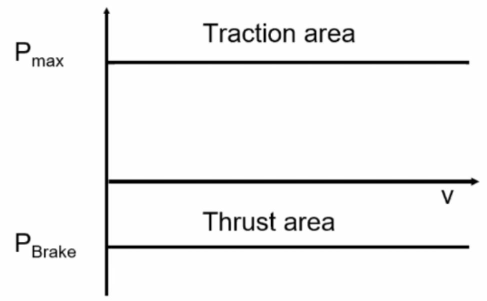
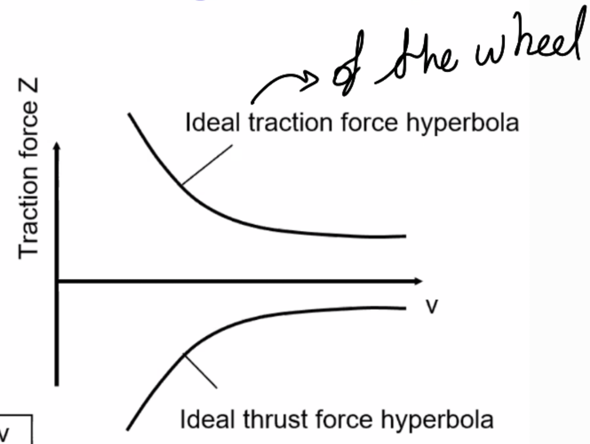
Transmission Role

Ideal Supply Characteristics of the Drive

Wish for an <u>ideal</u> supply characteristic:
the maximum wheel performance is to be constant throughout the entire velocity range





$$P_{max} = Z \cdot v = const.$$

$$Z = P_{max} \cdot \frac{1}{v}$$

Introduction – Driving Resistance

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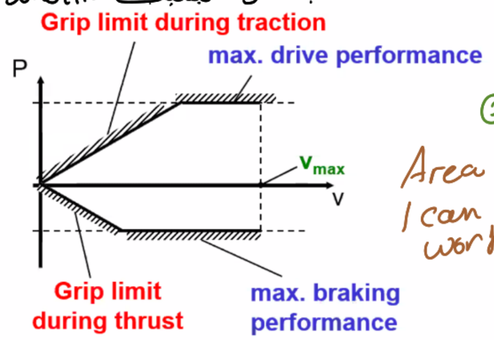
without slope, (slope=0) without Acceleration (a=0)

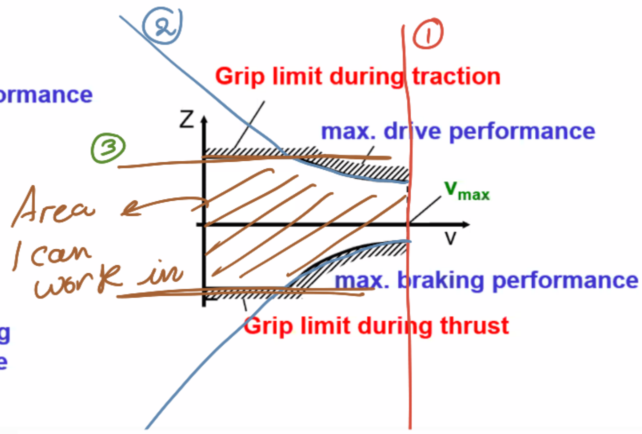
حتى لو في نزول ما بتسرع اكتر من هيك

However, the ideal supply characteristics are limited by:
1) *the maximum velocity of the vehicle v_{max}*
2) *the grip of the drive wheels ($v = 0 \Rightarrow Z \to \infty$)*
3) *the maximum performance of the drive system*

$$Z = P_{max} \cdot \frac{1}{v}$$

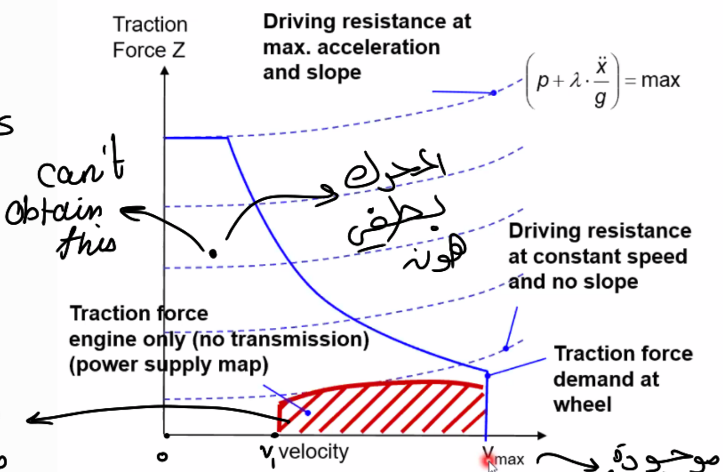
ما بقدر اوصل للسرعة مباشرة بسبب inertia





Introduction – Driving Resistance

if I connected the engine to the weels directly, the car won't be able to cross the red area and so a transmission train is needed



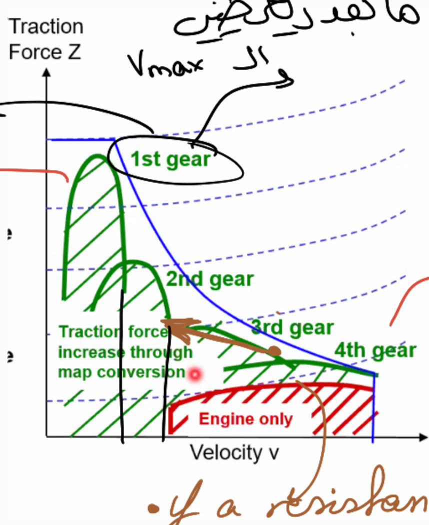
محرك الاحتراق الداخلي ما بقدر يعطيني force كافية

بدي حدا يدفش هون زرقها السيارة ما بتقدر

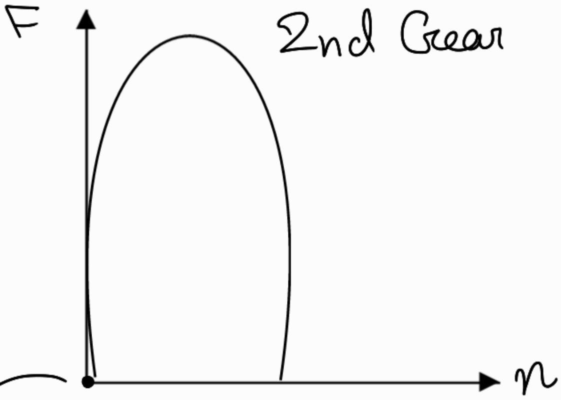
موجودة على الـ Dash Board

Used for high slopes

Maps of engine when Adding Transmission



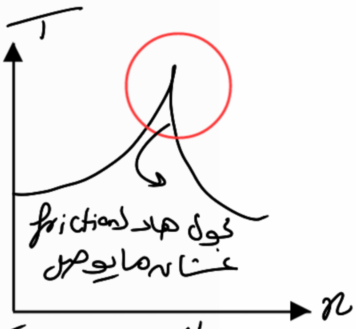
- If a resistance is added
- we need to go back to the previous gear to assure higher torque and so same speed



→ vehicle speed ≠ 0 (idle speed)

