SCHEME : K

Name : _____

Roll No. : _____ Year : 20___ 20___

Exam Seat No. : _____

LABORATORY MANUAL FOR

THEORY OF MACHINES

(313313)

MECHANICAL ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
(Autonomous) (ISO 9001: 2015) (ISO/IEC 27001:2013)

VISION:

To ensure that the Diploma level technical education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION:

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

QUALITY POLICY:

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation. Evaluation and monitoring system along with adequate faculty development programmes.

CORE VALUES:

MSBTE believes in the following:

- Skill development in line with industry requirement.
- Industry readiness and improved employability of Diploma holders.
- Synergistic relationship with industry.
- Collective and Cooperative development of all stake holders.
- Technological interventions in societal development.
- Access to uniform quality technical education.

A Practical Manual for

Theory of Machines

(313313)

Semester– (III/IV)

"K-SCHEME"

(Diploma in Mechanical/ Mechatronics/Production/ Automobile Engineering)
(ME/MK/PG/AE)

Maharashtra State
Board of Technical Education, Mumbai

(Autonomous) (ISO-9001-2015) (ISO/IEC 27001:2013)

Maharashtra State Board of Technical Education, Mumbai
(Autonomous) (ISO: 9001: 2015) (ISO/IEC 27001:2013)
4th Floor, Government Polytechnic Building, 49, Kherwadi,
Bandra (East), Mumbai – 400051,
(Printed on July, 2024)

Maharashtra State
Board of Technical Education, Mumbai
Certificate

This is to certify that Mr. / Ms. …… Roll No…… of Third/Fourth Semester of Diploma in …… of Institute ……

(Code……) has completed the term work satisfactorily in course **THEORY OF MACHINES (313313)** for the academic year 20…….to 20…..... as prescribed in the curriculum.

Place: …… Enrollment No……

Date: ..... Exam Seat No. ……

Course Teacher **Head of the Department** **Principal**

Seal of the Institute

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION MUMBAI

Preface

The primary focus of any engineering laboratory/ field work in the technical education system is to develop the much-needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programmes with National Education Policy2020 (NEP2020) and outcome-based education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher; instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. Accordingly, the 'K' scheme laboratory manual development team designed the practical to ***focus*** on the ***outcomes***, rather than the traditional age-old practice of conducting practical to 'verify the theory' (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

Knowledge of various mechanisms and machines is a pre-requisite for enabling a mechanical engineer to work in an industry. This course provides the knowledge of kinematics and dynamics of different machine elements and popular mechanisms such as four link mechanisms, cam-follower, belt-pulley, chain sprocket, gears, flywheel, brake and clutch to enable a diploma holder to carry out maintenance of these and it also serves as a prerequisite for course 'Elements of Machine Design' to be studied in later semester.

The Practical manual development team wishes to thank MSBTE who took initiative in the development of curriculum and implementation and also acknowledge the contribution of individual course experts who have been involved in laboratory manual as well as curriculum development (K scheme) directly or indirectly.

Although all care has been taken to check for mistakes in this laboratory manual, yet it is impossible to claim perfection especially as this is the first edition. Any such errors and suggestions for improvement can be brought to our notice and are highly welcome.

Lab Manual Development Team

Programme Outcomes (POs) to be achieved through Practical of this Course

Following POs are expected to be achieved through the practicals of the (Theory of machines) course.

PO1. Basic and Discipline specific knowledge: Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the mechanical engineering problems.

PO 2. Problem analysis: Identify and analyse well-defined mechanical engineering problems using codified standard methods.

PO 3. Design/ development of solutions: Design solutions for well-defined technical problems and assist with the design of systems components or processes to meet specified needs in mechanical engineering.

PO 4. Engineering Tools, Experimentation and Testing: Apply modern mechanical engineering tools and appropriate technique to conduct standard tests and measurements.

PO 5. Engineering practices for society, sustainability and environment: Apply appropriate technology in context of society, sustainability, environment and ethical practices.

PO 6. Project Management: Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities in diverse and multidisciplinary fields.

PO 7. Life-long learning: Ability to analyse individual needs and engage in updating in the context of technological changes in mechanical engineering.

List of Industry Relevant Skills-

The following industry relevant skills or the competency "Use principles of kinematics and dynamics in maintenance of various equipment's" are expected to be developed in you by undertaking the practicals of this laboratory manual.

1. Identify various links in popular mechanisms.
2. Select suitable mechanism for various applications.
3. Analyze the motion of cams and followers.
4. Select relevant belts, chains and drives for different applications.
5. Select relevant brakes and clutches for various applications
6. Select suitable flywheel and governor for various applications.

Practical- Course Outcome matrix

Course Outcomes (COs)

CO1- Apply knowledge and skill related to different mechanisms and its motion in given situation.
CO2- Determine velocity and acceleration for given mechanism.
CO3- Develop a Cam profile for given type of Follower and its motions in given situation.
CO4- Select the suitable power transmission devices for the given field/industrial application.
CO5- Use knowledge and skills related to balancing of masses and vibration for various applications.

Sr. No.	Laboratory Practical Titles	CO1	CO2	CO3	CO4	CO5
1	Identification of Mechanisms in the different laboratory and institute premises.	√	-	-	-	-
2	*Estimation of kinematic data for mechanism available in the laboratory	√	-	-	-	-
3	*Estimation of kinematic data for mechanism available in the laboratory	√	-	-	-	-
4	Degree of Freedom of given mechanism by using Kutzbach equation.	√	-	-	-	-
5	*Quick return mechanism used in a shaper machine	√	-	-	-	-
6	Velocity and Acceleration of four bar chain by relative velocity method.	√	√	-	-	-
7	*Velocity and Acceleration of single slider crank chain by relative velocity method.	√	√	-	-	-
8	Velocity and Acceleration of Slider crank chain by Klein's Construction Method.	√	√	-	-	-
9	Cam profile for knife edge Follower.	√	-	√	-	-
10	Cam Profile for roller follower.	√	-	√	-	-
11	*Measurement of follower displacement with Cam rotation for knife edge follower and roller follower	√	-	√	-	-
12	*Estimation of slip, length of belt, angle of contact in an open and cross belt drive.	-	-	-	√	-
13	Identification of gears and gear train in Lab and Machine shop.	-	-	-	√	-
14	*Preparation of different Gear trains from the given gears.	-	-	-	√	-
15	*Balancing of rotating unbalanced system	-	-	-	-	√

Guidelines to Teachers

1. ***Teacher need to ensure that a dated log book*** for the whole semester, apart from the laboratory manual is maintained by every student which s/he has to ***submit for assessment to the teacher*** in the next practical session.
2. There will be two sheets of blank pages after every practical for the student to report other matters (if any), which is not mentioned in the printed practical.
3. For difficult practical if required, teacher could provide the demonstration of the practical emphasizing of the skills which the student should achieve.
4. Teachers should give opportunity to students for hands-on after the demonstration.
5. Assess the skill achievement of the students and COs of each unit.
6. One or two questions ought to be added in each practical for different batches. For this teacher can maintain various practical related question banks for each course.
7. If some repetitive information like data sheet, use of software tools etc. has to be provided for effective attainment of practical outcomes, they can be incorporated in Appendix.
8. For effective implementation and attainment of practical outcomes, teacher ought to ensure that in the beginning itself of each practical, students must read through the complete write-up of that practical sheet.
9. During practical, ensure that each student gets chance and takes active part in taking observations/ readings and performing practical.
10. Teacher ought to assess the performance of students continuously according to the MSBTE guidelines

Instructions for Students

1. For incidental writing on the day of each practical session every student should maintain a ***dated log book*** for the whole semester, apart from this laboratory manual which s/he has to ***submit for assessment to the teacher*** in the next practical session.
2. For effective implementation and attainment of practical outcomes, in the beginning itself of each practical, students need to read through the complete write-up including the practical related questions and assessment scheme of that practical sheet.
3. Student ought to refer the data books, IS codes, Safety norms, Technical Manuals, etc.
4. Student should not hesitate to ask any difficulties they face during the conduct of practical.

Content Page

List of Practical and Progressive Assessment Sheet

Sr. No	Laboratory Practical Titles	Page No.	Date of performance	Date of submission	FA PR marks (25)	Dated sign. of teacher	Remarks (if any)
1	Identification of Mechanisms in the different laboratory and institute premises.	1					
2	*Estimation of kinematic data for mechanism available in the laboratory	6					
3	*Estimation of kinematic data for mechanism available in the laboratory	6					
4	Degree of Freedom of given mechanism by using Kutzbach equation.	13					
5	*Quick return mechanism used in a shaper machine	18					
6	Velocity and Acceleration of four bar chain by relative velocity method.	24					
7	*Velocity and Acceleration of single slider crank chain by relative velocity method.	28					
8	Velocity and Acceleration of Slider crank chain by Klein's Construction Method.	32					
9	Cam profile for knife edge Follower.	37					
10	Cam Profile for roller follower.	44					
11	*Measurement of follower displacement with Cam rotation for knife edge follower and roller follower	51					
12	*Estimation of slip, length of belt, angle of contact in an open and cross belt drive.	57					
13	Identification of gears and gear train in Lab and Machine shop.	63					
14	*Preparation of different Gear trains from the given gears.	68					
15	*Balancing of rotating unbalanced system.	73					

Note: To be transferred to Proforma of CIAAN-2023.

A suggestive list of LLOs is given in the above table. More such LLOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practical marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.

Practical No.01 Identification of Mechanisms in the different laboratory and institute premises.

I. Practical Significance

Understanding and identifying mechanisms in machines is crucial for multiple aspects of engineering, design, and maintenance. Knowing the mechanisms allows for accurate diagnosis of faults and failures. By identifying the mechanisms in a machine, engineers can optimize them for better performance, efficiency, and cost-effectiveness. Knowledge of existing mechanisms can inspire new designs and innovations. Proper identification of mechanisms ensures that safety-critical components are designed and maintained correctly

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. Identify type of mechanism used in given machine.
2. Select suitable mechanism for various applications.

III. Course Level Learning Outcome (CO)

CO1- Apply knowledge and skill related to different mechanisms and its motion in given situation.

IV. Laboratory Learning Outcome(s)

- Identify different mechanisms available in laboratories/institute premises
- Sketch the identified mechanism

V. Relative Affective Domain Related Outcome(s)-

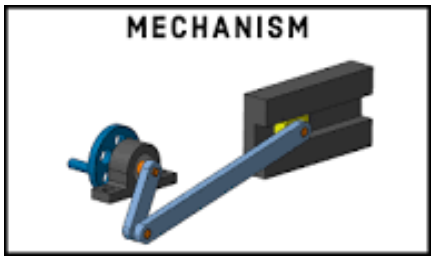
- Follow safety practices.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

Before performing this practical student must have knowledge kinematic link, pair, chain, mechanism, joints, types of joints, constrained motion, etc.

VII. Experimental setup

Students are suggested to visit TOM and Automobile engineering laboratory to identify various mechanisms.



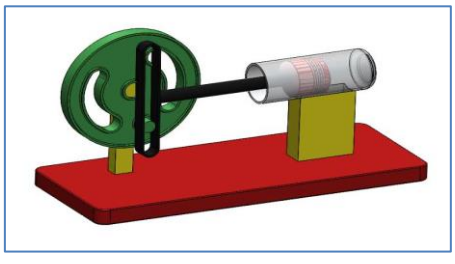


Fig 1.1: Experimental models/ setup of various mechanisms

VIII. Required Resources /Apparatus/Equipment with specification

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Single slider crank mechanism	Working model with suitable dimensions	01
2	Four bar mechanism	Working model with suitable dimensions	01
3	Scotch yoke mechanism	Working model with suitable dimensions	01
4	Beam engine	Working model with suitable dimensions	01
5	Locomotive coupler	Working model with suitable dimensions	01

IX. Precautions to be Followed

- Do not rotate the Mechanism with high speed.
- Use tools safely.

