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Design, Manufacture and Project (MMME2044)

Revision for Spring exam

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Overview

- **Outline of the format & scope** of the exam paper and a plan for revision
- **Summary of examined topics** on the functions, types and methods of design and selection machine elements

- You need to check the **timetable/location** of the MMME2044 exam

Learning objectives of MMME2044

- **The overall aim of this module is to**
  - ➢ enhance your **understanding, ability/skills** in design, e.g. group and individual projects,
  - ➢ be able to communicate efficiently of design in using CAD software and in presenting a good quality of drawings,
  - ➢ **demonstrate good level of knowledge of design methods, functions and selection of components used in machine systems.**

- The **Spring exam** is only to assess **your understanding and knowledge** of **taught topics covered in lectures.**

- To avoid heavy work load for revision, **NOT all taught topics in both semesters** will be included in the exam with **details given in the following slides**.

How is MMME2044 module assessed?

- **Coursework elements** **60%**
  - CAE tasks (Autumn & Spring) **formative**
  - Design & Make Project
    - Design (Autumn) ***(20%)***
    - Make and Test (After exams) ***(10%)***
  - Individual Project (Spring, almost done now) ***(30%)***
- **Examination – 2 hours** **40%**
  - **Close book in-person exam**

What could be included in the exam?

Topics could be included in the June exam covered in both autumn and spring semesters:

- ✓ **Machine Elements**
  - Bearings (1 & 2)
  - Bolted joints
  - Brakes and Clutches
  - Gears (1, 2 & 3)
  - Linkage mechanisms
- ✓ **Design Methods**
  - Design for manufacture/assembly
  - Sustainable and inclusive design

What will not be included in the exam?

A list of topics to be excluded from the exam

- **Lecture topics**
  - Machine system design & Selection of Springs
  - Pneumatics and Hydraulics
  - Seals
  - Shaft design
- **Group D&M (Air Motor) and individual (Gearbox Actuator) projects PDR and CDDR related, design, calculations or GA and detail drawings**
- **Any CAE Solidworks related tasks and topics**

MMME2044 Exam format

- **Two Sections:**
  - ➢Section A – Machine elements (2 questions)
  - ➢Section B – Design methods (1 question)
- Answer **All Three questions**
- Each question carries 20 marks
- **Close book in-person exam**

Note: **No formula sheet for exam,** instead equations will be given at the end of a question (check past exam papers as examples)

However, you need to know **basic concepts** and a few **fundamental equations**, e.g. **gear module**, ***m=d/N*** or **gear ratio**, **$Z=\omega_1/\omega_2=d_2/d_1=N_2/N_1$** as well as unit conversion, e.g. ***Pa*** ⇔***Mpa*** or ***rpm*** ⇔ ***rad/sec***

A few tips and hints for revision

- **Review lecture slides and handout materials**
  - Study contents & worked examples from **lecture slides, handouts & video recordings** (all available on **Moodle/Echo360**)
  - Be familiar with the **types of questions from past exam papers**
  - **True or False questions in Section A** (1/2 mark each) (see Lecture slides examples)
- **Format of MMME2044 exam (close book in person)**
  - **TWO hours duration**
  - **TWO Questions on Machine Elements** and **ONE Question on Design Methods** (**20 marks for each question**).
- **Except 2021-22 exam, the papers of other years were open book exams.**
- **Be careful about the use of CORRECT units in calculations.**

Additional support for revision

1) 16:00-18:00, Today, 12th May, Coates C19
2) 14:00-16:00, Monday, 15th May, Physics B1
3) 16:00-18:00, Friday, 19th May, Coates C19

- You're welcome to get in touch via email if you have further questions, I'll try to respond as prompt as I can

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End of Part 1

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Revision for Spring exam

Part 2

A note for the revision session

- The plan of this session is
  - ➢ to summarise the key learning objectives and
  - ➢ to highlight some important concepts, methods of machine elements and design considerations of related topics.
- The contents and examples used in the slides are to support the points of discussion but not to give an indication of any possible questions/solutions for this year's exam.

Section A: Machine elements

Topics for revision:

- Bearings (1 & 2)
- Bolted joints
- Brakes and Clutches
- Gears (1, 2 & 3)
- Linkage mechanisms

Revision Part 2

Section A: Bearings

Bearings are used to support a shaft and associated load and to allow relative motion of parts in a machine system.

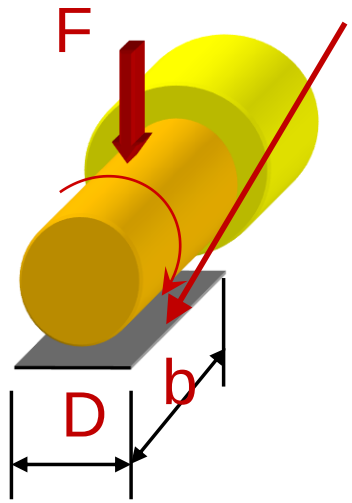
You should

- ✓ be familiar with the **three types of bearings** (**plain, hydrodynamic & rolling element**) and their applications;
- ✓ know how to design and select a suitable plain (boundary lubricated) bearing, understand the working mechanism of hydrodynamic bearing and be familiar with Stribeck curve;
- ✓ be able to determine the **life of rolling element bearing**, design suitable bearing mounting arrangement to take radial and axial forces.