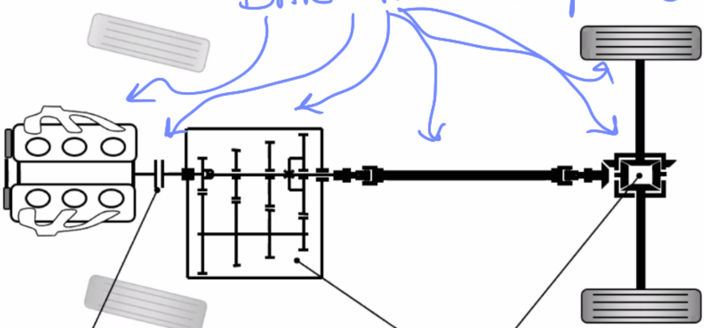
There is a Gap and so engine needs to be Accelerated

→ So i need an external force to reach 2nd Gear → 1st Gear / تشغيل



Transmission بتاكل → الclutch بتحكم لحتى تبدلك

Drive train components



Clutch (speed converter)

Functions:

- Disconnecting the drive train from the running engine when the vehicle is at standstill or during shifting
- Speed bridging at drive-off
- Vibration isolation
- "Overload protection" (blocked engine)

Transmission (speed-torque converter)

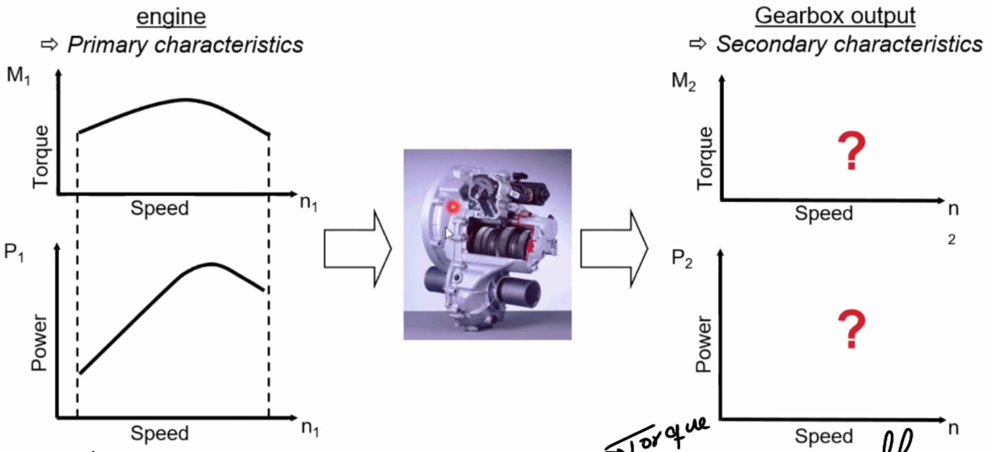
Functions:

- Conversion and adaptation of the engine map to the demand map in the full load range to the ideal traction force hyperbola by the optimal number of gears and their ratios
- reversal of direction of rotation

- Support of an optimised operation in terms of fuel consumption, emissions, noise, comfort and driving performance

امريكي ← Transmission = Gear Box → بريطاني

Introduction – Driving Condition Chart

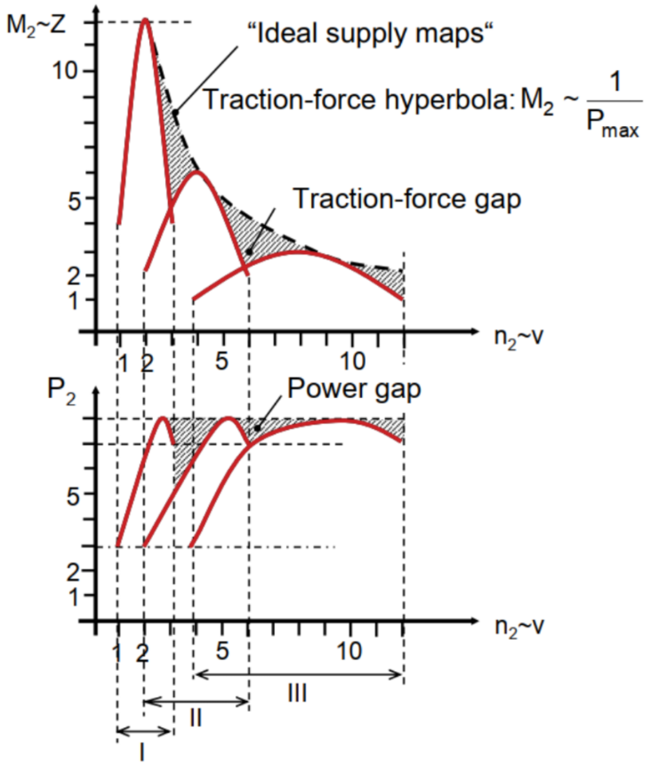


ضرب بـ i Torque converting: $M_2 = i \cdot M_1 \cdot \eta$ (Torque; η → efficiency)

قسمة على i Speed converting: $n_2 = \frac{n_1}{i}$ (200 ← ; input = 1000)

Power: $P_2 = P_1 \cdot \eta$

$i > 1$



$M \text{(Torque)} = \frac{P}{n}$ (n → Speed)

Traction force-velocity chart

⇧

Driving-condition chart

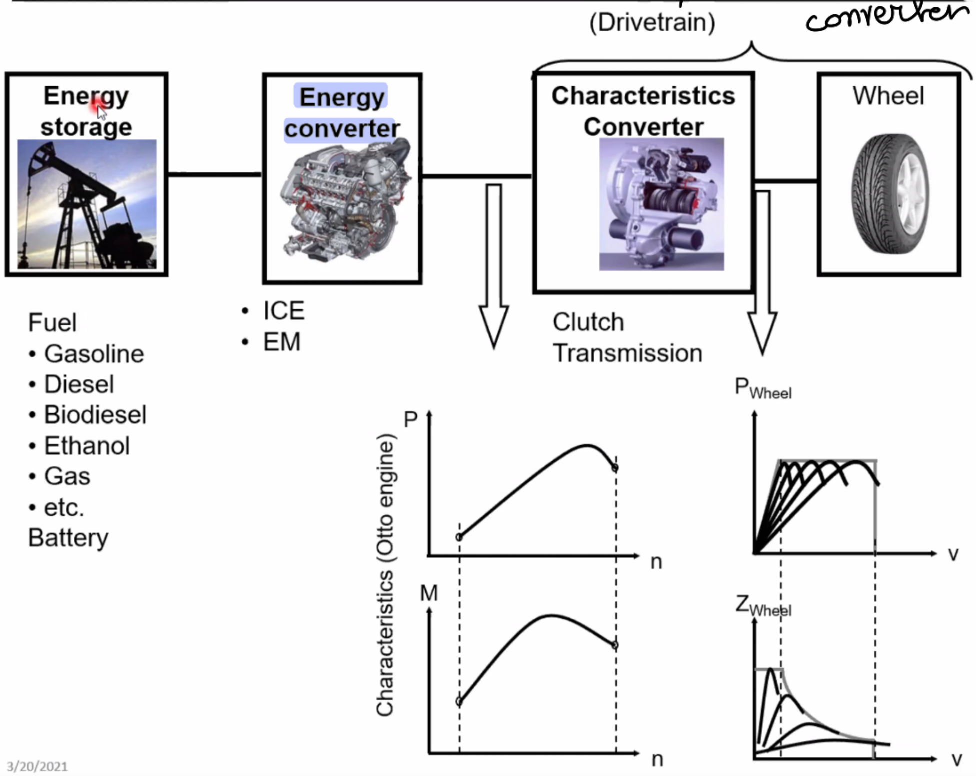
⇩

Performance-velocity chart

- Traction force-velocity charts are of great importance when evaluating ratio layout designs

Brief History of Transmissions

Not an energy converter



3/20/2021

Work at the drive wheels = W_R

Power at the drive wheels = P_R

$$W_R = \int_0^T P_R \cdot dt \quad ; \quad P_R = Z \cdot v \quad \text{(wheel slip neglected)}$$

