower speed compared to that of the grinding wheel. If the finished section to be ground is wider than the wheel, the wheel is fed in the transverse direction. Work pieces are normally mounted between centres and are driven by a dog.

Roll grinding is used for grinding "rolls" used in rolling mills.

(ii) **Thread grinding:** Internal or external threads can be finish ground by means of a single or multiple edge grinding wheel.



The threads are cut as grinding wheel (having annular thread grooves formed around (periphery) and work rotate. The process is carried on a special grinding machine having a master lead screw and gears and means of holding the work. The wheel rotates at 30 m/sec and work is rotated slowly. In the case of hardening stock probably grinding is the only means of forming threads. The accuracy of grinding exceeds that of any other method and the finish is exceeded only by good thread rolling. Pitch diameter can be ground to an accuracy of ± 0.002 mm per 25 mm and accuracy of lead may be maintained within 0.007 mm in 500 mm of thread length. Grinding eliminates tiny cracks due to hardening and also tearing is always present to some extent in any material removal method. Distortions due to heat treatment may be eliminated by grinding. Parts which would be distorted by milling threads can be satisfactorily ground. The thread parts which demand high accuracies and freedom from distortion, and stress cracks are usually made by this method.

Two variations of process are:

(i) Pass over or traverse method:

In first method the wheel is positioned at full thread depth and then the work is traversed past the wheel. The work table traverse is controlled by a master leadscrew and change gears are used to suit the thread pitch. The first thread form on the wheel gets worn out fast since it removes maximum metal, and remaining threads effecting the finish.

(ii) Plunge method:

In the case of plunge cut thread grinding, the wheel is plunged into work to full thread depth. The workpiece then makes one revolution and work traverses one pitch.

Effect of Speed: In grinding work, speed indicates the number of metres measured in the circumference of the grinding wheel, that passed the surface of the job.

Effect of Feed: It is the amount of wheel (grinding) advancement per revolution of its own parallel to the surface being machined.

Effect of Depth of cut: It is the advancement of grinding wheel in the job in a direction perpendicular to the surface being machined.

Q.12 An HSS tool is used for turning operation. The tool life is 1 hr when turning is carried at 30 m/min. The tool life will be reduced to 2.0 min if the cutting speed is doubled. Find the suitable speed in RPM for turning 300 mm diameter so that life is 30 min.

[10 marks : 2006]

Solution:

$$VT^n = C$$

when $V_1 = 30$ m/min, $T_1 = 1$ hr = 60 min.

when $V_2 = 2V_1 = 60$ m/min, $T_2 = 2$ min,

we can write $VT^n = C$

$$V_1 T_1^n = V_2 T_2^n$$

Taking log on both sides we get,

$$\log V_1 + n \log T_1 = \log V_2 + n \log T_2$$

$$n = \frac{\log\left(\frac{V_2}{V_1}\right)}{\log\left(\frac{T_1}{T_2}\right)} = \frac{\log(2)}{\log(60/2)} = 0.2$$

$\therefore C = VT^n = 30 \times (60)^{0.2} = 68$

Now for $T = 30$ min, $V = ?$, $N = ?$,

given diameter $d = 300$ mm = 0.3 m

$$VT^n = C$$

$$V(30)^{0.2} = 68$$

$$V = 34.44 \text{ m/min}$$

and

$$V = \pi DN \Rightarrow 34.44 = \pi \times 0.3 \times N$$

$$N = 36.54 \text{ rpm.}$$

Q.13 Determine the optimum cutting speed for an operation on a lathe machine using the following information

Tool change time	3 min
Tool regrind time	3 min
Machine running cost	Rs. 0.50 per min
Depreciation of tool regrind	Rs. 5.0
The constants in the tool life equation are 60 and 0.2.	