Section A: Bearings

Plain (rubbing) bearing selection

- ***pV* factor** = base design parameter, **$\leq \frac{1}{2} p_{max} V_{max}$**



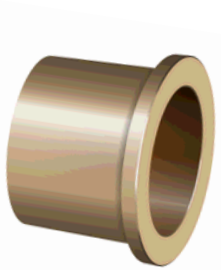
$$p = \frac{F}{bD}$$

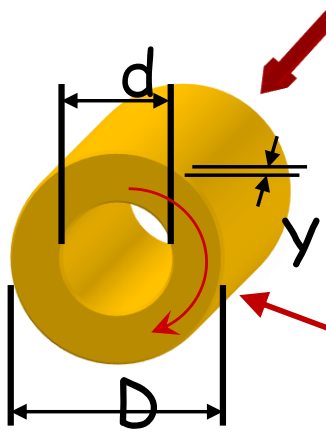
$$V = \omega \frac{d}{2}$$

For journal bearing,

Wear volume,

W = YbD





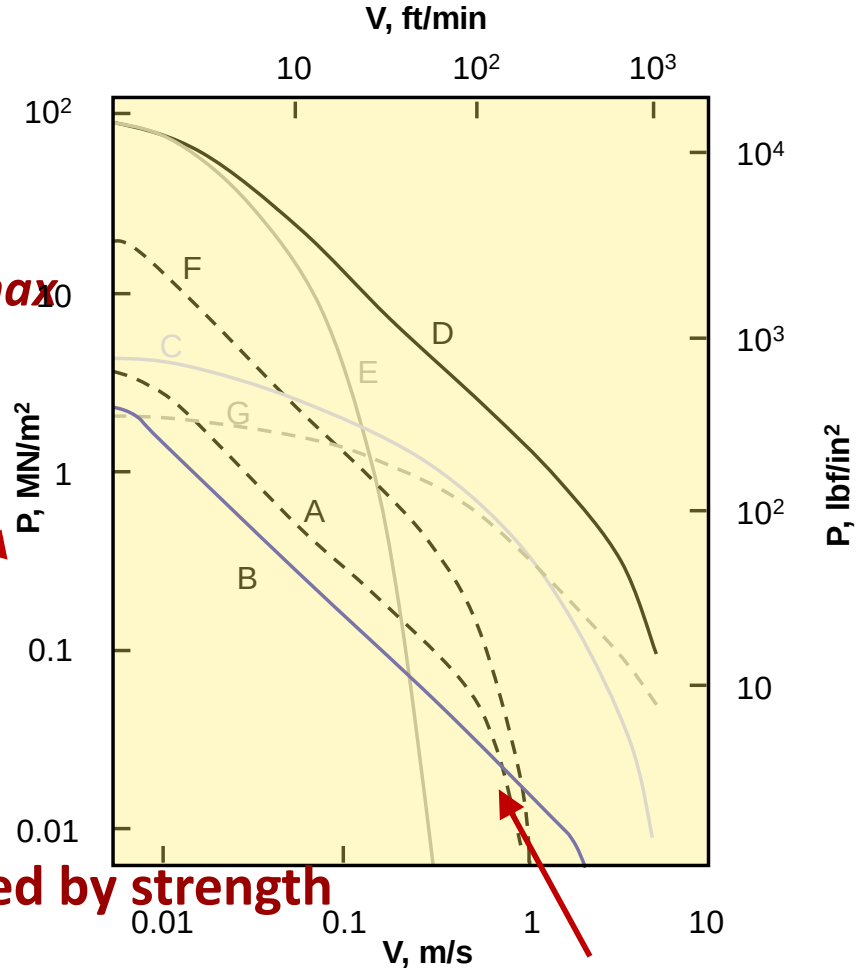
$$P = \frac{F}{\frac{\pi}{4}\left(D^2 - d^2\right)}$$

$$V = \omega \frac{D+d}{4}$$

For thrust bearing,

Wear volume,

$W = Y\pi/4(D^2-d^2)$



***Pmax* limited by strength**

***Vmax* limited by temperature rise**

Wear factor, K is a parameter that correlates wear, loading & life

$$K = \frac{W}{FVt}$$

Section A: Bearings

Rolling Element Bearings

Types, loading conditions, location & other considerations, e.g. misalignment, lubrication/seal and load taken from one part to another