Same

Diesel > gasoline >> gas

$$W_R = \eta_M \cdot \eta_K \cdot B \cdot H_u$$

J/Liter

- H_u: $\left[\frac{J}{L}\right]$ Lower calorific value of the fuel
- B: [L] Amount of fuel
- η_K: Average efficiency of power transmission (Drive eff.
- η_M: Average efficiency of engines

استهلاك الوقود

Amount of fuel

Driven Distance 100 Km

$$\text{Consumpt.} \ \frac{B}{L} = \frac{1}{\eta_M \cdot \eta_K \cdot H_u \cdot L} \cdot \left[\underbrace{G \cdot (p + f_R) \cdot L + \lambda \cdot m \int_0^L \ddot{x} \cdot dx + \frac{\rho}{2} \cdot c_w \cdot A \cdot (K^2 + 3e^2) \cdot L}_{Z} \right] + B_{LL}$$

G → mg ; f_R → wheels type

B_{LL} → idle consumption — يعني تكون السيارة واقفة

يعني Liter/100Km

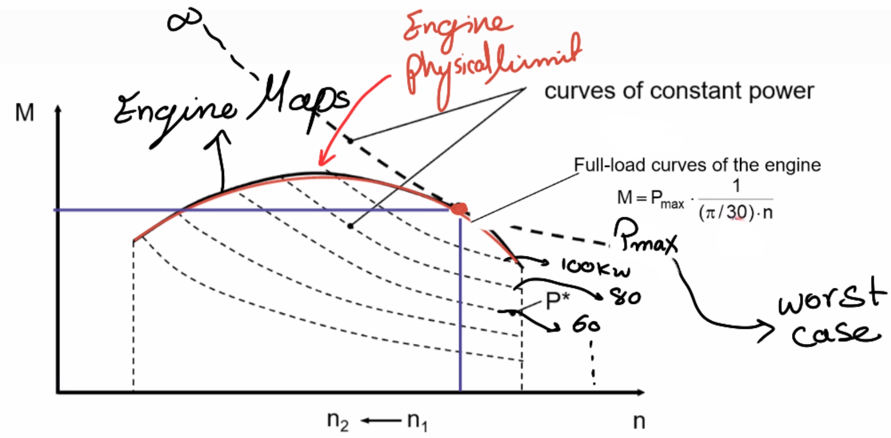
B_{LL}-reduction by: 1) switching off the engines during standstill

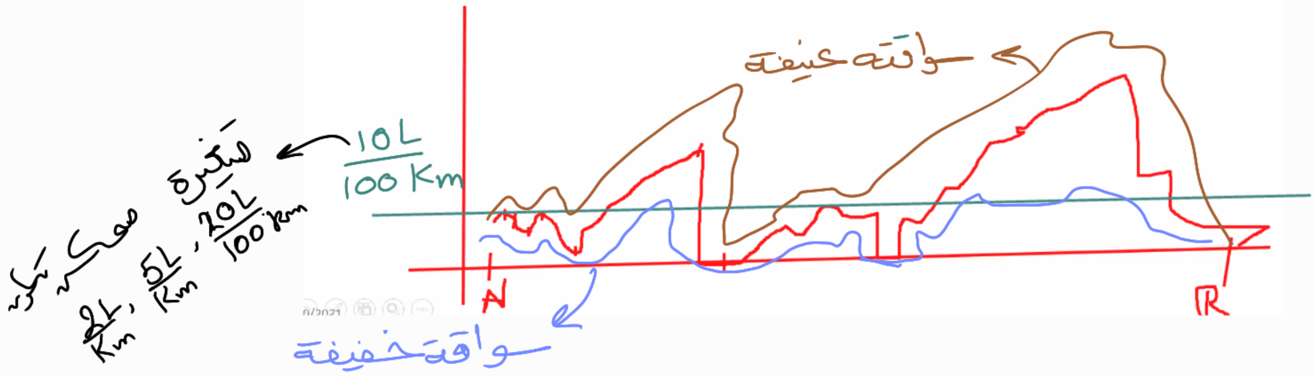
2) lowering the idle speed

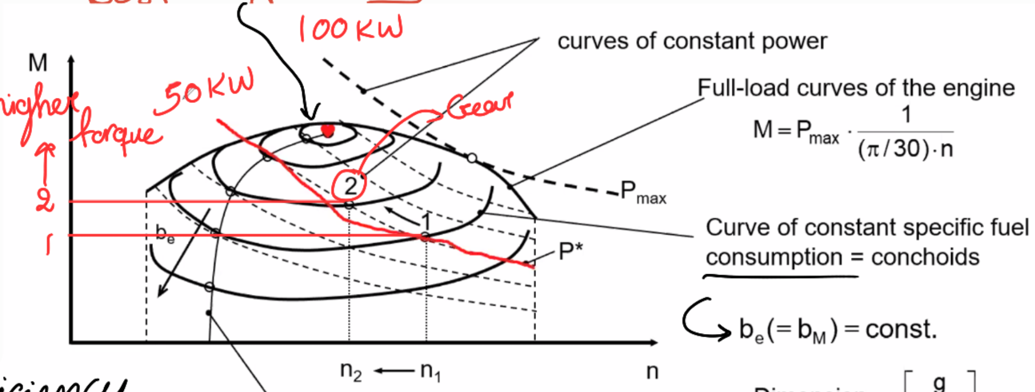
عالية على درجة حرارة قليلة

Reduction of consumption by:

- η_M, η_K high → increased efficiency of engine and power transmission (transmission, joints, shafts, etc.)
- η_M high → operating adjustment of engine by optimal transmission ratio
- H_u high → increased calorific value of fuel
- m small → small vehicle mass
- λ low → low inertia torques
- f_R low → low rolling resistance
- $\int_0^L \ddot{x}\,dx$ short → optimal acceleration → short accelerating time (-distance) in case of optimal engine operating point
- K low → low average velocity
- e small → preferably constant velocity
- $c_w A$ → preferably small







Operating curve of minimal fuel consumption (connecting line of the minimal consumptions on the power hyperbolas) → Best efficiency

Annotation: Reduction of consumption by shifting operating point (from 1 to 2), equal power P* for different speed and different consumption

less fuel consumption ←

Introduction – Transmission arrangements

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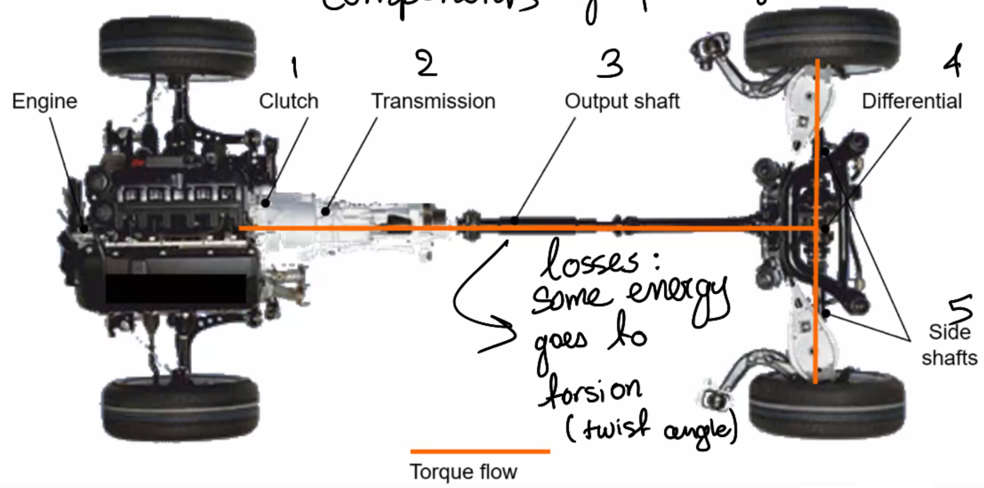
Transmission arrangements for standard drive