[10 marks : 2009]

Solution:

The constants in the tool life equation are 60, 0.2

$$\therefore VT^{0.2} = 60$$

$$\text{Tool change time} = 3 \text{ min}$$

$$\text{Tool regrind time} = 3 \text{ min}$$

$$\text{Machine running cost} = \text{Rs. 0.5/min}$$

$$\text{Depreciation of tool regrind} = \text{Rs. 5.0}$$

$$\begin{aligned} \text{Direct running cost, } C_t &= \text{Regrind time} \times \text{running cost/unit time} \\ &= 3 \text{ min} \times 0.5/\text{min} = \text{Rs. 1.5} \end{aligned}$$

$$\text{Tool changing time, } T_c = 3 \text{ min}$$

$$\text{Depreciation cost, } C_m = \text{Rs. 5.0}$$

Optimum speed, V_0 for minimum cost,

$$\begin{aligned} &= \frac{C}{\left[\left(\frac{1}{n}-1\right)\left(T_c + \frac{C_t}{C_m}\right)\right]^n} = \frac{60}{\left[\left(\frac{1}{0.2}-1\right)\left(3 + \frac{5}{1.5}\right)\right]^{0.2}} \\ &= 31.43 \text{ m/min.} \end{aligned}$$

Optimum cutting speed, V_0 for maximum production

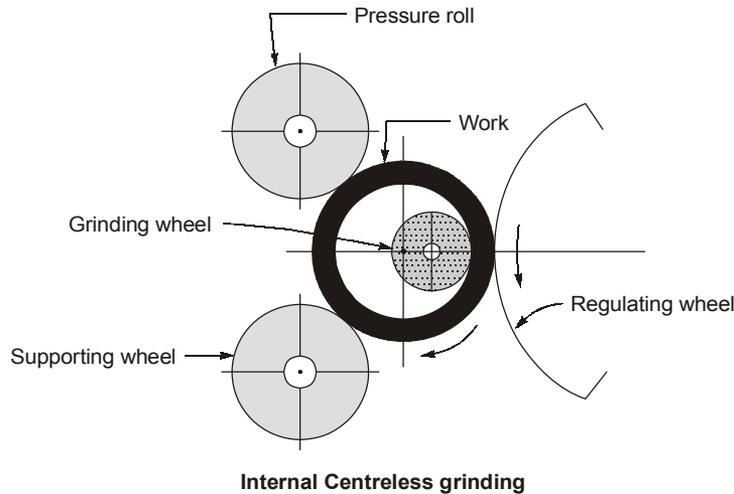
$$= \frac{C}{\left[\left(\frac{1}{n}-1\right)T_c\right]^n} = \frac{60}{\left[\left(\frac{1}{0.2}-1\right)3\right]^{0.2}} = 36.5 \text{ m/min.}$$

Q.14 Draw the typical configuration of Internal Centreless grinding mentioning main advantage and use. Draw tool life curves for cast alloy, High speed steel and ceramic tools.

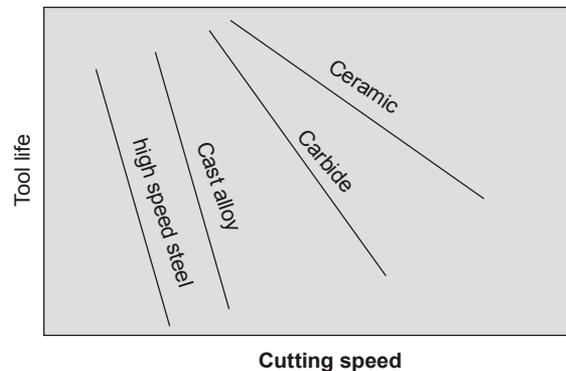
[5 marks : 2010]

Solution:

Centreless grinding: In internal centreless grinding, the work is supported by three rolls. One is the regulating rolls, and the other is a pressure roll to hold the workpiece firmly against the support and regulating rolls. This is illustrated in fig. The grinding wheel contacts the inside diameter of the workpiece directly opposite the regulating roll, thus assuring a part of absolutely uniform thickness and concentricity. The pressure roll is mounted to swing aside to permit loading and unloading.



Tool Life Curves:



Q.15 Why are tools coated? What are the common coating materials?

[5 marks : 2011]

Solution:

Tools are coated to provide certain desirable properties to the tool like wear resistance, hot hardness, better thermal characteristic.

Common Coating Material:

- (i) **High speed steel:** able to provide significantly improve the cutting speeds 3 to 5 times carbon tool steels.
- (ii) **Cast cobalt alloys:** provide the property to retain hardness even at elevated temperatures better than HSS and also used at 25 percent higher cutting speed than HSS.
- (iii) **Ceramic coating:** provide good abrasion resistance. They have excellent high temperature properties such as high resistance to diffusion wear, and high hot hardness.

Q.16 Write the advantages and disadvantages of climb milling. In connection with grinding define grinding ratio.