Bearing life calculation

$$L_{10} = \left(\frac{C}{P}\right)^{q}$$

L_{10} = basic rating life, **millions of revolutions (10^6)**

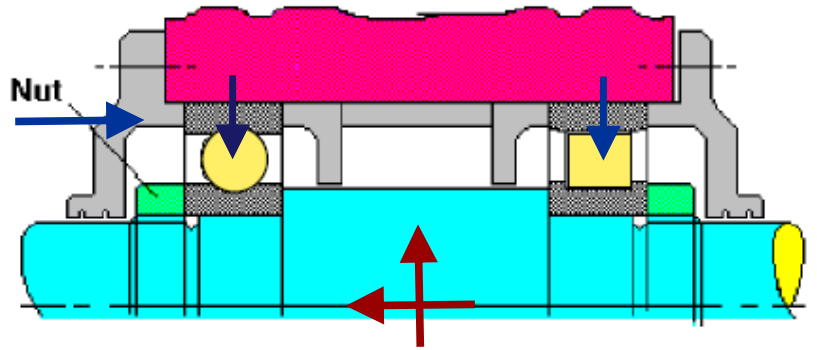
C = basic dynamic load rating, N

P = equivalent dynamic bearing load, N

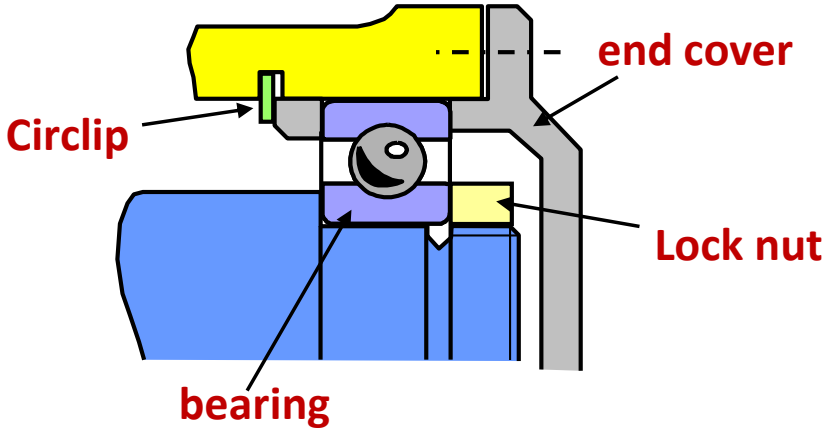
q = exponent of the life equation

(**3 for ball & 10/3 for roller bearings**)

$$F_m = \sqrt[q]{\frac{F_1^q U_1 + F_2^q U_2 + F_3^q U_3 \ldots}{U}}$$



Example for bearing location



Interference fit for rotating ring

Clearance fit for stationary ring

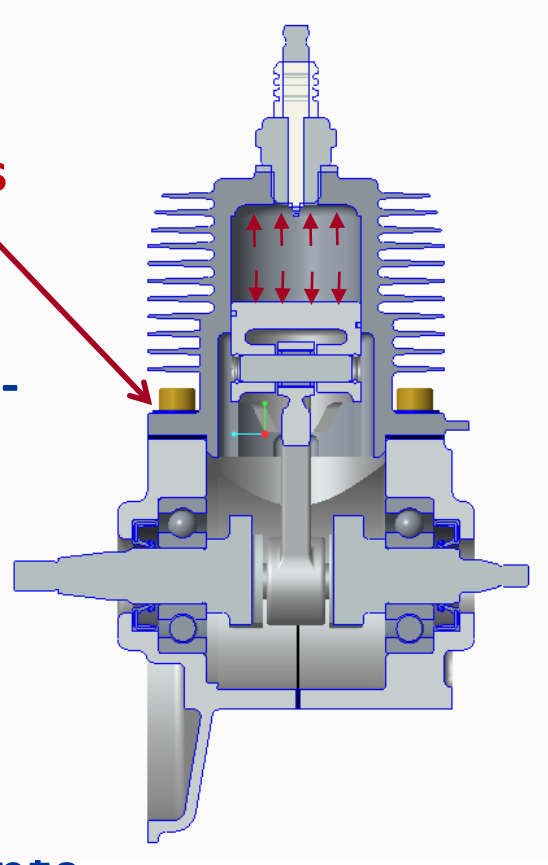
Section A: Bolted joints

Revision Part 2

Bolted joint or fastener is a device commonly used to connect two or more components in a mechanical system.

- **Bolted joints**
  - ✓ Pre-tension
  - ✓ Stiffness of bolt & clamped members
  - ✓ Strength of bolted joints

4xsocket screws to connect cylinder head & crankcase in a 2-stroke engine



You should

✓ be familiar with different types of joints and applications

✓ understand design considerations of pre-tensioned bolt joints

✓ be able to determine the stiffness of the bolt & clamped members, resultant loads and safety factor of pre-tensioned joint