X. Procedure

1. Select any machine or mechanism in lab or in college premises.
2. By analyzing machine identify and write down name of machine in observation table.
3. Identify fixed link in selected mechanism and write down name of that link in first column of observation table.
4. Identify second link connected to first (fixed link) and write down in second column of observation table.
5. Identify type of kinematic pair between first and second link and write down in third column of observation table.
6. Repeat procedure remaining link and complete table for selected machine.
7. Now select second machine/ Mechanism and repeat above procedure
8. At least five different machines must be selected.

XI. Observations and calculations

Name of the mechanism 1: ----------		
Name of First Link	**Name of Second Link**	**Type of Kinematic pair**

Name of the mechanism 2: ----------		
Name of the mechanism 3: ----------		
Name of the mechanism 4: ----------		
Name of the mechanism 5: ----------		

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Explain single slider crank mechanism with sketch
2. Explain Four bar chain mechanism with sketch
3. Explain Double slider chain mechanism.
4. Draw sketch of slotted lever mechanism.

[Space for Answer]

XVI. References / Suggestions for Further Reading

- **Animated mechanisms:** https://www.mekanizmalar.com

XVII Rubrics for Assessment Scheme

	Performance Indicators	Weightage
	Process Related (10 Marks)	**(40%)**
1	Handling of the measuring Instruments	30%
2	Calculation of final readings	10%
	Product Related (15 Marks)	**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			**Dated signature of Teacher**
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No: 02&03 *Estimation of kinematic data for mechanism available in the laboratory

I. Practical Significance

A mechanism is one in which one of the links of a kinematic chain is fixed. Different mechanisms can be obtained by fixing different links of the same kinematic chain. These are called as inversions of the mechanism. By changing the fixed link, the number of mechanisms which can be obtained is equal to the number of links. The inversion of a mechanism does not change the motion of its links relative to each other.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. Identify type of mechanism used in given machine.
2. Select suitable mechanism for various applications.

III. Course Level Learning Outcome (CO)

CO1- Apply knowledge and skill related to different mechanisms and its motion in given situation.

IV. Laboratory Learning Outcome(s)

- Identify number of links and pairs of given mechanism.
- Identify input link and its motion.
- Identify output link and its motion

V. Relative Affective Domain Related Outcome(s)-

- Follow safety practices.
- Practice good housekeeping.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices Follow ethical Practices.

VI. Minimum Theoretical Background with diagram

It is important to study the Kinematic response of the mechanism because of practical applications. It is also useful in determining the Kinematic equivalents of other mechanisms. While the motion of a Scotch-yoke mechanism is purely sinusoidal, that of the Slider-crank mechanism is not. Kinematic data such as displacement, velocity and acceleration of a simple Slider-crank mechanism can be obtained and compare the same with Scotch yoke Mechanism.

Experimental setup (Model)-

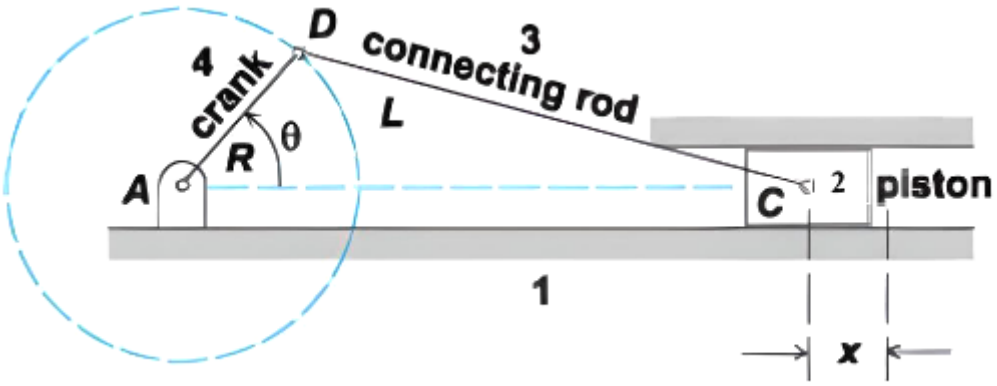


Fig 2.1: Single slider crank

Fig 2.2: Experimental setup Single slider crank

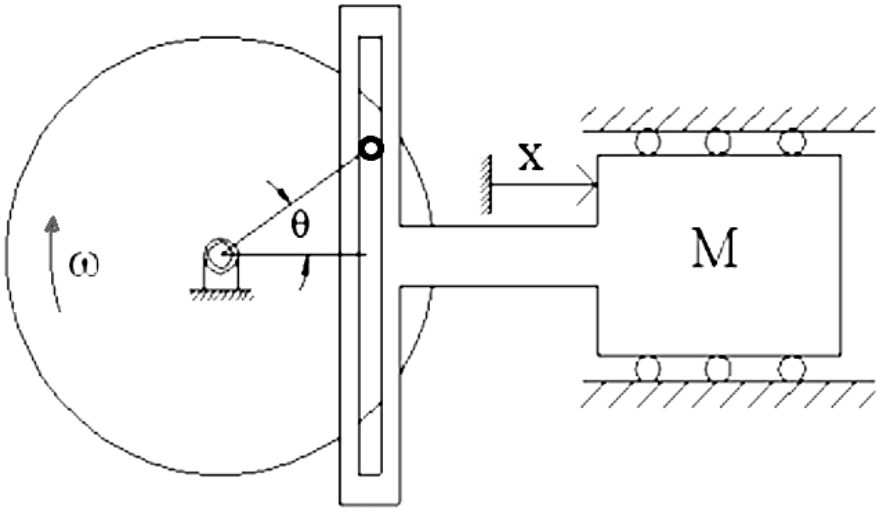


Fig 2.3: Scotch yoke Mechanism

Fig 2.4: Experimental setup Scotch yoke Mechanism

VII. Required Resources /Apparatus/Equipment with specification

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Working Model of Single slider Crank mechanism	Scale for Displacement, Angle measuring arrangement, motor with speed reduction arrangement	01
2	Working Model of Scotch Yoke Mechanism	Scale for Displacement, Angle measuring arrangement, motor with speed reduction arrangement	01
3	Tachometer	Range speed up to 2000RPM	01

VIII. Precautions to be Followed

- Do not rotate the Mechanism with high speed

IX. Procedure

1. Set the slider crank at 0 mm for the connecting rod, and 0° for the rotating disk.
2. Measure L the length of the connecting rod and R the radius for the rotating disk(crank).
3. Change the angle for the disk by 30° each time until 360°, and each time measure X.
4. Plot the graphs of (i) linear displacement 'X' of piston, velocity 'V' of piston (ii) acceleration 'a' of piston versus angular displacement of crank.
5. Repeat the procedure for Scotch-Yoke mechanism.

X. Observations and calculations

a) For single Slider Crank Mechanism

Angular Displacement(θ)	position X (mm)	Velocity V (mm/ sec)	Acceleration a (mm/sec^2)
0			
30			
60			
90			
120			
150			
180			

b) For Scotch yoke Mechanism

Angular Displacement(θ)	position X (mm)	Velocity V (mm/ sec)	Acceleration a (mm/sec^2)
0			
30			
60			
90			
120			
150			
180			

XI. Results

XII. Interpretation of Results

XIII. Conclusions and Recommendation

XV Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. List the different inversions of single slider crank Mechanism
2. Name four applications of Single crank Mechanism

[Space for Answer]

XVI. References / Suggestions for Further Reading

- http://www.youtube.com/watch?v=HhX-8RyP214
- https://www.youtube.com/watch?v=ZO8QEG4x0wY

XVII Rubrics for Assessment Scheme

	Performance Indicators	Weightage
	Process Related (10 Marks)	**(40%)**
1	Handling of the models/set up	20%
2	Observations of the models/set up	20%
	Product Related (15 Marks)	**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			**Dated signature of Teacher**
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No: 04 Degree of Freedom of given mechanism by using Kutzbach equation.

I. Practical Significance

In the design or analysis of a mechanism, one of the most important concern is the number of degrees of freedom (also called movability) of the mechanism. It is defined as the number of input parameters (usually pair variables) which must be independently controlled in order to bring the mechanism into a useful engineering purpose. It is possible to determine the number of degrees of freedom of a mechanism directly from the number of links and the number and types of joints.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer.

1. To determine degree of freedom of given mechanism

III. Course Level Learning Outcome (CO)

CO1- Apply knowledge and skill related to different mechanisms and its motion in given situation.

IV. Laboratory Learning Outcome(s)

1. Determine degree of freedom of given mechanism.

V. Relative Affective Domain Related Outcome(s)-

- Maintain tools and equipment.
- Follow safety practices

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VI. Minimum Theoretical Background with diagram (if required)

To use Kutzbach equation one should must know

Linkages, Joints, type of joints such as binary, ternary, Quaternary joints, lower pairs and higher pair joints.

Kinematic Chains, Open and Closed Chains

Degrees of Freedom (DOF)

Constraints and Motion, Kinematic Pairs

Experimental setup (Model)-

Fig 4.1 : Beam Engine

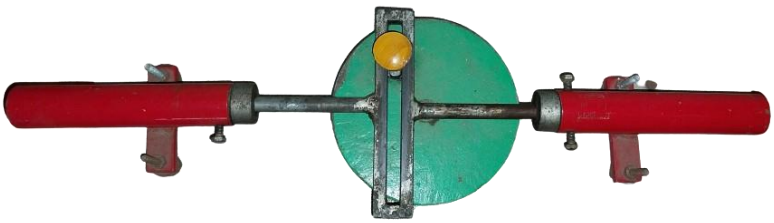


Fig 4.2 : Scotch yoke mechanism

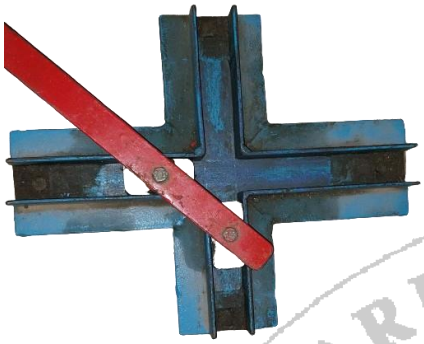


Fig 4.3 : Double slider cranck mechanism

Fig 4.4 : Cam Follower mechanism

Fig 4.5 : Ackerman steering gear

VII. Required Resources /Apparatus/Equipment with specification

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Single slider crank mechanism	Board mounted working model Crank of 50-60 mm diameter, connecting rod 150-200 mm length along with slider	01
2	Four bar mechanism	Working model with suitable length of four bars (like 100mm, 80mm,60mm and 70mm)	01
3	Scotch yoke mechanism	Working model with suitable dimensions	01
4	Beam engine	Working model with suitable dimensions	01
5	Locomotive coupler	Working model with suitable dimensions	01

VIII. Precautions to be Followed

- Do not rotate the Mechanism with high speed.
- Use tools safely.

IX. Procedure

1. Select mechanism and write name of mechanism in observation table
2. Count the number of links in the mechanism (*l)*
3. Count the number of binary joints in the mechanism (*a)*
4. Count the number of ternary joints in the mechanism (*b)*
5. Count the number of Quaternary joints in the mechanism (*c)*
6. Using formula provided in observation table calculate equivalent binary joints (*j)*

7. Count the number of Higher pairs in the mechanism (*h)*
8. Using formula provided in observation table calculate Degree of freedom (*n)*

X. Observations and calculations –

Name of Mechanism	Mechanism 1	Mechanism 2	Mechanism 3	Mechanism 4	Mechanism 5
Number of links (*l*)					
Number of binary joints (a)					
Number of ternary joints (b)					
Number of Quaternary joints (c)					
equivalent binary joints (*j*) *j* = a+2*b+3*c					
Higher pairs (*h*)					
Degree of freedom (*n*) *n* = 3 (*l* -1) – 2 *j-h*					

XI. Results

XII. Interpretation of Results

XIII. Conclusions and Recommendation

XIV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Explain Kutzbach equation and its applications.
2. Calculate degree of freedom of given mechanism
   a. Cam follower mechanism
   b. Slotted lever mechanism
   c. Pendulum pump
   d. Oldham coupling
   e. Foot operated air pump

[Space for Answer]

XV. References / Suggestions for Further Reading

- https://youtu.be/3-jC-eTAwME
- https://www.youtube.com/watch?v=mRHj5QMdEm8
- https://youtu.be/Nz7RC6H8fBU

XVII Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (10 Marks)		**(40%)**
1	Handling of the Set up/measuring Instruments	20%
2	Calculation of final readings	20%
Product Related (15 Marks)		**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			Dated signature of Teacher
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No: 05 *Quick return mechanism used in a shaper machine

I. Practical Significance

Quick return mechanism used in a shaper machine is an important and useful inversion of single slider crank mechanism. Knowing its working and its features is essential for a diploma engineer.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. Identify type of mechanism used in given machine.
2. Select suitable mechanism for various applications.