[2 marks : 2012]

Solution:

The advantage of climb milling are:

1. Job is forced against table which results in elimination of vibrations.
2. Chips are deposited behind the cutter and out of its way.
3. Cutter do not touch the worked surface, better surface finish.
4. Low power consumption.
5. Thin sheet can be easily machined.

Disadvantages of climb milling:

1. More impact load on cutter on starting each cut.

Grinding ratio is defined as

$$GR = \frac{\text{Volume removed from workpiece}}{\text{Volume removed from grinding wheel}}$$

Q.17 Explain with fig. a drill-jig mentioning various provisions. What is the difference between FMS and FMC? Write some disadvantages of FMS. [10 marks : 2012]

Solution:

Jigs and fixtures are the auxiliary devices used in mass production. Fixture locates the work piece and Jig along with location, guides the tool. Jigs are used in drilling, boring, reaming etc. and fixtures are used in milling, shaping etc.

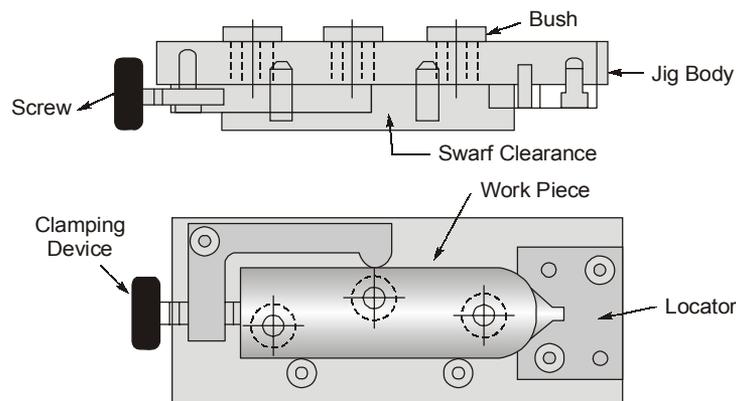
Components of Jig and Fixture :

1. Locating elements
2. Clamping elements
3. Tool guiding
4. Main body

3-2-1 Principle : There are 12 degree of freedom of a work piece i.e., movement about negative and positive axis and clock-wise and anti-clockwise rotation about the three axis. By providing three pins in the base, five degree of freedom will be arrested i.e. movement about negative Z-axis and the clockwise and anti clockwise rotation about X and Y axis. These three pins also ensure that machining always takes place on single plane perpendicular to the base, along the length direction. This arrests movement of work piece along negative Y-direction in clock-wise and anti -clock wise rotation about Z-axis. A sixth pin is provided on a plane perpendicular to the previous two planes, which also arrests movement about negative X-axis. By providing six pins, nine degree of freedom is arrested. Two more Degree of freedom will be arrested by providing clamping elements and from 12th direction, tool comes for machining. A smaller size of pin is called a button and is used in walls.

Radial location : This principle of location is used when there is already one drilled hole in the work piece. Since, there will be variation in the size of hole, conical pins are inserted in the hole to accommodate this variation. Two more pins are provided on the sides to arrest two more degree of freedom.

V-location : Radial locations are used when work piece is either cylindrical or spherical and when it is held between the 2-V jaws all the degrees of freedom will be arrested. One V is movable and the other one is fixed.



FMS: A flexible manufacturing system integrates all major elements of manufacturing into a highly automated system. *FMS* consists of a number of manufacturing cells, each containing an industrial robot (service several *CNC* machines) and an automated material handling system, all interacted with a central computer. This system is highly automated and is capable of optimizing each step of the total manufacturing operation. Flexible manufacturing system represents the highest level of efficiency, sophistication and productivity that has been achieved in manufacturing plants. The flexibility of *FMS* is such that it can handle a variety of part configurations and produce them in any order.

In *FMS*, the time required for change over to a different part is very short. The quick response to product and market demand variations is a major attribute of *FMS*.

FMC: In view of rapid changes in market demand and of the need for more product variety in smaller quantities flexibility of manufacturing operations is highly desirable. Manufacturing cells can be made flexible by using *CNC* machines and machining centres and by means of industrial robots or other mechanized systems for handling materials.

Flexible manufacturing cells are usually intended, so their design and operation are more exiting than those for other cells. The selection of machines and robots, including the types and capacities of end effectors and their control.