Section A: Bolted joints

- Recommended pre-tension for non-permanent & permanent joints

$$F_i = 0.75A_s\sigma_P \quad F_i = 0.9A_s\sigma_P$$

- Resultant loads

$$F_b = \frac{K_b P}{K_b + K_c} + F_i > 0$$

$$F_c = \frac{K_c P}{K_b + K_c} - F_i \leq 0$$

- With a reserve factor of ***n0,*** make sure

$$NF_i \geq n_0 P \frac{K_c}{K_b + K_c}$$

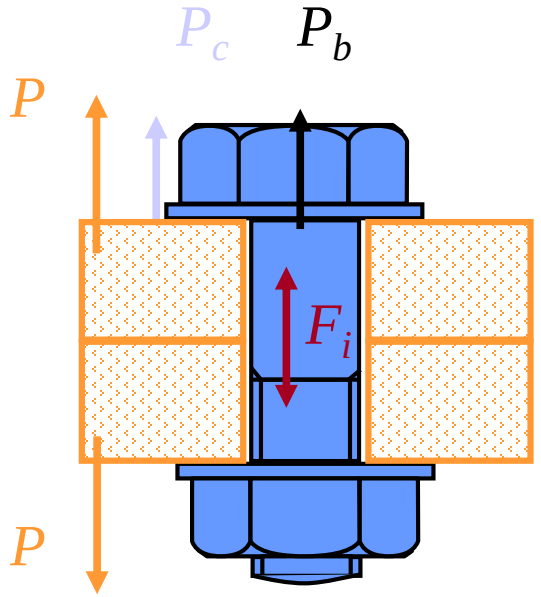
- Calculate the tightening torque $T = KF_i d$

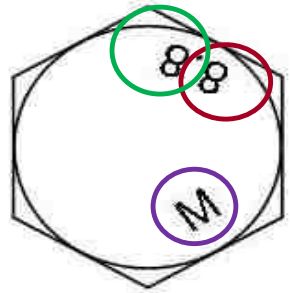
BS 3692:2001 Metric bolt strength **designation**

$$\sigma_{UTS} = 8 \times 100 = 800(MP_a)$$

$$\sigma_Y = 0.8 \times \sigma_{UTS} = 640(MP_a)$$

$$\sigma_P = 0.85 \times \sigma_Y = 544(MP_a)$$



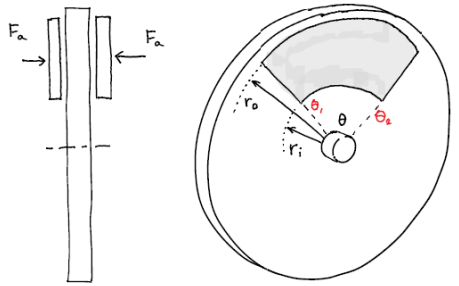


K **≈ 0.2**

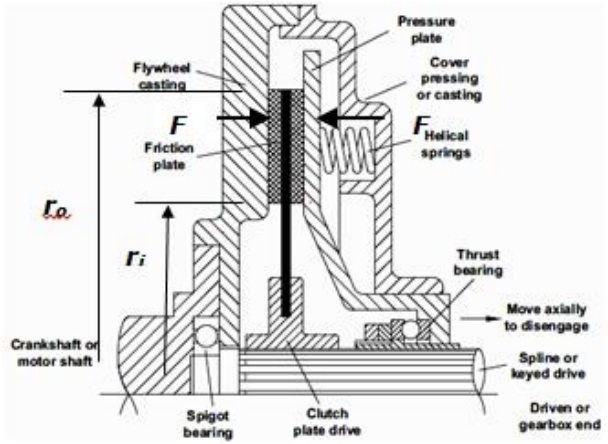
Section A: Brakes & Clutches

Revision Part 2

- **Brakes** enable slow down the speed of a system by absorbing energy & **Clutches** allow smooth connection of two rotating shafts
- **Friction brakes/clutches:**
  - ✓ Disc brakes
  - ✓ Drum brakes



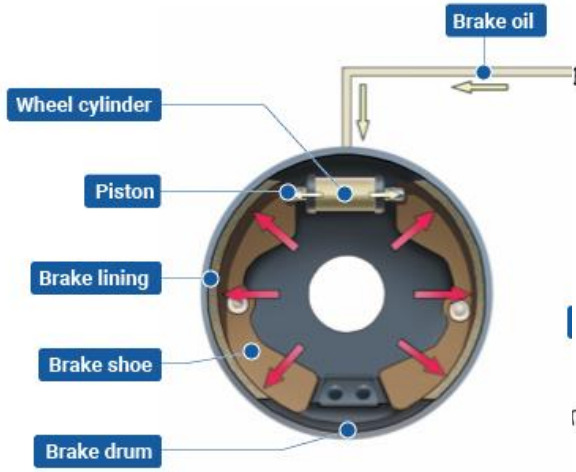
Disc brake with wide pad

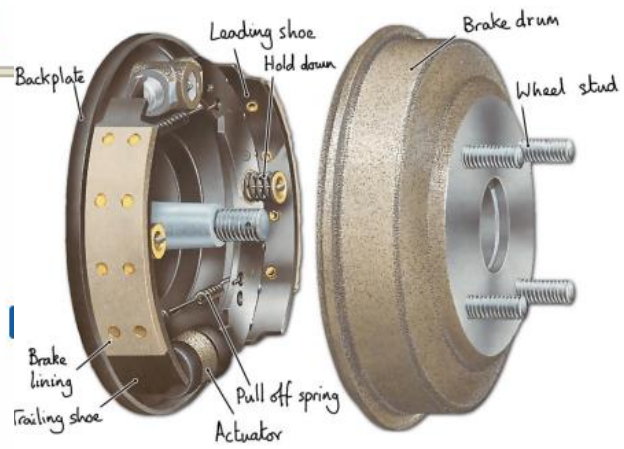


Cross-section of a disc clutch

It is useful to

- ✓ be familiar with the general layout and working mechanisms of disc brakes;
- ✓ Be familiar with the working mechanism of drum brakes;
- ✓ be familiar with terms, e.g. leading or trailing shoes, selection considerations for suitable frictional materials.