III. Course Level Learning Outcome (CO)

CO1- Apply knowledge and skill related to different mechanisms and its motion in given situation.

IV. Laboratory Learning Outcome(s)

1. Identify various links and pairs in the given mechanism.
2. Identify various type motion in the given pair.
3. Identify various kinematic chain in the given configuration.

V. Relative Affective Domain Related Outcome(s)-

- Follow safety practices.
- Practice good housekeeping.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practice.

VI. Minimum Theoretical Background with diagram

Figure 5.1 is schematic of the quick return mechanism used in shaper machine.

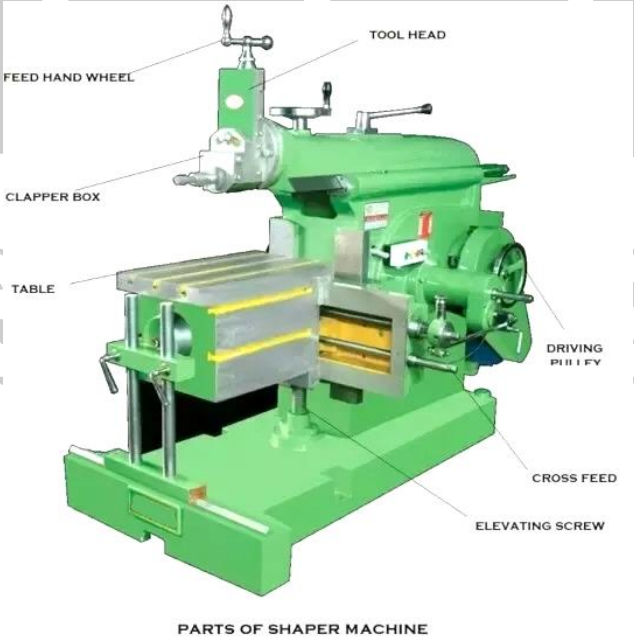


Fig.5.1 A Typical shaper machine

VII. Experimental setup-

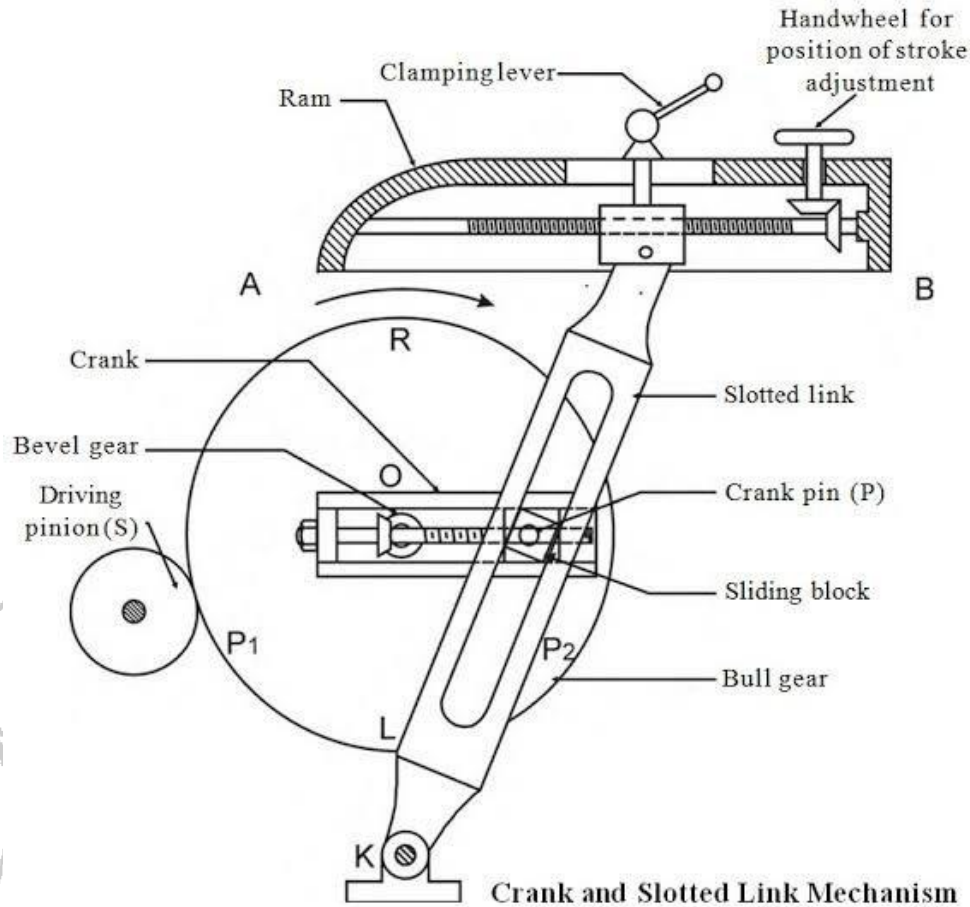


Fig.5.2 Quick return mechanism in shaper machine

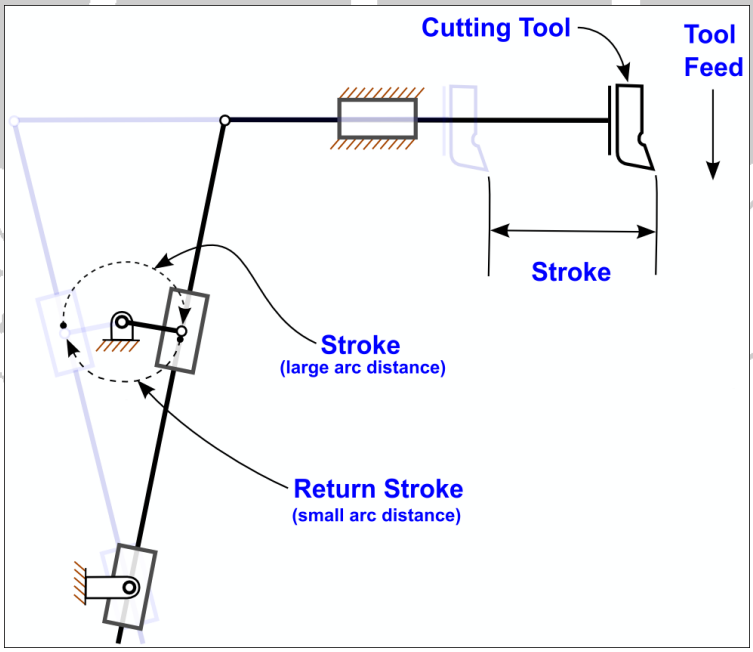


Fig.5.3 :Schematic of the quick return mechanism used in shaper machine

VIII. Required Resources /Apparatus/Equipment with specification

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Shaper machine	Available in institute's workshop	01
2	Stop watch	Mechanical stopwatch	01
3	Steel rule	1 m length	01
4	Spanner set, hammer and mallet	Available in workshop	01
5	Tachometer	Mechanical or optical type of tachometer	01

IX. Precautions to be Followed

- Due safety precautions while operating a shaper machine. Handle the Bourdon pressure gauge with due care.

X. Procedure

1. Open the cover plate of shaper machine to observe the mechanism.
2. Rotate the bull gear manually and identify the various kinematic links and pairs formed among them.
   a. Mark a point on body of machine and ram.
   b. Start the machine and observe the movement of ram in cutting and idle stroke.
   c. Note down the movement of point on ram with respect to point on body of machine, this gives stroke length.
   d. Note down time required for cutting stroke and idle stroke.
   e. Now, adjust the stroke length by varying the radius of the crank.
   f. In order to adjust the position of the ram, the ram fixing screw is loosened. The ram is moved to the required position and the screw is tightened again.
   g. Again, measure the time required for completion of cutting and idle stroke length.
   h. Close the cover plate and ensure the proper working of the machine.
   i. Tabulate the observations.

XI. A) Observations Table-

a. Identification of kinematic pair

Name of First Link	Name of Second Link	Type of Kinematic pair

b. Ratio of cutting to idle time

Sr. No.	Stoke length (mm)	Time(s)		Time Ratio
		Cutting stroke	Return stroke	
1				
2				
3				
4				

*** Minimum two readings are to be recorded by adjusting the crank radius.**

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. List the link of which the motion is constrained in the quick return mechanism in a shaper machine.
2. List the sliding and turning pairs in the quick return mechanism.

3. State the procedure of changing the length of cutting stroke of the quick return mechanism.

[Space for Answer]

XVI. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=6_0huFZPB9U

XVII Rubrics for Assessment Scheme

	Performance Indicators	Weightage
	Process Related (10 Marks)	**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
	Product Related (15 Marks)	**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			**Dated signature of Teacher**
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No: 06 Velocity and Acceleration of four bar chain by relative velocity method.

I. Practical Significance

Determination of velocity and acceleration of the links is essential for calculation of forces acting on those links in various mechanisms.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer.

1. Identify type of mechanism used in given machine.
2. Select suitable mechanism for various applications.

III. Course Level Learning Outcome (CO)

CO2-Determine velocity and acceleration for given mechanism.

IV. Laboratory Learning Outcome(s)

1. Draw velocity and acceleration polygon of four bar chain.
2. Calculate angular velocity and linear velocity of a link using given data.

V. Relative Affective Domain Related Outcome(s)-

- Follow safety practices.
- Practice good housekeeping.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

Knowledge of Various Mechanism and its links, Velocity and Acceleration analysis using Relative velocity Method.

VII. Experimental setup (Model)-

Any two working models of four bar chain available in Theory of Machine lab (or any other lab in Mech Engg. Dept.) in the institute.

Fig.6.1 Beam Engine mechanism

VIII. Required Resources /Apparatus/Equipment with specification

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Model of 4 bar chain mechanism	Working model with suitable dimensions	01
2	Steel rule	1 m length	01
3	Tachometer	Range 0-6000 RPM	01

IX. Precautions to be Followed

- Due safety precautions to be taken while measuring angular speed.

X. Procedure

1. Select any working model of four bar chain mechanism available in the laboratory. (Data obtained in experiment 3 can be used here.)
2. Measure the length of links of the mechanism.
3. Measure the angular speed of the crank.
4. Use this data to draw velocity and acceleration polygons using relative velocity method.

XI. Observations and calculations –

a. Lengths of various links

Sr. No.	Name of the Link	Length(m)
1		
2		
3		
4		

b. Angular speed of crank

***** Minimum two readings of angular velocities are to be recorded.

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Calculate angular or linear velocities of various links.
2. Calculate angular or linear acceleration of various links.

[Space for Answer]

XVI. References / Suggestions for Further Reading

- https://youtu.be/EoyUEffmYoE
- https://www.youtube.com/watch?v=te6IhV7KfZc

XVII Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (10 Marks)		**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
Product Related (15 Marks)		**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			Dated signature of Teacher
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No: 07 *Velocity and Acceleration of single slider crank chain by relative velocity method.

I. Practical Significance

Determination of velocity and acceleration of the links is essential for calculation of forces acting on those links in various mechanisms.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer.

1. Identify type of mechanism used in given machine.
2. Select suitable mechanism for various applications.

III. Course Level Learning Outcome (CO)

CO2-Determine velocity and acceleration for given mechanism.

IV. Laboratory Learning Outcome(s)

1. Draw velocity and acceleration polygon of Single slider chain mechanism.
2. Calculate angular velocity and linear velocity of a link using given data.

V. Relative Affective Domain Related Outcome(s)-

- Follow safety practices.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.
-

VI. Minimum Theoretical Background with diagram (if required)

Knowledge of Various Mechanism and its links, Velocity and Acceleration analysis using Relative velocity Method.