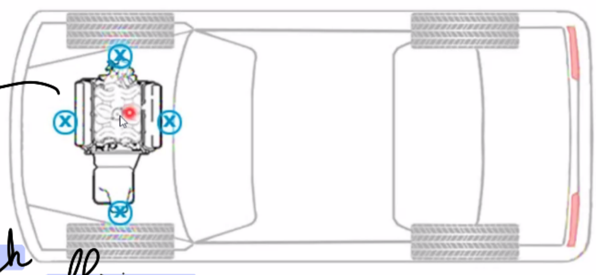
components of power train



Introduction – Transmission arrangements

Engine transversally installed

- These engines are aligned in such a way that the engine sits horizontally across the engine, with the transmission mounted beside and not behind it.
- Normally used in economy cars because it shortens the drivetrain and saves weight.
- The longer shaft will naturally have a lesser torsional stiffness which means it transfers power less efficiently due to twisting more, forcing the car to steer slightly to the side that the longer driveshaft is on.
- In terms of driving dynamics, a front-mounted transverse engine places the majority of the car's weight over the front wheels. This makes for maximum traction for the driven wheels which is obviously advantageous for acceleration and for tackling slippery surfaces.
- Sacrificing the ability to handle to very high amounts of power. (No high Acceleration)



Introduction – Transmission arrangements

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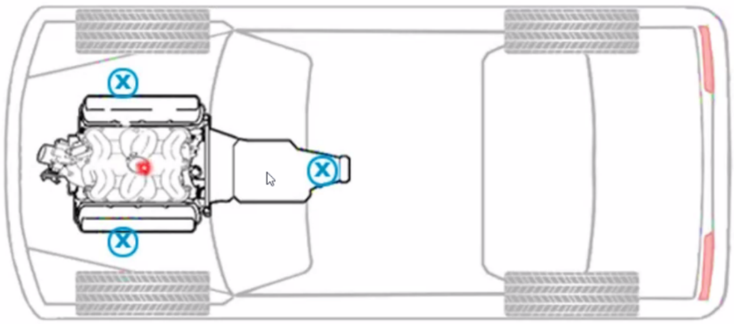
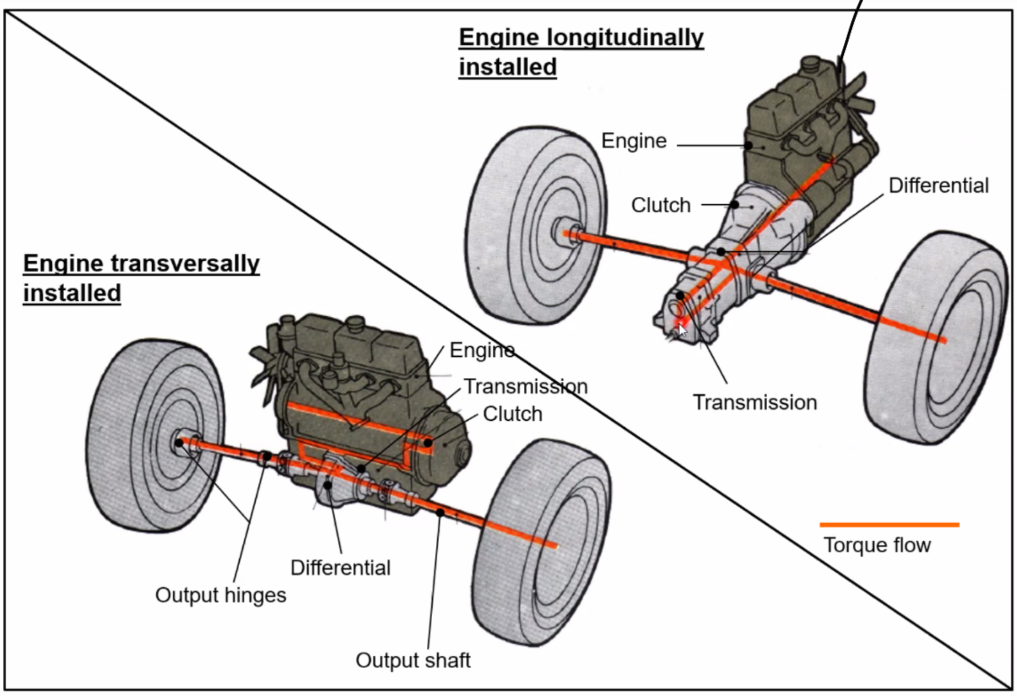
Engine longitudinally installed

Dashboard

- For longitudinal the engine sits **straight** and has the transmission **behind** it.
- Longitudinal setups are favored for high performance setups where fuel economy isn't really the main goal.
- Cabin space can also be hindered, through the long engine itself effectively pushing the dashboard placement back, and through the transmission tunnel running down the center of the car.

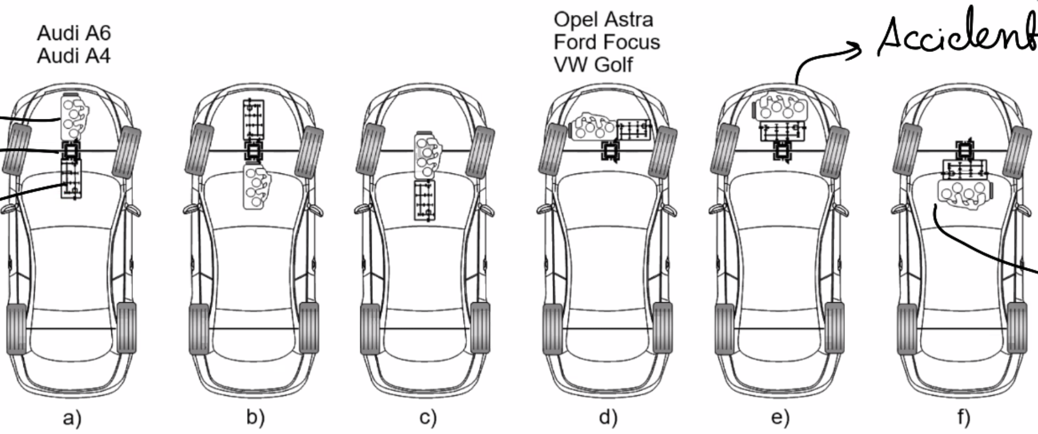


I need larger space



العجل الامامية الاحتكاك اعلى وال slipping أعلى

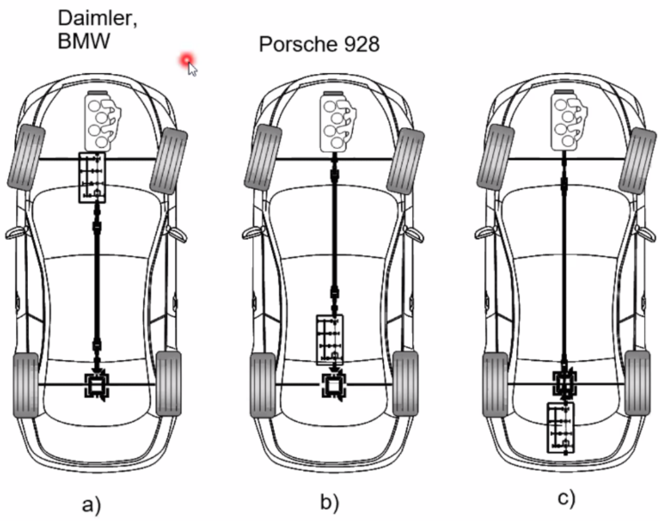
Arrangement of drive units for passenger cars with front-wheel drive



a) Longitudinal engine in front of axle, transmission longitudinally
b) Longitudinal engine behind axle, transmission longitudinally
c) Longitudinal engine above axle, transmission longitudinally
d) Transverse engine next to transmission ← معظم السيارات هيك
e) Transverse engine above transmission
f) Transverse engine behind transmission