Section A: Gears (1, 2 & 3)

Revision Part 2

Gears are toothed members of various types to transmit power between shafts reliably and durably

You should

- ✓ know different types of gears and how they are classified
- ✓ be familiar with gear's terminology and fundamental equations;
- ✓ be able to calculate gear ratio & draw schematic diagram of a gear train (simple, compound, reverted or planetary);
- ✓ be able to evaluate a gear train used in, e.g. cars and wind turbines
- ✓ be able to use AGMA standard to do gear stress calculation and design analysis

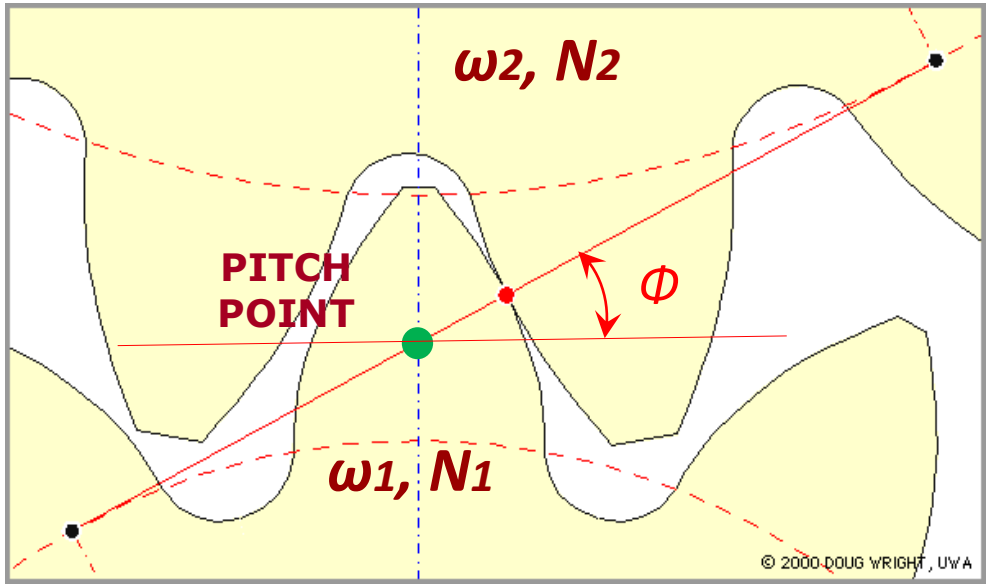
Section A: Gears 1

Revision Part 2

Gear fundamentals

Common gear types and classification

- e.g. Spur, helical gears, bevel gears and worm gears classified by **shaft arrangement**

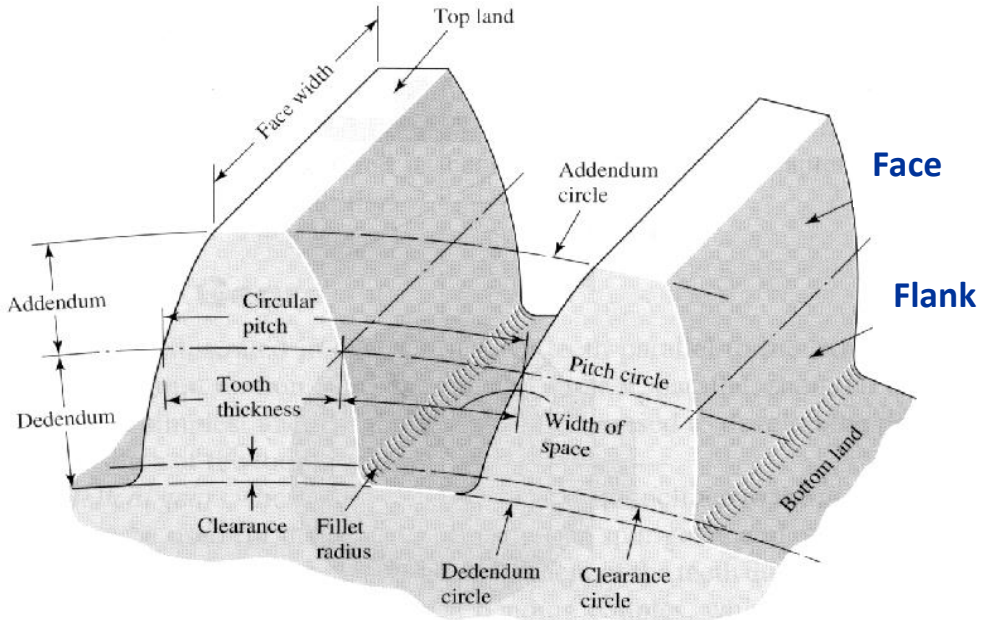


Key design parameters

Module (***m=D/N***), number of teeth (***N***), Pressure angle (ϕ)

For a pair of spur gears to work properly both should have the **same module (*m*) and pressure angle (ϕ)**

Don't need to memorise equations for other parameters



Basic gear ratio equation:

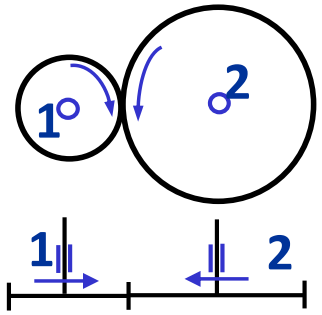
$$Z = \frac{\omega_1}{\omega_2} = \frac{d_2}{d_1} = \frac{N_2}{N_1}$$

Section A: Gears 2

Gear trains

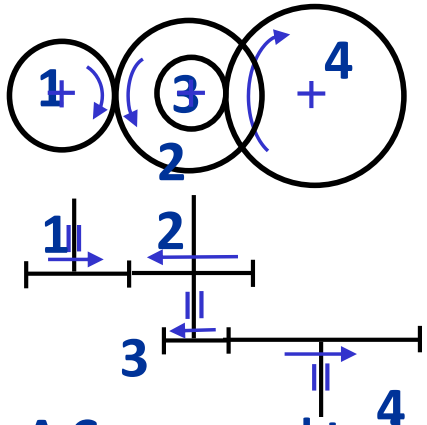
For simple and compound trains

$$Z = \frac{\omega_{In}}{\omega_{Out}} = \pm \frac{product\ of\ number\ of\ teeth\ on\ wheels}{product\ of\ number\ of\ teeth\ on\ pinions}$$



A simple train

$$Z = \frac{\omega_1}{\omega_2} = -\frac{D_2}{D_1} = -\frac{N_2}{N_1}$$



A Compound train

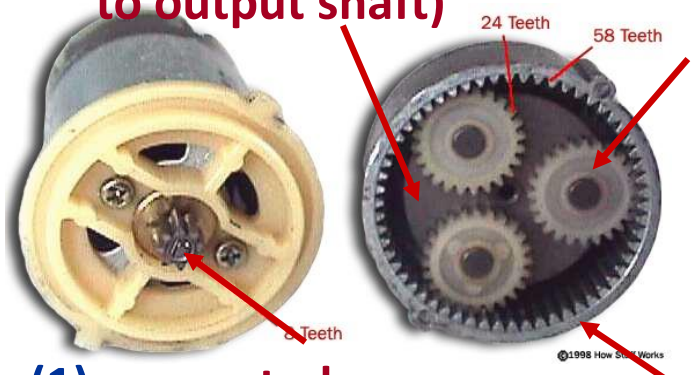
$$Z = \frac{\omega_1}{\omega_4} = \frac{N_2 N_4}{N_1 N_3}$$

For a planetary train

$$Z = \frac{\omega_F - \omega_A}{\omega_L - \omega_A} = \pm \frac{product\ of\ number\ of\ teeth\ on\ wheels}{product\ of\ number\ of\ teeth\ on\ pinions}$$

It is useful to have a look of more examples from lecture slides.

Carrier Plate (A, attached to output shaft)

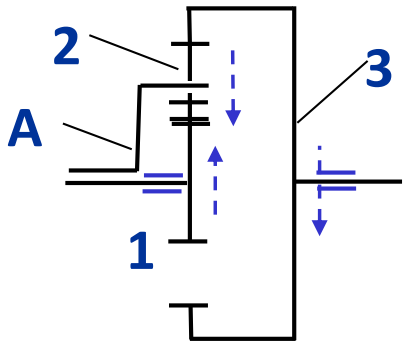


Planets (2) rotate along with Carrier Plate

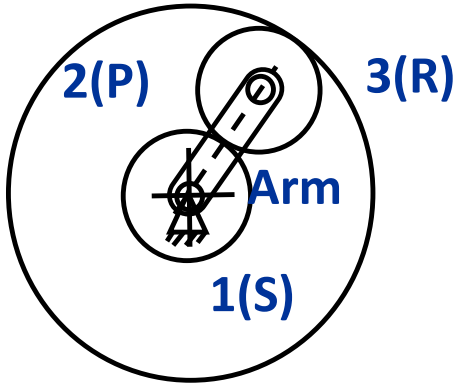
Sun (1) connected to motor

Ring (3) is stationary

$$Z = \frac{\omega_S}{\omega_A} = 1 + \frac{N_R}{N_S}$$



Planetary train



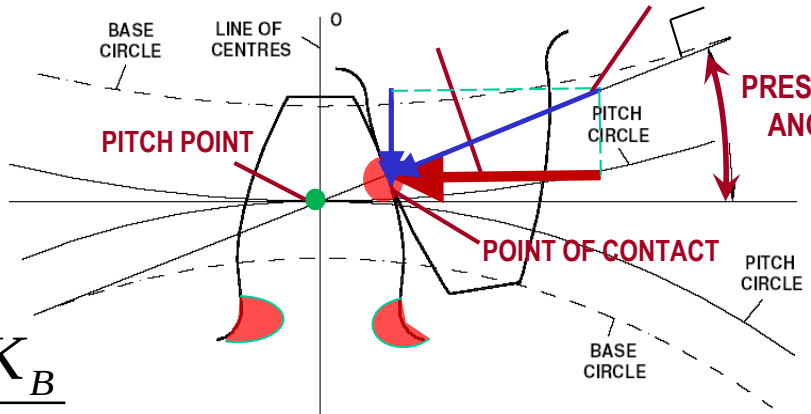
$$Z = \frac{\omega_1 - \omega_A}{\omega_3 - \omega_A} = -\frac{N_3}{N_1}$$