VII. Experimental setup (Model)-

Any two working models of single slider crank mechanism available in Theory of Machine lab (or any other lab in Mech Engg. Dept.) in the institute.

Fig7.1: Single slider crank mechanism

VIII. Required Resources /Apparatus/Equipment with specification

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Model of Single Slider crank mechanism		01
2	Steel rule	1 m length	01
3	Tachometer	Range 0-6000 RPM	01

IX. Precautions to be Followed

- Due safety precautions to be taken while measuring angular speed.

X. Procedure

1. Select any working model of single slider crank mechanism available in the laboratory. (Data obtained in experiment 3 can be used here.)
2. Measure the length of links of the mechanism.
3. Measure the angular speed of the crank.
4. Use this data to draw velocity and acceleration polygons using relative velocity method.

XI. Observations and calculations –

a. Lengths of various links

Sr. No.	Name of the Link	Length(m)
1		
2		
3		
4		

b. Angular speed of crank

***** Minimum two readings of angular velocities are to be recorded.

Sr. No.	Angular Velocity crank ω (rad/sec)
1	
2	

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Calculate angular or linear velocities of various links.
2. Calculate angular or linear acceleration of various links.

[Space for Answer]

XVI. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=uuQGCzVOhSA
- https://youtu.be/ysvC6dFTAUA

XVII Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (10 Marks)		**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
Product Related (15 Marks)		**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			Dated signature of Teacher
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No: 08 Velocity and Acceleration of Slider crank chain by Klein's Construction Method.

I. Practical Significance

Determination of velocity and acceleration of the links is essential for calculation of forces acting on those links in various mechanisms. Klein's construction, being a graphical method, is a simple method of calculation of velocity and acceleration in single slider crank mechanism.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer.

1. Identify type of mechanism used in given machine.
2. Select suitable mechanism for various applications.

III. Course Level Learning Outcome (CO)

CO2-Determine velocity and acceleration for given mechanism.

IV. Laboratory Learning Outcome(s)

- Draw velocity and acceleration polygon of Single slider chain mechanism.
- Calculate angular velocity and linear velocity of a link using given data.

V. Relative Affective Domain Related Outcome(s)-

- Follow safety practices.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

Knowledge of Various Mechanism and its links, Velocity and Acceleration analysis using Klein's construction method.

VII. Experimental setup (Model)-

A working models of single slider crank mechanism available in Theory of Machine lab (or any other lab in Mech Engg. Dept.) in the institute.

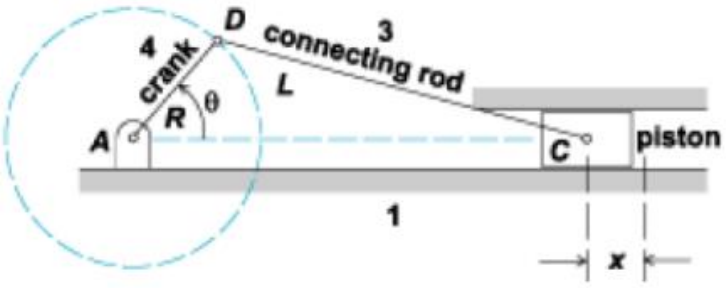
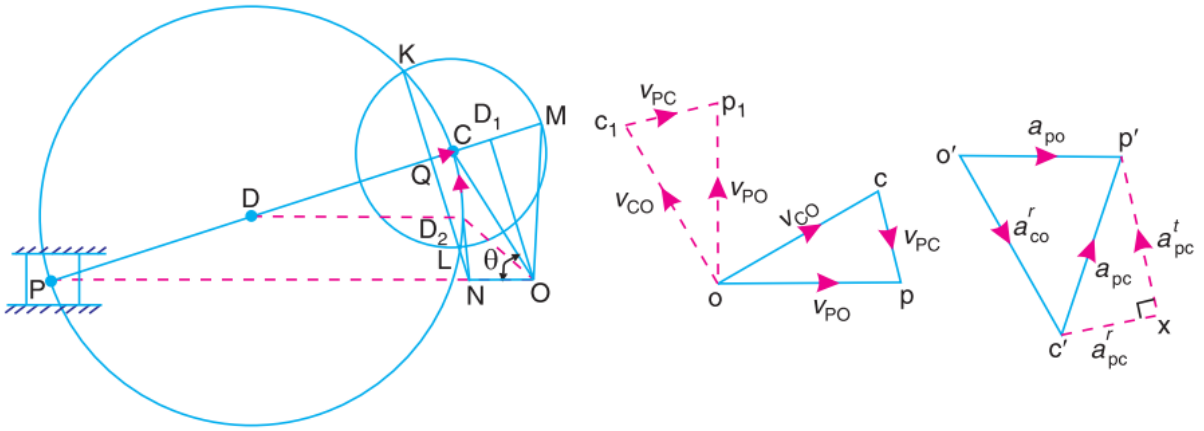


Fig 8.1: Single slider crank mechanism



(*a*) Klien's acceleration diagram. (*b*) Velocity diagram. (*c*) Acceleration diagram.

Fig 8.2: Klein's construction

VIII. Required Resources /Apparatus/Equipment with specification

No.	Name of Resource	Suggested Broad Specification	Quantity
1	Drawing Board	D2 size	01
2	Drawing sheet	A3 or A4 size	01
3	Mini drafter, steel rule, sets squares	Standard mini drafter, steel rule of 30 cm	01

IX. Precautions to be Followed

- Due safety precautions to be taken while measuring angular speed.

X. Procedure

1. Draw the configuration diagram of the given slider crank mechanism to some suitable scale.
2. Klein's velocity diagram: Draw OM perpendicular to OP and extend it to intersect line PC produced at M. The triangle OCM is the required velocity diagram.
   Velocity of piston or slider P is given as,
   $$V_p = \omega \times OM$$
   Other velocities are given as,
   $$V_{co} = \omega \times OC \text{ and } V_{pc} = \omega \times CM$$
3. Klein's acceleration diagram:
   In the configuration diagram drawn already,
   First of all draw a circle with C as center and CM as radius.
   Draw another circle with PC as diameter and D (mid-point of PC) as center. This circle intersects previously drawn circle at point K and L.
   Join KL and produce it to intersect PO at N. Let KL intersect PC at Q. Quadrilateral CQNO is the required acceleration diagram. Acceleration of piston (or slider) P is given as,
   $$a_p = \omega^2 \times NO$$
   Different radial and tangential components are given as,
   $$a_r co = \omega^2 \times OC$$

$$a_r pc = \omega^2 \times QC$$
$$a_t pc = \omega^2 \times NQ$$

1. Important points to remember:
   a. Acceleration of piston P is zero when point N coincides with center O. At this moment the velocity is maximum. This occurs when the angle between crank OC and connecting rod PC is slightly less than 90°.
   b. If point N lies to the right side of O, at this moment of crank rotation, the acceleration of piston is negative i.e. it is undergoing retardation.

Observations and calculations –

a. Lengths of various links

Sr. No.	Name of the Link	Length(m)
1	Crank	
2	Connecting Rod	
Use data obtained in experiment 2 can be used here		

Angle made by crank with line of stroke θ =

XI. Results

XII. Interpretation of Results

XIII. Conclusions and Recommendation

XIV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. State the significance of Klein's construction
2. Compare Klein's construction with relative velocity-acceleration method.

[Space for Answer]

XV. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=7lfYHr6zRzE
- https://www.youtube.com/watch?v=jgwprdibxRc
- https://www.youtube.com/watch?v=k202Yisjc5g

XVII Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (10 Marks)		**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
Product Related (15 Marks)		**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			Dated signature of Teacher
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No:9 Cam profile for Knife edge Follower

I. Practical Significance

Cam is rotary disc shaped element paired with follower of having shape like pointed knife edge, roller, flat and spherical shaped. The mechanism is used to obtain reciprocating motion by movement of follower using special shape (profile) of cam. The movement of follower is used for valve movement in IC engines, diesel fuel pumps, automation systems, toys, printing press, etc

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. 'Use of suitable cam and follower mechanism in industrial application'

III. Course Level Learning Outcome (CO)

CO3- Develop a cam profile for given type of follower and its motions in practical situation.

IV. Laboratory Learning Outcome(s)

- Generate cam profile for given follower to obtain desired follower motion.

V. Relative Affective Domain Related Outcome(s)-

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

The figure shows pair of cam and knife edge follower. The cam is rotated for one complete rotation of 360° and knife edge of follower will move up and down as per the profile or shape of the cam. It has two types as per nature of the axis of cam and direction of motion of follower during its use.

1. Radial follower: The line of movement or axis of the follower is same or passes through the axis of cam during rotation of cam, it is known as radial follower.

2. Offset follower:

The line of movement or axis of the follower is offset or away from the axis of cam with certain distance either left or right during rotation of cam, it is known as radial follower.

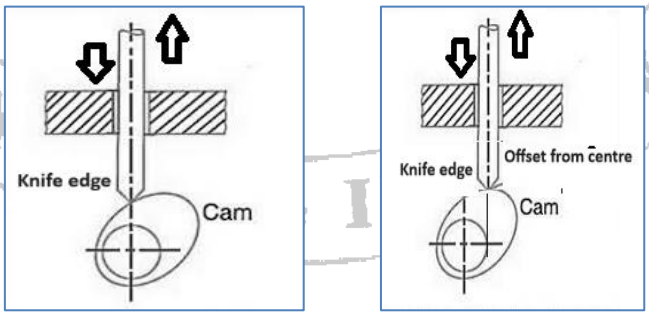


Fig.9.1 Radial and Offset knife edge follower

VII. Experimental setup

(Use set up or working model of disc shape cam with rotary movement manually and pointed knife edge follower for demonstration). The displacement of follower can be measured by mounting vertical scale near follower.

Fig.9.2 Working model of Cam and follower

1. **Cam and Radial follower**: Knife edge follower in line with cam center of rotation.

Problem statement of radial follower:

Draw cam profile for knife edge follower,

i) Minimum radius of cam = 40 mm

ii) Stroke of follower = 40 mm

iii) Outstroke 90° with uniform velocity.

iv) Dwell for next 60°

v) Follower return to original position during 90° of cam rotation with SHM.

The axis of knife edge passes along with axis of cam and rotates in clockwise direction.

2. **Cam and offset follower**: Knife edge follower mounted offset by suitable distance with cam axis of rotation.

Problem statement of Offset follower:

A cam is to give the following motion to a knife edged follower.

i) Outstroke during 60° of cam rotation.

ii) Dwell for the next 30° of cam rotation.

iii) Return stroke during next 60° of cam rotation.

iv) Dwell for the remaining 210° of cam rotation. The stroke of the follower is 40 mm and minimum radius of the cam is 25 mm. The motion of the follower is to take place with S.H.M. during out stroke and with uniform acceleration and retardation during return stroke. Draw the profile of the cam when the axis of the follower is offset by 10 mm from the axis of the cam shaft.

VIII. Required Resources /Apparatus/Equipment with specification

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Model of cam and knife edge follower	Wooden / suitable Working model	01
2	Drawing sheet	A2 Sheet	01
3	Drawing instruments	----	01

IX. Precautions to be Followed

1. Draw cam profile accurately particularly during offset follower.

X. Procedure

a. Read the problem statement carefully and underline important data like radius of cam, lift or displacement, various angles and follower motion.

b. Draw displacement diagram as per steps given:

1. Select scale for lift(s) 1 cm = 10 mm and angle of cam rotation 1 cm = 30°
2. Mark θ rise (out stroke), θ dwell1 , θ return(fall) and θ dwell2 as per scale on horizontal base line and displacement on vertical ordinate.
3. Divide the θ rise (out stroke) angle represented on base line into 6 equal parts and similarly displacement ordinate into 6 equal parts, give numbers 1, 2, 3, 4 ... and S1, S2, S3, S4, ...
4. Draw vertical lines from points 1, 2, 3, 4, ..., parallel to the displacement ordinate. Draw horizontal lines from points S1, S2, S3, S4 parallel to the base line.
5. Now mark the meeting points of lines from point 1 and S1, point 2 and S2, point 3 and S3, . . and name them as P1, P2, P3, P4, P5, P6 respectively.
6. Join them with a straight line (rise or outstroke θ0).
7. Repeat the procedure for return stroke θ return.