Arrangement of drive units for passenger cars with standard drive

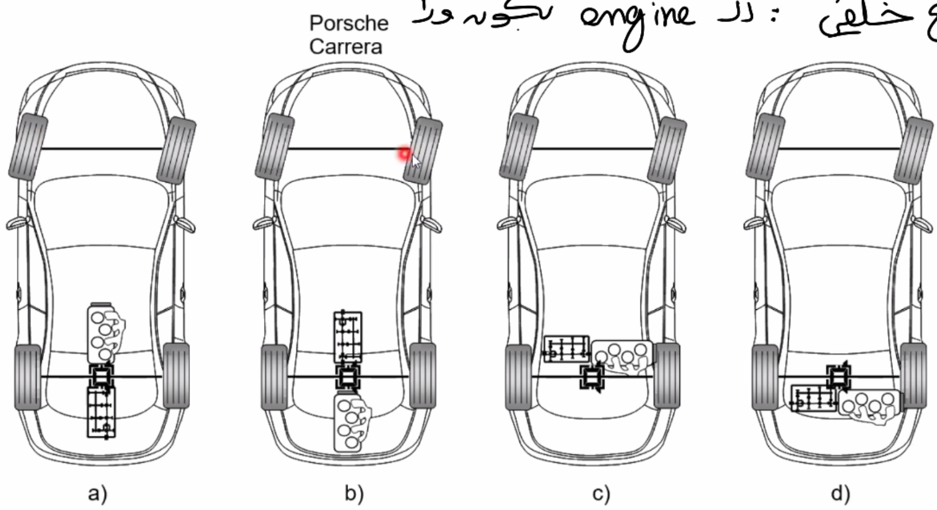
دفع رباعي



a) Longitudinal engine in front above / behind front axle, transmission longitudinally, axle drive with differential on the rear axle
b) Longitudinal engine in front above /
c) behind front axle, transmission longitudinally in front of rear axle or behind rear axle (transaxle principle)

Arrangement of drive units for passenger cars with rear-wheel drive

دفع خلفي : الـ engine بكون ورا



a) Longitudinal engine in front of axle
b) Longitudinal engine behind axle
c) Transverse engine next to transmission in front of axle
d) Transverse engine next to transmission behind axle

flywheel

2 masses ← أصبح

بجزئه طاقة

Dual Mass Flywheel - DMF

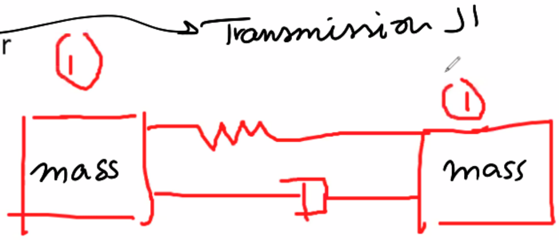
Why DMF: The periodic burn processes achieved in internal-combustion piston engines and the resultant rotary oscillation have increased. The noise and vibrations generated, such as gearbox rattle, bodywork resonance and excitation movement vibrations, in turn have an adverse effect on noise and driving comfort.

Aim: Reducing the system's eigenfrequency (→ natural) by changing masses of the vibration system and damping the vibration since high vibration amplitudes induce transmission rattling.

Engine explosions → noise & vibration → should not reach wheels and transmission

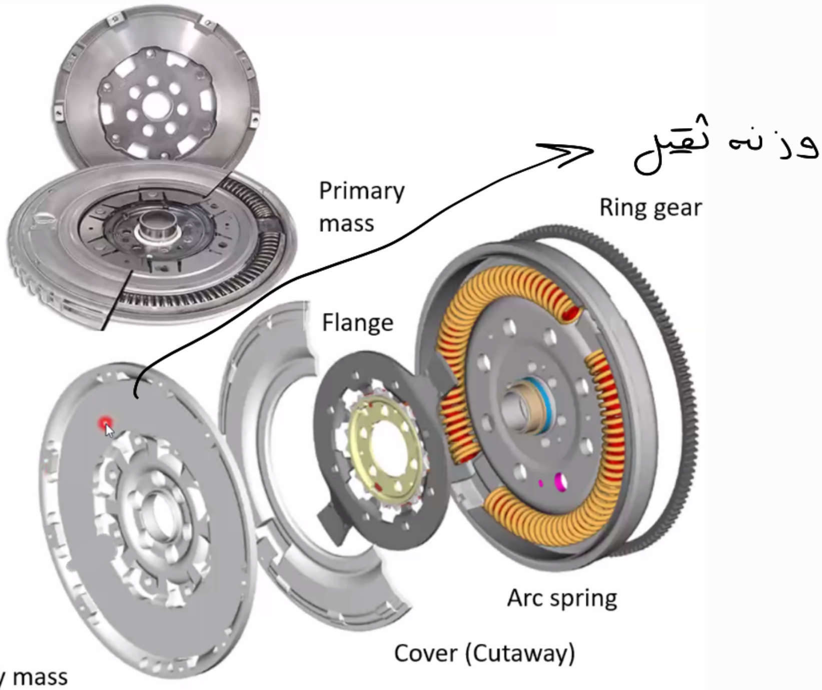
Main parameters of a DMF system are:

- The primary (→ عند ال engine) and secondary-side (→ Transmission عند ال) mass moment of inertia
- The spring rate of the torsion damper
- Damping characteristics

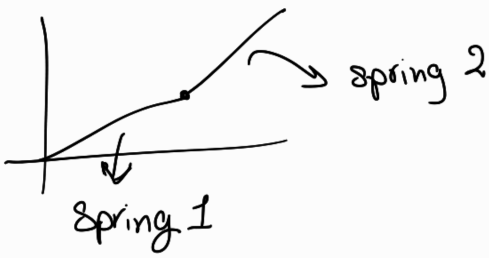


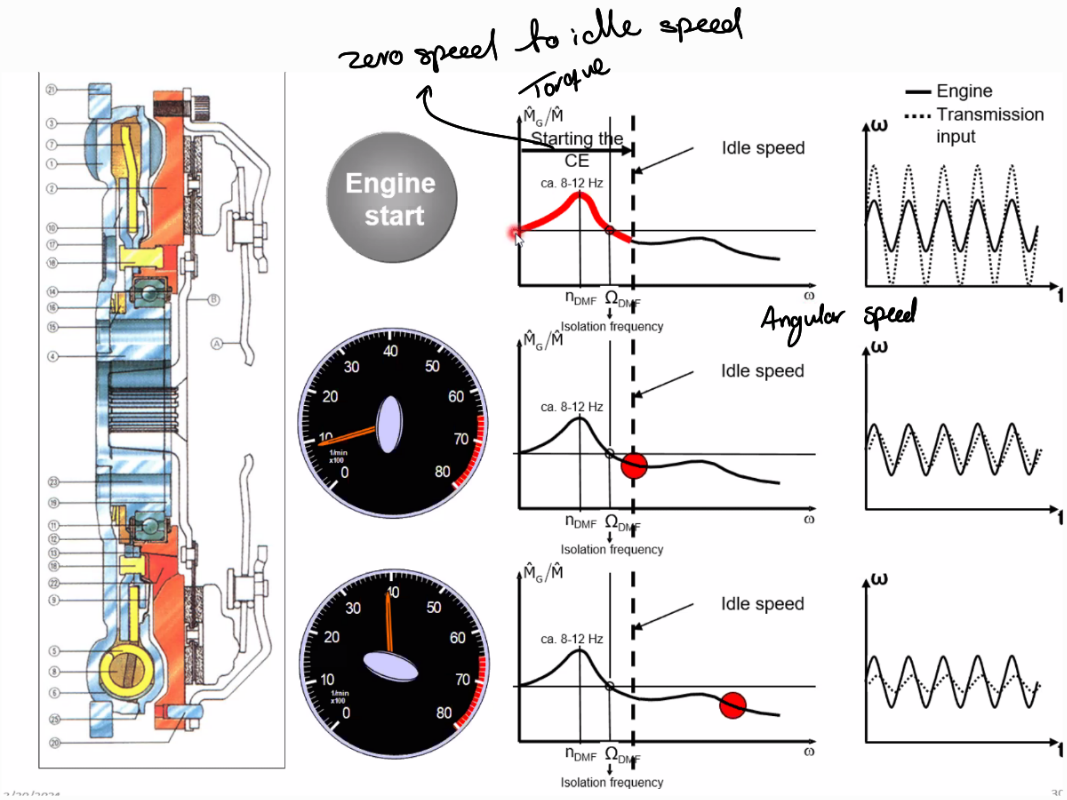
DMF Structure:

- The primary centrifugal mass is bolted interfaces with crankshaft. Together with a cover, it surrounds a space that forms the spring channel.
- The arc springs are in a spring channel. The slides ensure good passage through the spring channel. Grease packing in the spring channel reduces the friction between arc spring and slide.
- The torque is transmitted from the engine via flange



There is two spring stiffness





natural frequency في اكتر من

Flywheel - Resonance curve with/without DMF

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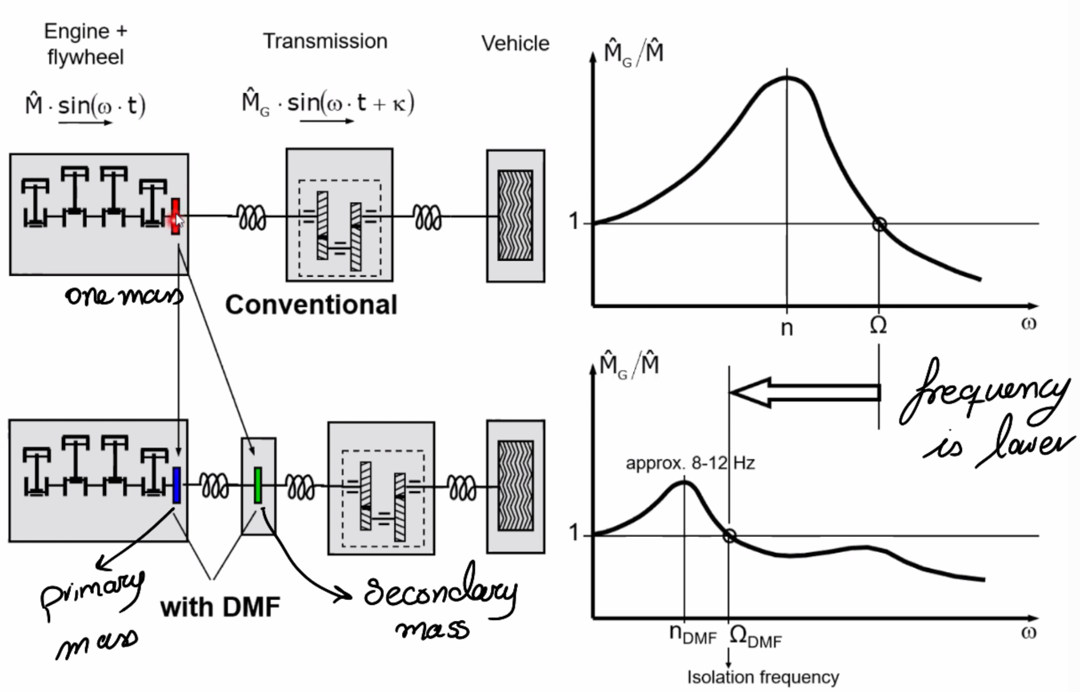
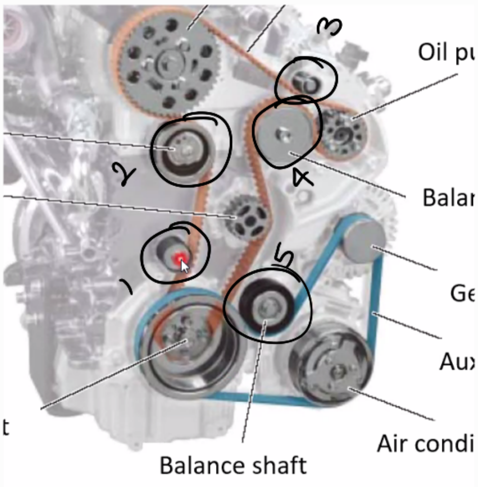
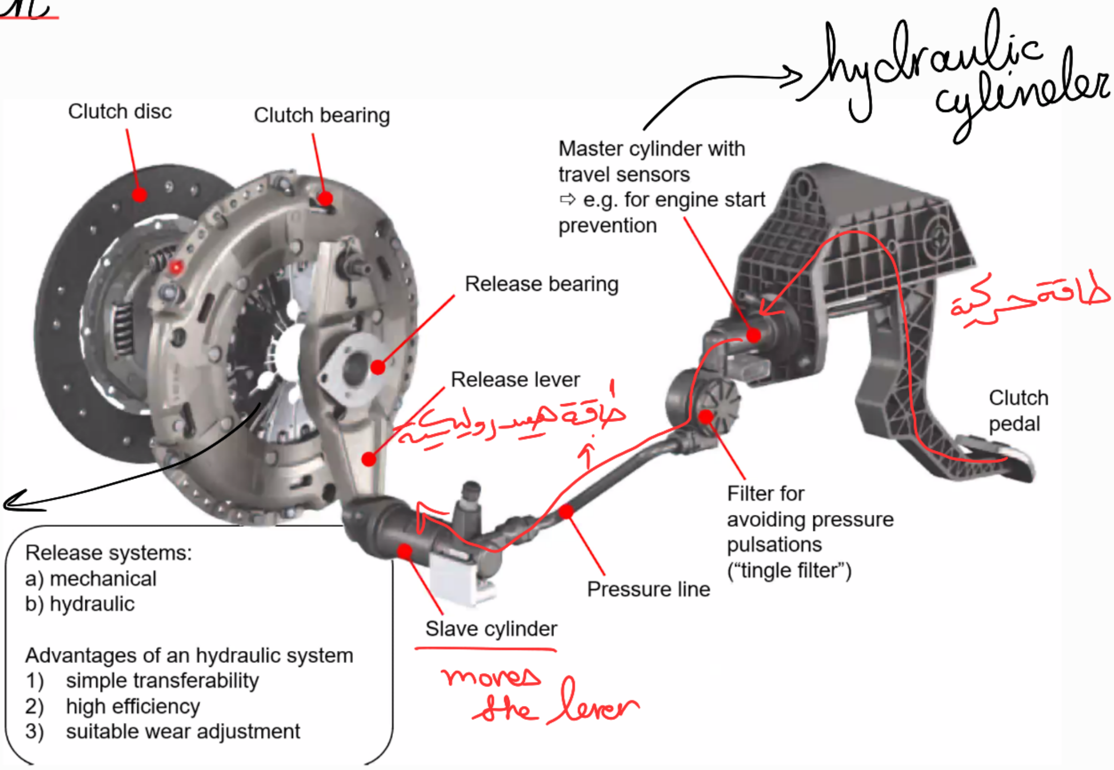