Section A: Gears 3

- **Common types of gear failure and their causes**
- **Transmitted force**

$$W_T = \frac{60\times10^3 P}{\pi d_1 n_1}(kN) \qquad W_T = \frac{P}{V_{\frac{d_1}{2}}}$$

Transmitted force



Force from pinion to gear

- **AGMA equations for bending & contact stresses**

Bending stress $$\sigma = W_t K_O K_V^{'} K_S \frac{1}{F\,m} \frac{K_H K_B}{Y_J}$$

Contact stress $$\sigma_C = Z_e \sqrt{W_t K_O K_V^{'} K_S \frac{K_H}{Fd} \frac{Z_R}{Z_I}}$$

- **AGMA equations for allowable bending & contact stresses**

Allowable bending stress $$\sigma_{all} = \frac{\sigma_{FP}}{S_F} \frac{Y_N}{Y_\theta Y_Z}$$

Allowable contact stress $$\sigma_{C,all} = \frac{\sigma_{HP}}{S_H} \frac{Z_N Z_W}{Y_\theta Y_Z}$$

Make sure

$$\sigma \le \sigma_{all}$$

$$\sigma_c \le \sigma_{C,all}$$

Section A: Linkage mechanisms

Revision Part 2

Linkage mechanisms use **links, joints** and **linkage chains** to enable transformation of **motion, force and power** in a machine system.

You should

- ✓ be familiar with the terminology of Degree of Freedom (DoF), links and different types of joints;
- ✓ be able to use Gruebler's equation to calculate DoF of a linkage.

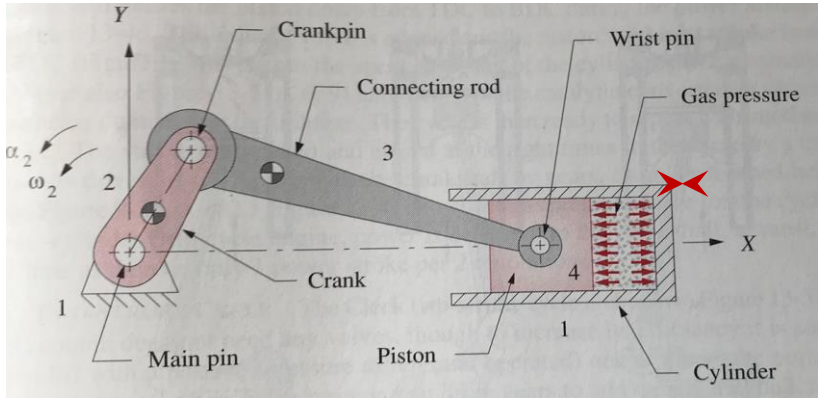
Gruebler's equation: $M = 3(L-1) - 2J$

a means to determine DoF and characteristics of a linkage

Slider is considered a **link**, L=4,

Piston sliding as a joint, J=4

M = 3*(4-1) – 2*4 = 1



A slider-crank mechanism for an IC engine

Section B: Design methods

Topics for revision:

- Design for Manufacture/Assembly
- Sustainable and inclusive design

Section B: Design for Manufacturing & Assembly

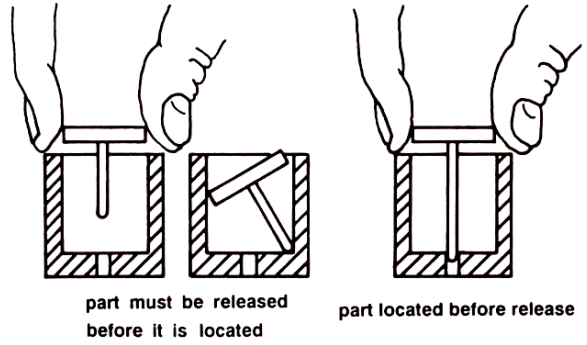
Revision Part 2

You should

- ✓ understand that DFMA is a systematic approach and a series of guidelines for
  - ➢ simplifying the product structure,
  - ➢ reducing parts count, manufacturing & assembly cost,
  - ➢ quantifying improvements.
- ✓ be familiar with general DFA and DFM guidelines
- ✓ be able to calculate design efficiency of assembly in practical applications
- ✓ be able to apply the DFMA methods in design.