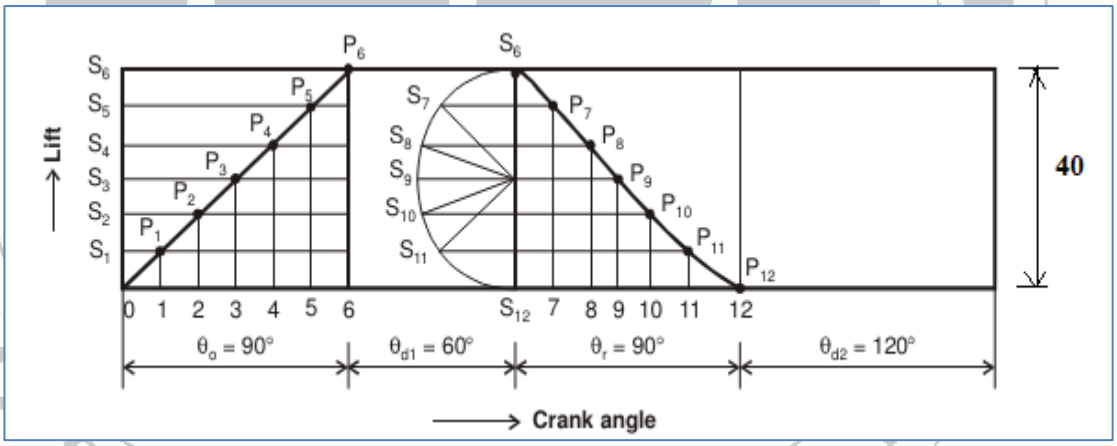


Fig.9.3 Displacement diagram (Problem No.1)

c. Draw Cam profile as per steps given:

1. Draw a base circle with radius equal to the minimum radius of the cam (as given in the problem) with 0 as centre.
2. Check the axis of the follower passes/offsets through the axis of the cam shaft, mark trace point A accordingly.
3. From OA**, mark angle θ rise (out stroke), θ dwell1 , θ return(fall) and θ dwell 2** as per their values and mention values of angle respectively
4. Divide the angular displacement during θ rise (out stroke) and θ return(fall) **into the same number of equal even parts** as in displacement diagram.
5. Mark the numbers as in displacement diagram, i.e., 0 to 6 and 6' to 0'.
6. Join the points 1, 2, 3 and 0', 1', 2', . . . etc, with centre O and draw lines extended crossing the base circle.

7. Now take distance from displacement diagram and mark that distance on the profile diagram for θ rise (out stroke) and θ return(fall)
8. Join the points with a smooth curve. The curve is the complete profile of the cam.

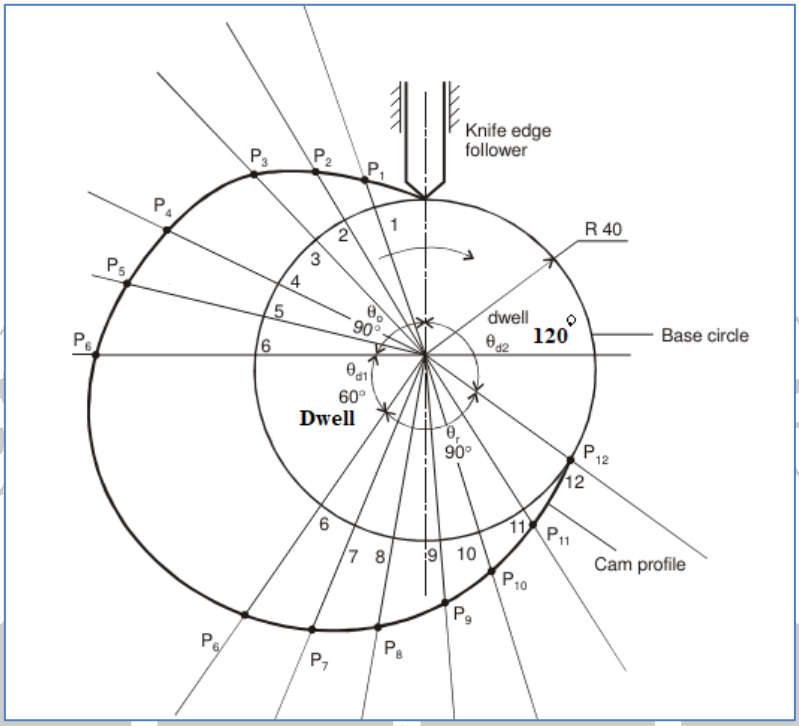


Fig.9.4 Cam Profile diagram (Problem No.1)

XI. Observations and calculations

Sr. No.	Parameters	Problem 1	Problem2
1	Type of follower		
2	Type (radial/Offset)		
3	Lift in mm		
4	Angle of rise (outward)		
5	Type of Motion of follower for rise (outward)		
6	Dwell 1		
7	Angle of return (fall)		
8	Type of Motion of follower for return (fall)		
9	Dwell 2		
10	Minimum radius of cam		

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Draw sketch of types of followers and cams.
2. Write any two practical uses of cam and follower.
3. State demerits of knife edge follower.
4. Draw displacement diagram for a follower subjected to uniform acceleration and retardation during rise and return with following details: Stroke length = 48 mm Angle of rise = 180° Angle of return = 90° Angle of dwell after return = 90°
5. Construct a cam profile with knife edge follower having an offset of 10 mm for the following data. Outstroke = 60° with SHM, Dwell = 30°, Return 60° with uniform velocity and remaining is dwell period. Minimum radius of cam = 50 mm, lift of follower = 25 mm.

[Space for Answer]

XVI. References / Suggestions for Further Reading

- Cam Animation: https://www.youtube.com/watch?v=zLeQNfcatmg-
- Cams and Followers: https://www.youtube.com/watch?v=u5nwkm5IbqY
- Different Types of Cams & Followers: https://www.youtube.com/watch?v=Ibs10c9FX0M
- How Do Cam and Follower Mechanisms Work: https://www.youtube.com/watch?v=HsXWewecMLE

XVII Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (10 Marks)		**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
Product Related (15 Marks)		**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			Dated signature of Teacher
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No:10 Cam profile for Roller Follower

I. Practical Significance

A cam is a rotating or a reciprocating element of a mechanism which imparts rotating, reciprocating or oscillating motion to another element called follower. It is always used in a pair. The roller in the form of circular disc and it will have line contact with the cam. The roller followers are extensively used where more space is available such as in stationary gas and oil engines and aircraft engines.

I. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. 'Use of suitable cam and follower mechanism in industrial application'

II. Course Level Learning Outcome (CO)

CO3- Develop a cam profile for given type of follower and its motions in practical situation.

III. Laboratory Learning Outcome(s)

- Generate cam profile for given follower to obtain desired follower motion.

IV. Relative Affective Domain Related Outcome(s)-

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

V. Minimum Theoretical Background with diagram (if required)

When the contacting end of the follower is a roller, it is called as roller follower as shown in fig.10.1. The rolling motion takes place between the roller and the cam. As compared with knife edge follower, rate of wear and tear is less due to less friction between roller and cam.

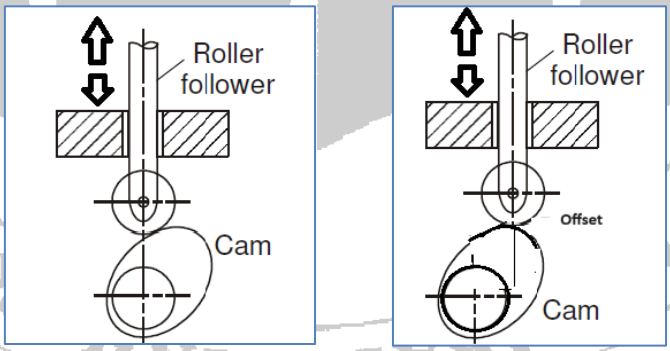


Fig.10.1 Radial and offset Roller follower

VI. Experimental setup

Use set up or working model of disc shape cam with rotary movement manually and Roller follower for demonstration. The displacement of follower can be measured by mounting vertical scale near follower.

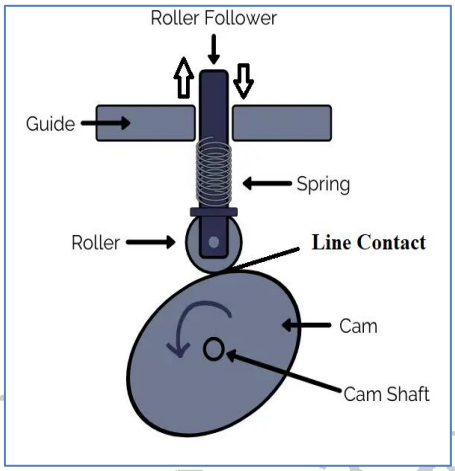


Fig.10.2 Working of Cam and Roller follower

1. **Cam and Radial follower**: Roller follower in line with cam center of rotation.

Problem statement of radial follower:

A cam with a minimum radius of 25 mm, rotating clockwise, at a uniform speed is to be designed to give a roller follower, at the end of a valve rod, motion described below:

i) to raise the valve through 50 mm during 120° rotation of cam.

ii) to keep the valve fully raised through next 30°

iii) to lower the valve during next 60°

iv) to keep the valve closed during rest of the revaluation i.e. 150°.The diameter of roller is 20 mm and the diameter of the cam shaft is 25 mm. Draw the profile of cam when the line of stroke of the valve rod passes through the axis of cam shaft. Use S.H.M. motion while rise and return.

2. **Cam and offset follower**: Roller follower mounted offset by suitable distance with cam axis of rotation.

Problem statement of Offset follower:

Construct the profile of a cam to suit the following specification.

i) Diameter of Cam shaft = 40 mm

ii) Least radius of cam = 25 mm

iii) Roller Diameter = 25 mm

iv) Angle of lift = 120°

v) Angle of fall = 150°

vi) Lift of the follower = 40 mm,

vii) Number of pauses (dwell) is two of equal interval between motions. During the lift, the motion is S.H.M. during the fall the motion is uniform acceleration and de-acceleration. The speed of the cam shaft is uniform and the line of stroke of the follower is offset 12.5 mm from the centre of the cam.

VII. Required Resources /Apparatus/Equipment with specification

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Model of cam and Roller follower	Wooden / suitable Working model	01
2	Drawing sheet	A2 Sheet	01
3	Drawing instruments	----	01

VIII. Precautions to be Followed

1. Draw cam profile accurately

IX. Procedure

The following steps are given to draw cam profile problem No.2

Displacement diagram

1. Choose scale 1 : 20°. Draw a line of given q = 360° means of 18 cm length.
2. Draw vertical line equal to lift of the follower = 40 mm.
3. Divide the line into number of the strokes given.
4. Complete the rectangle.
5. Draw a semi-circle taking lift as diameter.
6. Divide this semi-circle into equal even parts say six.
7. The points a to e on semi-circle are projected across the corresponding positions of the cam angles as shown in Fig.10.3
8. For return stroke, divide the angular displacement into equal even number of parts say six.
9. Draw vertical line from point 3' and divide it into same equal even number of parts.
10. The curve joining these points represents the displacement curve for return stroke.