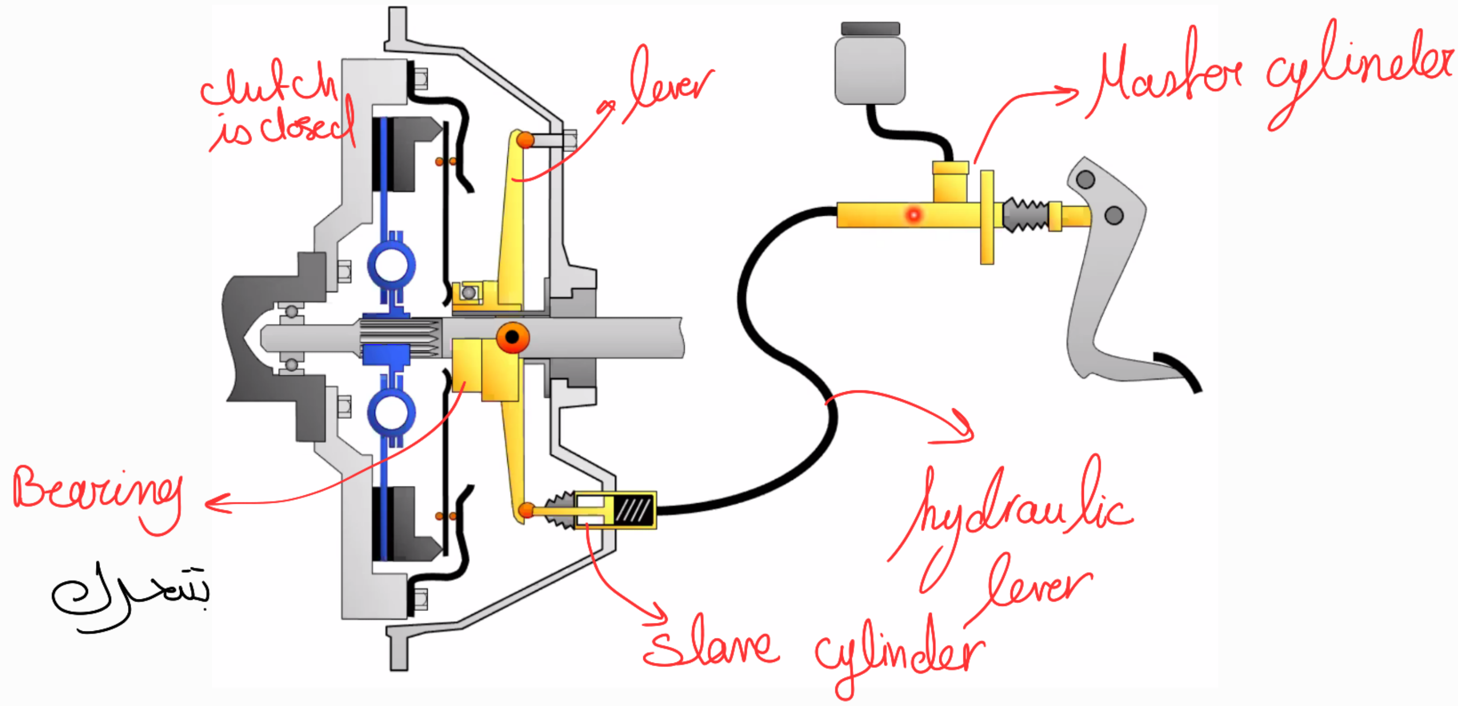
*we can reduce frequency using Balace shafts