Section B: Design for Manufacturing & Assembly

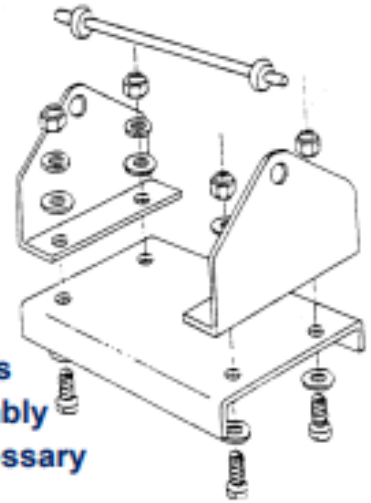
Revision Part 2



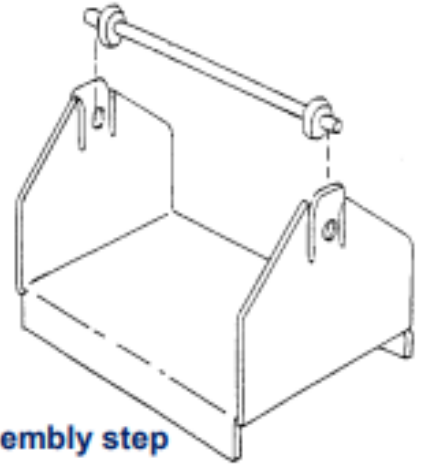
Design to aid insertion

Example: Rollbar Redesign

'..If more than 1/3 of the components in a product are fasteners, the assembly logic should be questioned.'

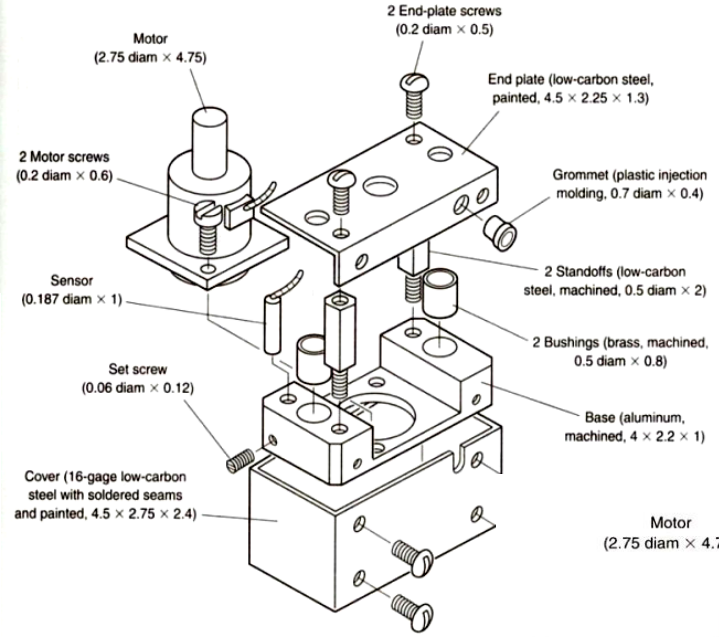


- 24 Parts
- 8 different parts
- multiple assembly processes necessary



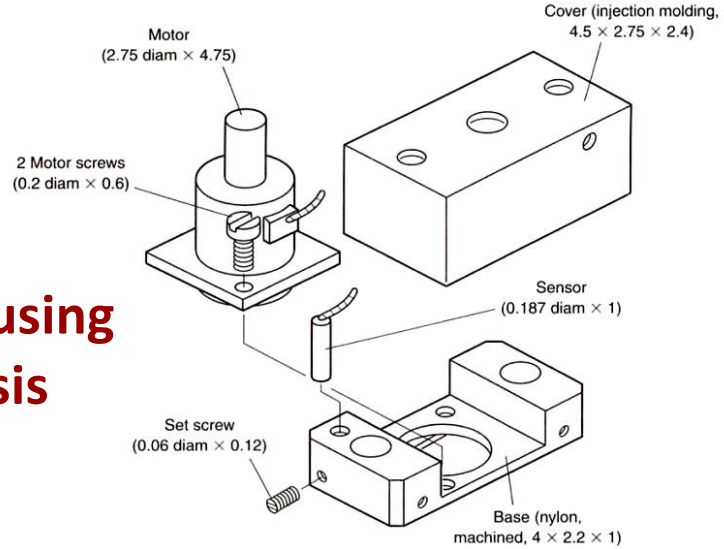
- 2 Parts
- one assembly step

Using DfMA principles, redesign an motor drive assembly



Initial design

Redesign by using DFA analysis



Section B: Sustainable and inclusive design

Revision Part 2

You should

- ✓ understand the concept and general principles of **sustainable and inclusive design**
- ✓ be able to use sustainable design methods, e.g. product lifecycle assessment and the Six Rs approach in practical design situations
- ✓ be able to use general inclusive design methods in practical design situations
- ✓ be able to calculate Energy Return on Investment (EROI) and cost-effectiveness with a given scenario

SEM Survey of MMME2044 Module

Design, Manufacture and Project

- Take a few minutes to complete the **SEM survey use the QR code or access link**

  https://bluecastle-uk-surveys.nottingham.ac.uk

- It would be useful if you can complete the SME survey questions on
  - If you have learnt something useful and enhanced your knowledge and skills in design
  - If you work well with Module Conveners, Design Tutors, Technicians, etc, in MMME2044 activities
  - What can be done for better and more efficient learning in the future

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End of Part 2

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Revision for Spring exam

Part 3 Questions and answers

Gook luck with your MMME2044 revision & exam

For any additional questions?

You may join in the additional support sessions