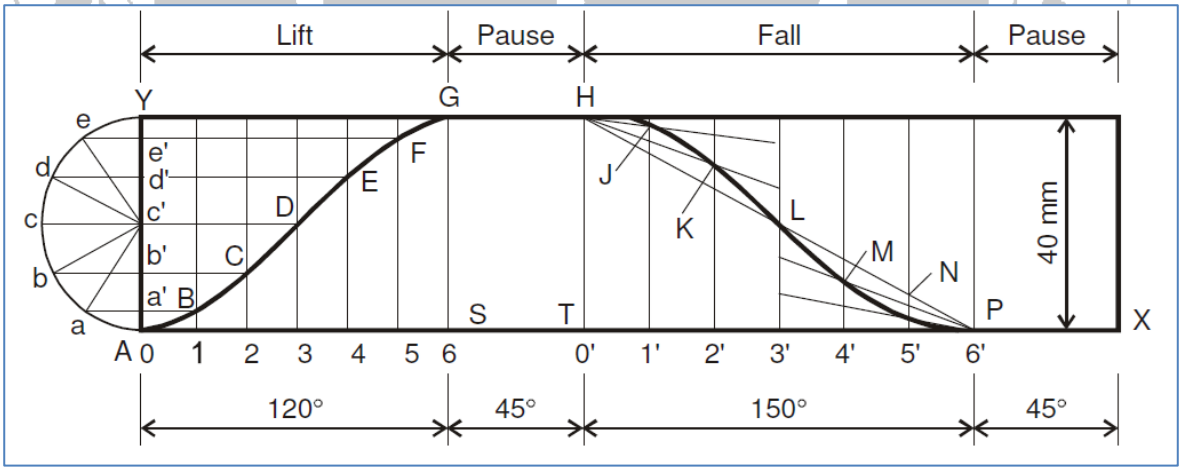


Fig.10.3 Displacement diagram (Problem No.2)

Cam profile:

Draw a base circle with centre O and radius equal to the least radius of cam (i.e., 25 mm).

ii. Draw a prime circle with centre O and radius

OA = Least radius of cam + Radius of roller = 25 +25/2 = 37.5 mm

iii. Draw a circle with centre O and radius equal to 20 mm to represent the cam shaft.

iv. Draw an offset circle with centre O and radius equal to 12.5 mm.
v. Join OA, from OA draw angular displacements of the cam i.e. draw angle AOS = 120° to represent lift of the follower, angle SOT = 45° to represent pause, angle TOP = 150° to represent fall of the follower and angle POA = 45° to represent dwell or pause.
vi. Divide the angular displacements during lift and fall (i.e., angle AOS and TOP) into the same number of equal even parts (i.e. six parts) as in the displacement diagram.
vii. From points 1, 2, 3, ..., etc. and 0', 1', 2', 3' ... etc, on the prime circle. Draw tangents to the offset circle.
viii. Set off 1B, 2C, 3D, ... etc and equal to the displacements as measured from the displacement by joining the points A, B, C, ..., M, N, P with a smooth curve.
ix. Join the bottoms of the circles with a smooth curve as shown in fig.10.5. This is the required profile of the cam.

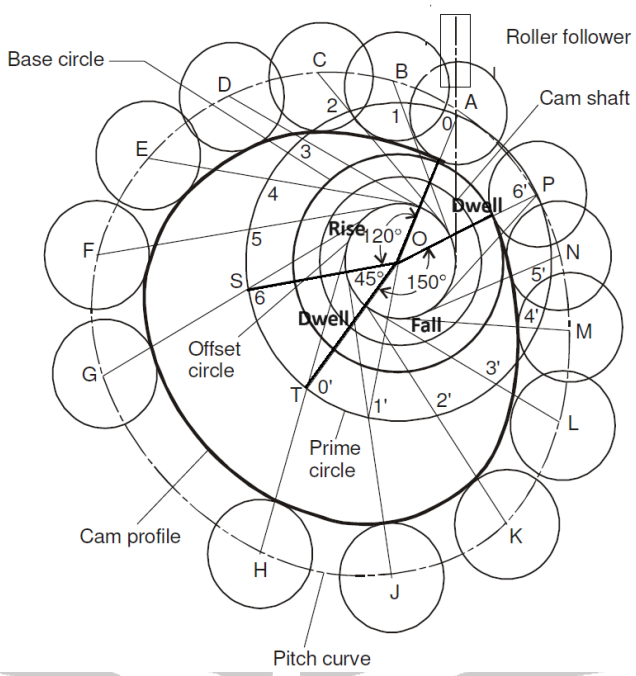


Fig.10.4 Cam Profile diagram (Problem No.2)

X. Observations and calculations

Sr. No	Parameters	Problem 1	Problem2
1	Type of follower		
2	Type (radial/Offset)		
3	Lift in mm		
4	Angle of rise (outward)		
5	Type of Motion of follower for rise (outward)		
6	Dwell 1		
7	Angle of return (fall)		
8	Type of Motion of follower for return (fall)		
9	Dwell 2		
10	Minimum radius of cam		

XI. Results

XII. Interpretation of Results

XIII. Conclusions and Recommendation

XIV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Compare Roller and Knife edge follower.
2. Roller follower is preferred to knife edge follower, justify
3. Draw displacement diagram for a follower subjected to SHM during rise and uniform acceleration and retardation during return with following details:
   Stroke length = 40 mm
   Angle of rise = 180 °
   Angle of return = 180°

4. Draw the profile of cam imparting motion to a roller follower with following details
   Stroke length = 42 mm, Roller diameter = 14 mm
   Base circle diameter = 60mm, Angle of rise = 120°,
   Dwell after rise = 60°, Angle of return = 180°
   The follower rises with SHM and returns with uniform velocity.

[Space for Answer]

XV. References / Suggestions for Further Reading

- www.youtube.com/watch?v=-xZ47RKrgYU
- https://www.youtube.com/watch?v=TYX7C2p-9G4
- https://www.youtube.com/watch?v=_BDw_4g6Pg0&t=1s

XVI Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (10 Marks)		**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
Product Related (15 Marks)		**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			Dated signature of Teacher
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No:11 *Measurement of Follower displacement with cam rotation of Knife edge and Roller Follower

I. Practical Significance

Cam is a circular or cylindrical disc with arc or special profile which moves the follower by tracing the profile to obtain the required motion. Cam profile will decide the desired motion of the follower. Cam will impart rotating, reciprocating or oscillating motion to the follower.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. 'Use of suitable cam and follower mechanism to obtain desired motion in industrial application'

III. Course Level Learning Outcome (CO)

CO3- Develop a cam profile for given type of follower and its motions in practical situation.

IV. Laboratory Learning Outcome(s)

- Identify the displacement of follower with cam rotation.

V. Relative Affective Domain Related Outcome(s)-

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

The knife edge follower is having sharp edge and due to high wear rate not suitable for actual use. The roller follower is having rolling smooth contact which reduce friction and wear.

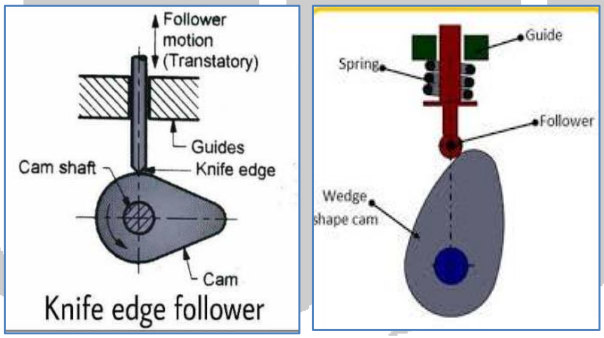


Fig.11.1 knife edge and Roller follower

VII. Experimental setup

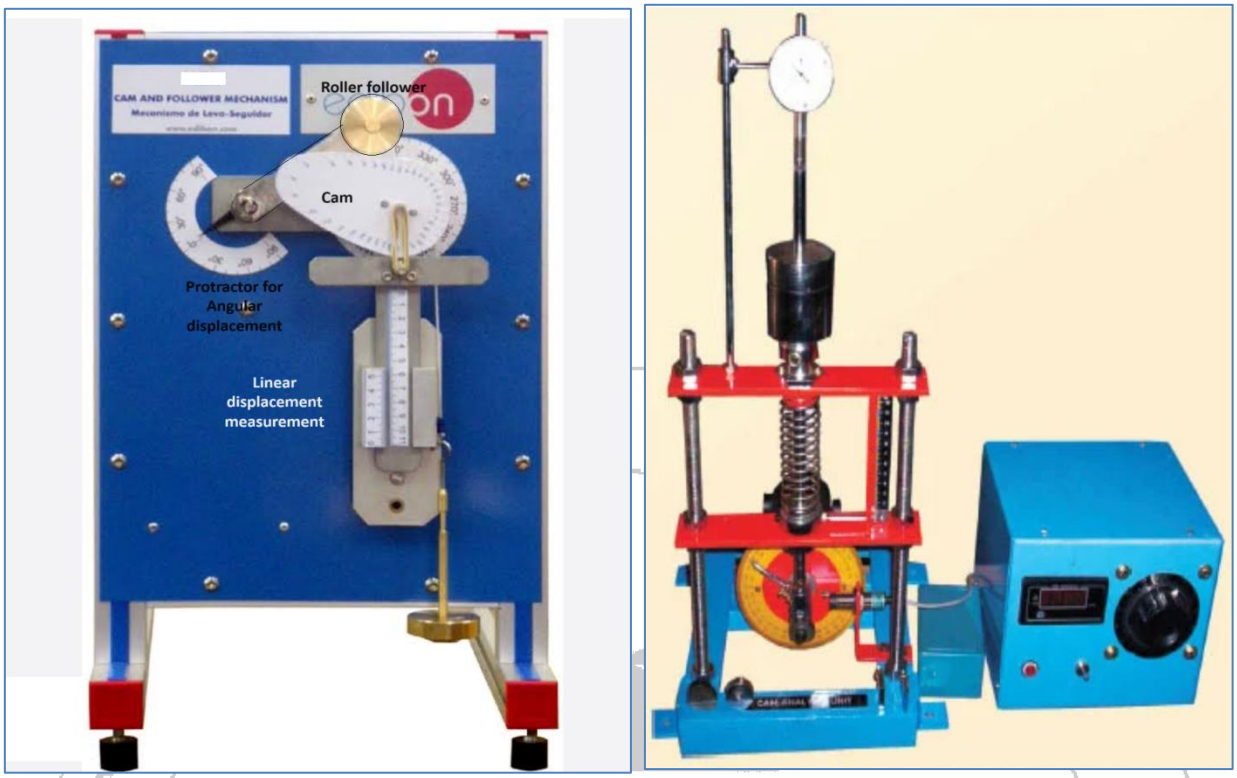


Fig.11.2 Set up of Cam and follower (Use suitable set up)

VIII. Required Resources /Apparatus/Equipment with specification

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Cam and Follower mechanism set up	Cam shaft driven by a D.C.motor/Manual operated. Knife edge and Roller follower Spring mounted. A graduated circular protractor and a dial gauge to note the follower displacement for the angle of cam rotation.	1
2	Disc types Cam set	Set of cams having different profiles (3-4 Nos)	1

IX. Precautions to be Followed

1. Properly mount cam on the cam shaft for accurate movement.
2. Read the displacement of follower linear and angular using Protractor and Dial gauge respectively.

X. Procedure

A. Knife Edge follower

1. Mount the cam on cam shaft properly and measuring protractor and dial gauge properly in the set up.
2. First mount Knife edge follower to contact cam surface with the help of spring and guide mechanism.

3. Rotate the cam slowly for cam rotation of 30°, 60°, 90°,……. up to 360° for one complete rotation.
4. Note the vertical linear movement of Knife edge follower using dial gauge and angular displacement using calibrated protractor.
5. Change the cam and repeat the process.

B. Roller Follower

1. Mount the cam on cam shaft properly.
2. First mount Roller follower to contact cam surface with the help of spring and guide mechanism.
3. Rotate the cam slowly for cam rotation of 30°, 60°, 90°,…. up to 360° for one complete rotation.
4. Note the vertical linear movement of Roller follower using dial gauge and angular displacement using calibrated protractor.
5. Change the cam and repeat the process.

XI. Observations and calculations

1. Radius of base circle of cam: _____
2. Diameter of Roller Follower: _____
3. Total lift of Knife edge Follower: _____
4. Total angular movement of Roller Follower: _____

Table 11.1 Displacement of Knife Edge Follower

Sr. No	Cam Type 1 rotation	Follower Displacement		Cam Type 2 rotation	Follower Displacement	
	(°)	mm	(°)	(°)	mm	(°)
1	30			30		
2	60			60		
3	90			90		
4	120			120		
5	150			150		
6	180			180		
7	210			210		
8	240			240		
9	270			270		
10	300			300		
11	330			330		
12	360			360		

Table 11.2 Displacement of Roller Follower

Sr. No	Cam Type 1 rotation	Follower Displacement		Cam Type 2 rotation	Follower Displacement	
	(°)	mm	(°)	(°)	mm	(°)
1	30			30		
2	60			60		
3	90			90		
4	120			120		
5	150			150		
6	180			180		
7	210			210		
8	240			240		
9	270			270		
10	300			300		
11	330			330		
12	360			360		

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Draw sketch wedge cam and cylindrical cam.
2. Draw sketch of Cam for sudden drop of follower to half of stroke of follower after half rotation of cam.
3. Draw use of cam for vertical movement of conical punch for sheet metal punching operation.