As with other flexible manufacturing systems the cost of flexible cells is high. Cellular manufacturing generally requires more machine tools and this increases manufacturing cost; however, this disadvantage is out-weighted by increased speed of manufacture, flexibility and controllability. Proper maintenance of the tools and the machinery is essential, as is the implementation of two or three shift operations of the cells.

Disadvantages:

- High cost
- Not suited for mass production
- Skilled manpower needed

Q.18 Write a least four factors on which the thrust force in drilling depends.

A hole is being drilled on a block aluminium alloy with 10 mm drill at a fee of 0.25 mm/rev. The spindle is running at $N = 850$ rpm. Calculate the metal removal rate.

[5 marks : 2013]

Solution:

Factors are:

1. Helix angle
2. Chisel angle
3. Point angle
4. Feed rate

$$MRR = \frac{\pi}{4} D^2 f \left(\frac{N}{60} \right) = \frac{\pi}{4} \times (10)^2 \times 0.25 \times \frac{850}{60} = 278 \frac{\text{mm}^3}{\text{s}} \text{ Ans.}$$

Q.19 Why does titanium have poor machinability? Write at least four general characteristics that coatings for cutting tools and dies should possess.

You are asked to turn ductile cast iron with various microstructure and hardness as shown in the following table.

		Hardness(HB)	Ferrite	Pearlite
1.	Annealed	186	97	3
2.	As cast	265	20%	80%
3.	Annealed	170	100	—
4.	As cast	207	60	40

Draw a figure showing variation of tool life with cutting speed and the effect of workpiece hardness and microstructure.

[10 marks : 2013]

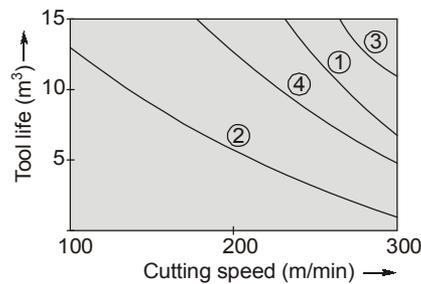
Solution:

Causes of poor machinability:

- Low thermal conductivity which does not allow heat generation during machining to dissipate from the tool edge, causing high tool tip temperature and excessive plastic deformation wear.
- High work hardening tendency leading to high cutting force.
- High chemical reactivity of titanium alloys causes chip to weld to the tool
- Low elastic modulus

General Characteristics of Coating for cutting tools and dies:

- It should have good abrasion resistance
- It should prevent built-up edge formation
- It should be stable at very high temperature
- It should possess property of red hardness

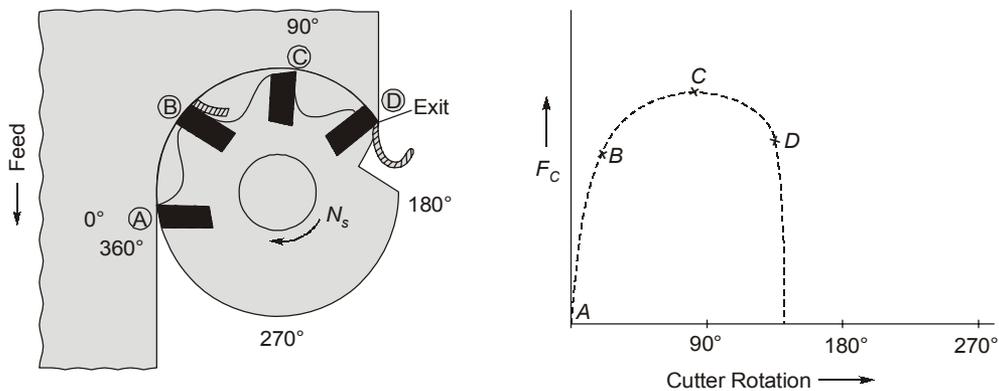


Variation of tool life with cutting speed for various micro-structure

Q.20 Milling is an interrupted cutting process, show with figure conventional face milling with cutting force diagram for Fe showing the above nature of the process.

[5 marks : 2013]

Solution:



Conventional face milling

Q.21 Write two advantages of thread rolling and explain with figure two-die cylindrical machine.

[4 marks : 2013]

Solution:

Advantages of thread rolling:

- It strengthens the thread in tension, shear and fatigue.
- It is most economical and fastest method of making threads.