[Space for Answer]

-

XVI. References / Suggestions for Further Reading

- Cam Animation: https://www.youtube.com/watch?v=zLeQNfcatmg-
- Cams and Followers: https://www.youtube.com/watch?v=u5nwkm5IbqY
- Different Types of Cams & Followers: https://www.youtube.com/watch?v=Ibs10c9FX0M
- How Do Cam and Follower Mechanisms Work: https://www.youtube.com/watch?v=HsXWewecMLE

XVII Rubrics for Assessment Scheme.

	Performance Indicators	Weightage
	Process Related (10 Marks)	**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
	Product Related (15 Marks)	**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			**Dated signature of Teacher**
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No:12 *Estimation of Slip, Length of belt and Angle of contact in an Open and Cross belt drive.

I. Practical Significance

The power transmission is carried out between driver and driven shaft when they are located at far distance from each other. The Belt drives are mostly used in machine tools like belt driven lathe machine, drive for compressor and electric motor, Floor mill drive system, Conveyors for material handling system, etc

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. 'Use of Belt drive system for power transmission in industrial application'

III. Course Level Learning Outcome (CO)

CO3- Select the suitable power transmission devices for the given field/industrial application.

IV. Laboratory Learning Outcome(s)

- Identify the displacement of follower with cam rotation.

V. Relative Affective Domain Related Outcome(s)-

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

The figure shows open and cross belt drive arrangement. The basic definitions related to belt drive are:

1.Slip of the best: During transmission of power using belt, sometimes the frictional grip belt and pulleys is less and which may cause forward motion of driver pulley without movement of belt which affects velocity ratio of belt drive, known as slip of belt.

Slip is calculated as:

V.R= N2/N1= D1/D2 (1-{S/100})

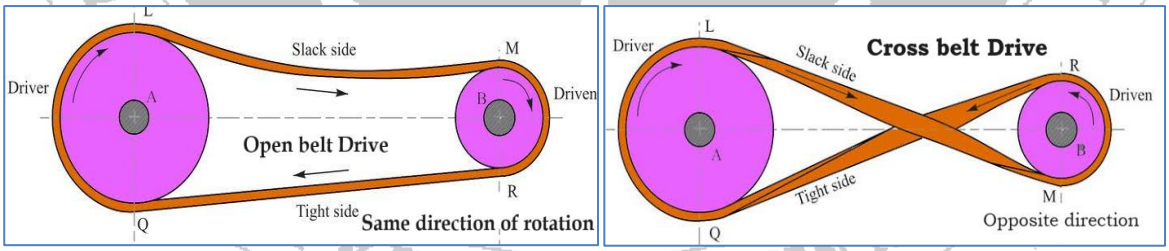


Fig.12.1 Open belt and Cross belt Drive

2. Length of Belt: The length of the belt is the total length of the belt which covers the portion of driver and driven pulley considering center distance between driver and driven pulleys.

Length of Open belt drive:

$L = \pi (R1+R2) + 2X + (R1 - R2)^2 / X$

Where R1= Radius of Driver pulley

R2= Radius of Driven Pulley

X = Centre Distance between Driver and Driven pulley

Length of Cross belt drive:

$L = \pi (R1+R2) + 2X + (R1+ R2)^2 / X$

Where R1= Radius of Driver pulley
R2= Radius of Driven Pulley
X = Centre Distance between Driver and Driven pulley

3. Angle of contact: It is the angle of wrap around a pulley and it has effect on friction between belt and pulley.

Open Belt drive $\theta = 180° - 2\alpha$ and $\alpha = \sin^{-1}(R1-R2)/X)$

Cross belt drive $\theta = 180° + 2\alpha$ and $\alpha = \sin^{-1}(R1+R2)/X)$

VII. Experimental setup

Fig.12.2 Set up Belt drive (Use suitable set up)

VIII. Required Resources /Apparatus/Equipment with specification

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Belt drive set up	Driver and driven pulley of same/different diameter with belt and electric motor for driver shaft with frame.	1
2	Tachometer	Mechanical direct contact type / Optical range up to 2000 RPM	1

IX. Precautions to be Followed

- Properly mount belt drive to note slip of belt.
- Use tachometer carefully.

- Do not wear loose clothes closure to belt and rotating pulleys.

X. Procedure

1. Mount he belts properly between driver and driven pulley.
2. Measure Diameter of driver and driven pulleys and center distance between them.
3. Check electric connections and start the supply to rotate the electric motor.
4. Measure speed (RPM) of driver and driven pulleys using tachometer.
5. Calculate slip, angle of contact and length of belt.

XI. Observations and calculations

1. Diameter of Driver Pulley (D1):_____
2. Diameter of Driven Pulley (D2) :_____
3. Centre distance between both pulleys(X): _____

Table 12.1 (a) Slip of Open belt drive

Sr. No	Driver pulley (N1) RPM	Driven pulley (N2) RPM	Slip (%)
1			
2			

Table 12.1 (b) Slip of Cross belt drive

Sr. No	Driver pulley (N1) RPM	Driven pulley (N2) RPM	Slip (%)
1			
2			

Table 12.2 (a) Length of Open belt drive

Sr. No	Driver pulley (R1) mm	Driven pulley (R2) mm	Centre distance (X) mm	Length of belt
1				
2				

Table 12.2 (b) Length of Cross belt drive

Sr. No	Driver pulley (R1) mm	Driven pulley (R2) mm	Centre distance (X) mm	Length of belt
1				
2				

Table 12.3 (a) Angle of Contact of Open belt drive

Sr. No	Driver pulley (R1) mm	Driven pulley (R2) mm	Centre distance (X) mm	Angle of contact θ
1				
2				

Table 12.3 (b) Angle of Contact of Cross belt drive

Sr. No	Driver pulley (R1) mm	Driven pulley (R2) mm	Centre distance (X) mm	Angle of contact θ
1				
2				

Sample calculations:

XI. Results

XII. Interpretation of Results

XIII. Conclusions and Recommendation

XIV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. List practical applications of open belt and cross belt drives
2. Calculate V.R, Length of belt and angle of contact if diameter of driver pulley is 40 mm and driven pulley is 60 mm mounted 120 mm apart.
3. Check the specification printed on belt and writes its meaning. (example: A-63, B-75)
4. Visit the workshop and calculate V.R of any machine having belt drive.

[Space for Answer]

XV. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=yxCBhD9nguw
- https://www.youtube.com/watch?v=j6woGQdUPFs
- https://www.youtube.com/watch?v=jSfADe_xcKc

XVII Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (10 Marks)		**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
Product Related (15 Marks)		**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			Dated signature of Teacher
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No:13 Identification of Gears and Gear train in Lab

I. Practical Significance

Gears are mechanical element having tooth provided on periphery to mesh with another gear for transmission of power with desired velocity ratio. The gears are mounted in a set to form gear train and used in machine tools like lathe, milling, automotive transmission gear box, materials handling cranes, clock mechanisms, Pumps, Conveyors, Crushers, etc

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. 'Use of suitable cam and follower mechanism in industrial application'

III. Course Level Learning Outcome (CO)

CO4- Select the suitable power transmission devices for the given field/industrial application.

IV. Laboratory Learning Outcome(s)

- Identify the type of gears and gear train.

V. Relative Affective Domain Related Outcome(s)-

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

Gears are classifies as spur, helical, bevel, worm and worm wheel, rack and pinion gears. A gear train is mechanical systems consist of two or more gears that contact each other to transmit power from one shaft to another. These gears are used to change rotational motion, change torque, and change the direction of rotation. It has types like Simple gear train, Compound gear train epicyclic gear train.

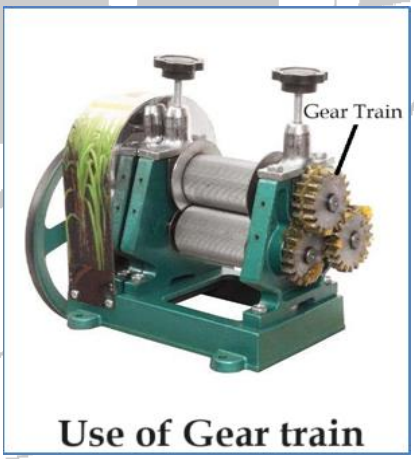
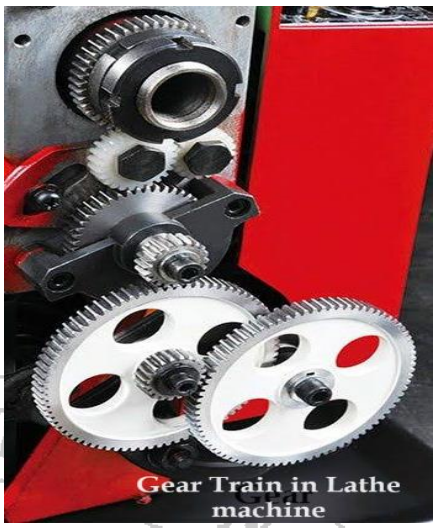


Fig.13.1 Types of gears and Gear trains

VII. Experimental setup



(Source: digital.library.cornell.edu/catalog)

Fig.13.2 Models or actual gear trains on machine

VIII. Required Resources /Apparatus/Equipment with specification

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Model of Gear trains	Working Model of Gear Trains: i) Simple Gear Train ii) Compound Gear train iii) Reverted Gear Train iv) epicyclic Gear Train	01
2	Gears	Actual Samples of various types of gears	01

IX. Precautions to be Followed

1. Handle the set up carefully.
2. Do not wear loose clothes during practical when gears are in motion.

X. Procedure

1. Collect the samples of gears and identify the type as per shape of teeth.
2. Note down diameter and number of teeth gear.
3. Observe demonstration models of gear train for simple gear train, compound gear train, epicyclic gear train available in laboratory.
4. Note down number of gears used in gear train with type of gear train.
5. Visit applied mechanics, machine shop to know actual applications of gear trains

XI. Observations and calculations

Table 13.1 Identification of Types of Gears

Sr. No	Type	Diameter	Number of teeth
1			
2			
3			
4			
5			

Table 13.2 Identification of Types of Gear trains (Demo models)

Sr. No	Type of Gear train	Number of gears used	Number of shafts
1			
2			
3			
4			
5			

Table 13.3 Identification of Types of Gear trains
(Machine shop/Applied mechanics lab or Automobile Engineering lab)

Sr. No	Name of machine/Equipment	Type of Gear train	Number of gears used
1			
2			
3			
4			
5			

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendation

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Compare Simple and compound gear train.
2. List practical applications of gear drive.
3. Draw sketch of rack and pinion mechanism.
4. Name the gear train used in 1. Wrist watch 2. Gear drive in Bicycle

[Space for Answer]

XVI. References / Suggestions for Further Reading

- Types of Gears: https://www.youtube.com/watch?v=edZnqd638-w
- Simple gear train: https://www.youtube.com/watch?v=QhYp4G3i5YQ
- Types of Gear Trains: https://www.youtube.com/watch?v=LmYhzHnMH9o

XVII Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (10 Marks)		**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
Product Related (15 Marks)		**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			Dated signature of Teacher
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No:14 *Preparation of different Gear trains from the given gears.

I. Practical Significance

Gear trains are combination of gears to obtain desired velocity of output shaft. The gear trains are prepared according to the configuration, velocity at output desired, space availability to mount effectively. Gear trains find its applications in simple clock mechanism to differential gear mechanism in automobiles.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

1. 'Use of suitable gear train in given industrial application'

III. Course Level Learning Outcome (CO)

CO4- Select the suitable power transmission devices for the given field/industrial application.

IV. Laboratory Learning Outcome(s)

- Identify the type of gears and gear train.
- Construct gear train for desirable velocity ratio.

V. Relative Affective Domain Related Outcome(s)-

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

1.Simple gear train: Only one gear in each shaft to transmit motion in series of gears.

2.Compound gear train: If more than one gear is mounted on the shaft and mesh with another gear on another shaft to transmit motion.

3.Elliptical gear train: It consists of one or more planetary gears and rotates around sun gear located at center with internal gear casing.

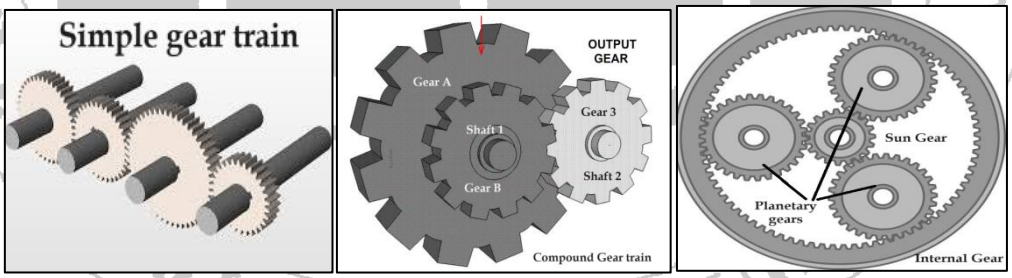


Fig.14.1 Types of Gear trains

VII. Experimental setup

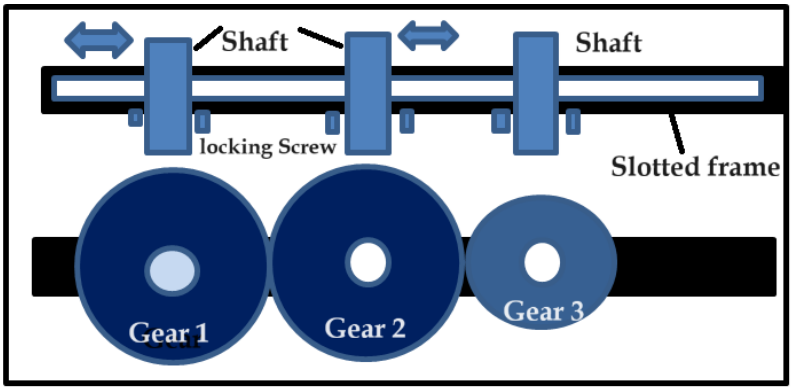


Fig.14.2 Set up for gear train preparation

VIII. Required Resources /Apparatus/Equipment with specification

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Set up of Gear trains	Experimental set up to arrange gears and shaft such that desired gear train can be obtained forgiven velocity ratio.	01
2	Set of Gears	Actual Samples of various types of gears	01
3	Tool kit	Tachometer, tools for change of gears	01

IX. Precautions to be Followed

1. Handle the set up carefully.
2. Do not wear loose clothes during practical when gears are in motion.

X. Procedure

1. Identify set spur gears of same/different diameters.
2. Note down diameter and number of teeth on gear.
3. Decide the type of gear train and mount gears on shafts mounted on adjustable slotted frame. Lock the position of shaft mounted on bush/bearing so that it can freely rotate.
4. Operate the gear train and measure velocity ratio.

XI. Observations and calculations

Table 14.1 Simple gear train (using two gears)

Sr. No	Gear type and shaft No	Diameter	Number of teeth	Velocity ratio
1				
2				

Table 14.2 Simple gear train (using Three gears)

Sr. No	Gear type and shaft No	Diameter	Number of teeth	Velocity ratio
1				
2				

Table 14.3 Compound Gear train (using two gears on shaft 1 and one gear on shaft 2)

Sr. No	Gear type and shaft No	Diameter	Number of gears used	Velocity ratio
1				
2				

Table 14.4 Compound Gear train (using two gears on shaft 1 and Two gear on shaft 2)

Sr. No	Gear type and shaft No	Diameter	Number of gears used	Velocity ratio
1				
2				

I. Results

II. Interpretation of Results

III. Conclusions and Recommendation

IV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. List practical applications of Simple gear train.
2. Draw sketch of Compound gear train.
3. Name the gear train used in 1. Lathe machine 2. Differential in automobiles
4. Compare Simple, compound and epicyclical gear train.
5. Define velocity ratio and train value in gear train.

[Space for Answer]

XII. References / Suggestions for Further Reading

- Types of Gears: https://www.youtube.com/watch?v=edZnqd638-w
- Simple gear train: https://www.youtube.com/watch?v=QhYp4G3i5YQ
- Types of Gear Trains: https://www.youtube.com/watch?v=LmYhzHnMH9o

XVII Rubrics for Assessment Scheme

	Performance Indicators	Weightage
	Process Related (10 Marks)	**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
	Product Related (15 Marks)	**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			**Dated signature of Teacher**
Process Related (10)	**Product Related (15)**	**Total (25)**	

Practical No:15 *Balancing of rotating unbalanced system

I. Practical Significance

The rotary engines or machines are subjected to unbalanced forces if it is not balanced and may cause excessive vibrations, wear and reduces life and early failure of components. The balancing of rotating masses consists of evenly distribution of mass in a rotating body to reduce vibration and improve performance. It is important in turbines, car engines, engine crank shaft, aerospace and jet engines, lathe machines, Grinders, large mixers,etc

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer

2. 'Use of principle of balancing in rotary devices/equipment'

III. Course Level Learning Outcome (CO)

CO5- Use knowledge and skills related to balancing of masses and vibration for various applications.

IV. Laboratory Learning Outcome(s)

- Construct balanced system for rotating masses.

V. Relative Affective Domain related Outcome(s)-

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram (if required)

The rotating masses are get subjected to centrifugal forces due to high speed of rotation. The Shaft is stastically balanced then it will remain stable in any angular position without rotary motion. If it is subjected to motion for doing work,then it needs dynamically balaced system foooth and vibration free performace.

1. Static balancing: During static balancing no motor drive is provided and balancing of masses is carried out by setting position of massses so that cetrifugal forces of masses are equal and opposie. In case of several masses in the same plane the vector sum should be zero.

2. Dynamic balancing: In order to have a complete balance of the several revolving masses in different planes, the following conditions must be satisfied:

a. The forces in the reference plane must balance i.e. the resultant force must be zero.

b. The couple about the reference plane must balance, i.e. the resultant couple must be zero.

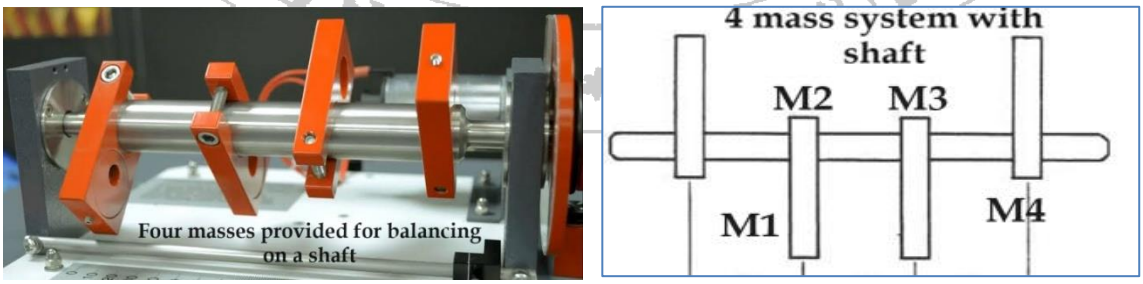


Fig.15.1 Principle of balancing

VII. Experimental setup

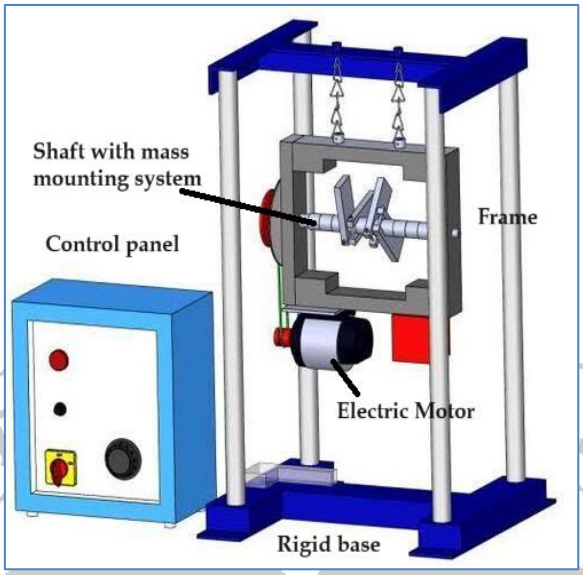


Fig.15.2 Balancing practical set up

VIII. Required Resources /Apparatus/Equipment with specification

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Set up Static and Dynamic balancing	Static & Dynamic Balancing Machine. Single phase motor connected to a shaft, containing 4 rotating masses. Each rotating mass has a facility to insert. Pulley is provided to add weights to balance the unbalance shaft	01
2	Tool kit	Tools for setting masses	01

IX. Precautions to be Followed

1. Handle the set up carefully.
2. Do not wear loose clothes during practical when shaft and masses are in motion.

X. Procedure

Static balancing:

1. Insert given weights in sequence 1-2-3-4 from pulley side.
2. Fix the pointer and pulley on shaft.
3. Fix the pointer on 0° (θ2) on the circular protractor scale.
4. Fix the weight no.1 in horizontal position.
5. Rotate the shaft after loosening previous position of pointer and fix it on θ3.
6. Fix the weight no. 2 in horizontal position.
7. Loose the pointer and rotate the shaft to fix pointer on θ4.
8. Fix the weight no.3 in horizontal position.
9. Loose the pointer and rotate the shaft to fix pointer on θ1.
10. Fix the weight no. 4 in horizontal position.

11. Now the weights are mounted in correct position.
12. Test the set up for static balancing, the system will remain steady in any angular position.

Dynamic balancing: -

13. Now put the belt on the pulleys of shaft and motor.
14. Switch on the Supply the main power to the motor through dimmer stat.
15. Gradually increase the speed of the motor. If the system runs smoothly and without vibrations, it shows that the system is dynamically balanced. Adjust the masses for perfectly dynamic balancing.
16. Gradually reduced the speed to minimum and then switch off the main supply to stop the system.

XI. Observations and calculations

Electric motor_____ H.P
Shaft diameter: _____ mm
No. of masses: _____

Table 15.1 Observation of masses

Mass No	Mass in grams	Radius in cm	Weight No
M1			
M2			
M3			
M4			

Table 15.1 Observation of Dynamic balancing

Plane	Weight no	Mass (M)	Radius (r)	Angle (θ)	Distance (L)	Couple (M.r.L)

Calculations:

1. Analytical method

2. Graphical method

V. Results

VI. Interpretation of Results

VII. Conclusions and Recommendation

VIII. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. State the effect of unbalanced rotary masses system in a machine.
2. Write the mathematical condition for static and dynamic balancing.
3. Explain the method of balancing for a. single mass by another mass rotating in same plane b. Several masses rotating in different planes
4. M1= 5kg, M2= 8 kg, M3= 10 kg, M4 are rotating in same plane at same radius with angular position for M2, M3 and M4 from M1 are 60^{o}, 120^{o}, 210^{o} respectively. Find the mass M4 for complete balance.

[Space for Answer]

XII. References / Suggestions for Further Reading

- Dynamic balancing: https://www.youtube.com/watch?v=jFJTskwku5k
- Static and Dynamic balancing : https://www.youtube.com/watch?v=x_XbXQRFM8o
- Difference between Static and Dynamic unbalance: https://www.youtube.com/watch?v=JB8i7LtY3mU

XVII Rubrics for Assessment Scheme

	Performance Indicators	Weightage
	Process Related (10 Marks)	**(40%)**
1	Handling of the measuring Instruments	20%
2	Observations/Calculation of final readings	20%
	Product Related (15 Marks)	**(60%)**
3	Interpretation of result	20%
4	Conclusions	20%
5	Practical related questions	20%
	Total	100 %

Marks Obtained			**Dated signature of Teacher**
Process Related (10)	**Product Related (15)**	**Total (25)**	