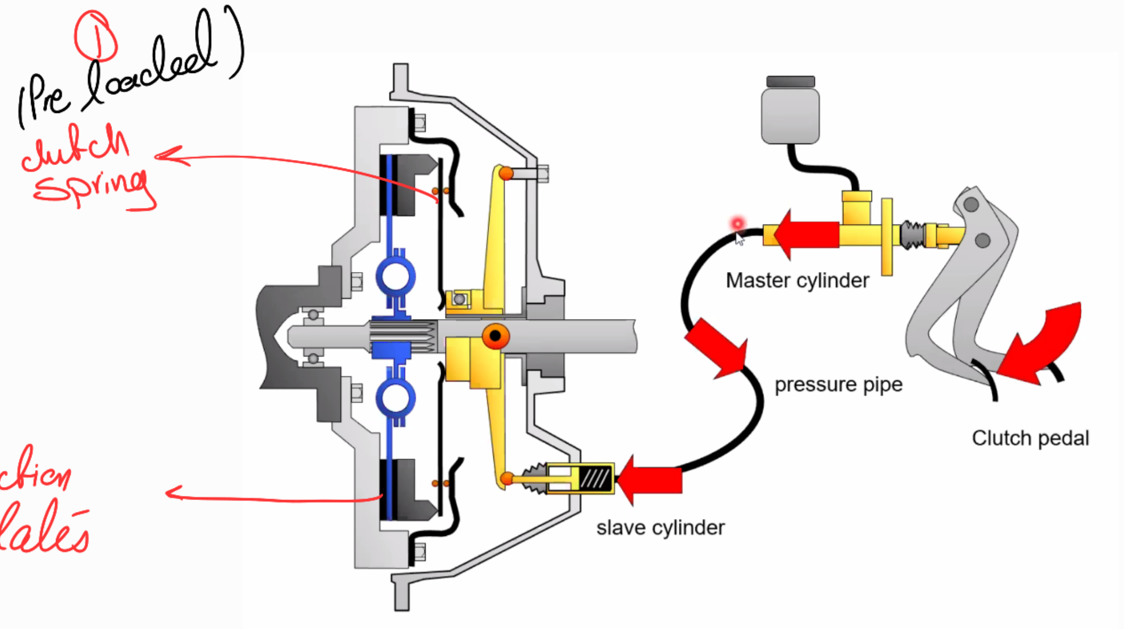


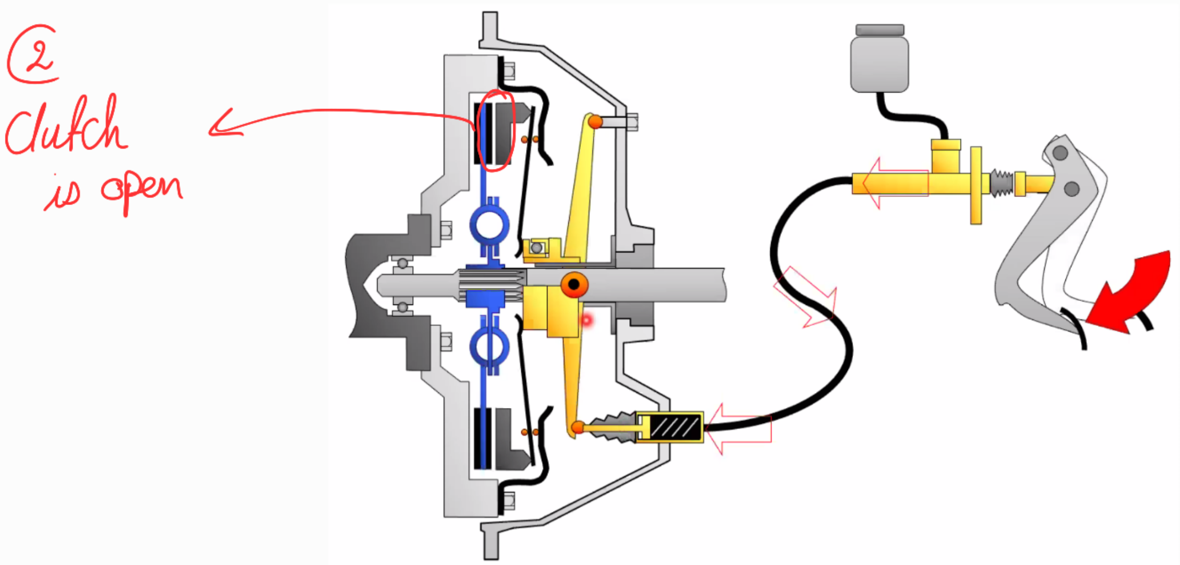
Clutch



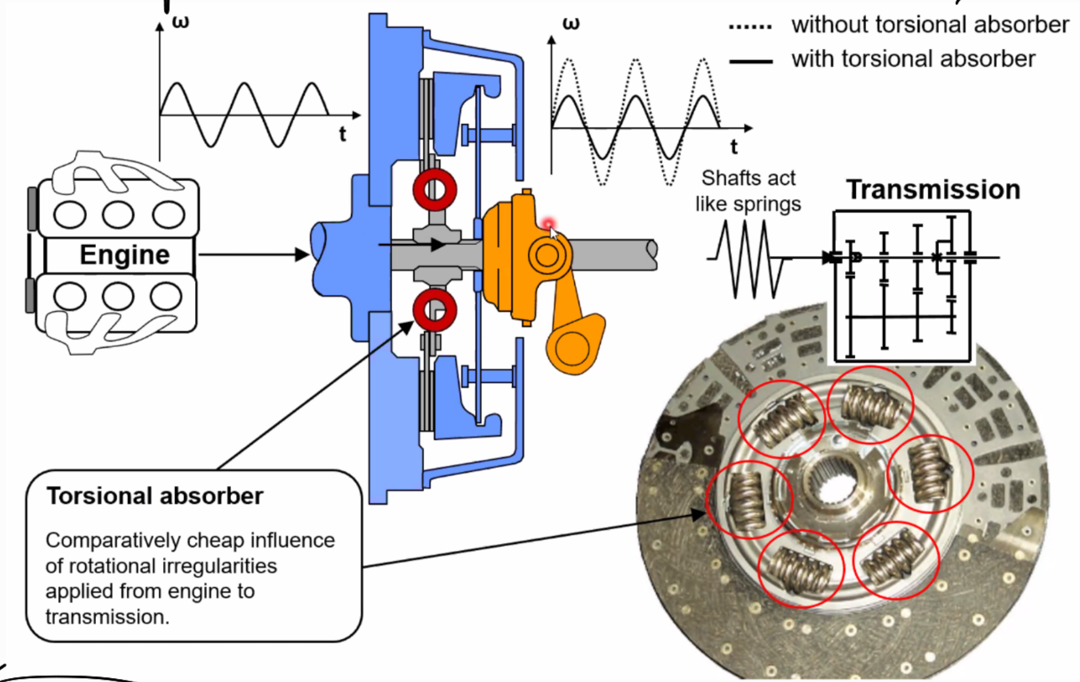
leave spring
تضغط لكي تفصل
ال clutch


clutch is closed
lever
Master cylinder
Bearing
تتحرك
hydraulic lever
slave cylinder


① (Pre loaded)
clutch spring
friction plates
Master cylinder
pressure pipe
Clutch pedal
slave cylinder


② Clutch is open

Torsion Damper (DMF مرحلة ثانية تجبر) vibration تقلل ال



No lubrication

Clutch - Dry Double Disc Clutch (with ceramic discs)

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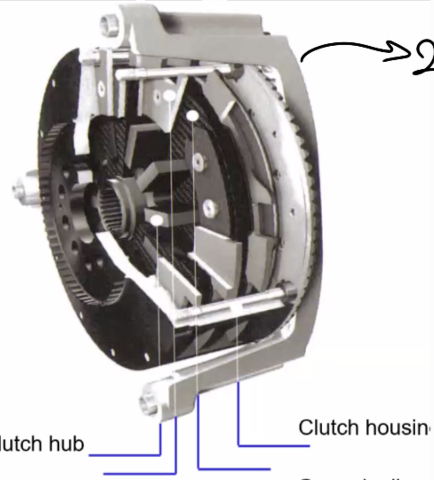
- Pure carbon is often used for race clutches, but with a very short service life (<15,000 km)
- Long service life possible with ceramic discs with carbon fibres (>100,000 km)
- Low vehicle centre of gravity possible due to small diameter
- Low clutch weight reduces the masses to be accelerated

Clutch data:
∅ 192 mm
length 58 mm
3.8 kg
(usually approx. 10-12 kg)

R_M



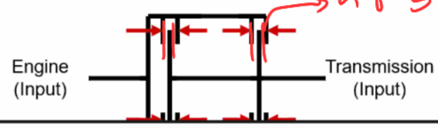
⇨ *High clutch torque despite low diameter: increase number of friction surfaces!*
Here: z=4 friction surfaces

As a reminder:

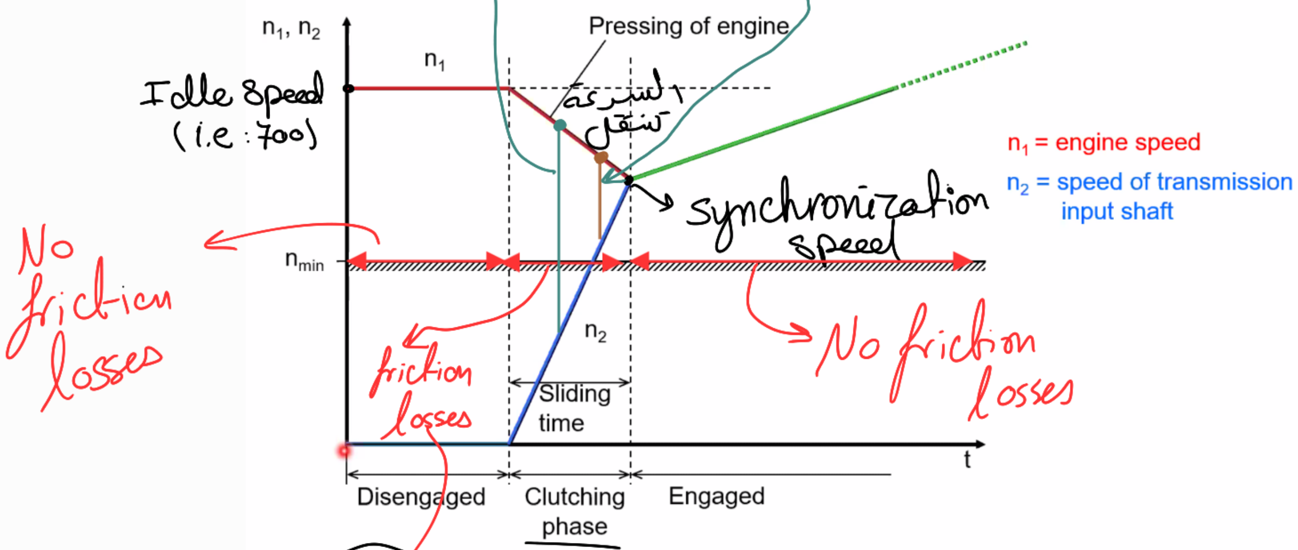
$M = \mu \cdot z \cdot F_N \cdot R_M$

Torque — friction coefficient — Normal force — mean Radius of clutch

Equivalent model:



Clutch – Driveaway Process with a Friction Clutch



How large is the frictional work during engaging?

عند رفع القدم

عند دعسة ال clutch

لتسكير ال clutch

وتربط الموتور

مع ال transmission

عند ازالة القدم يجب انه تكون ببطئ

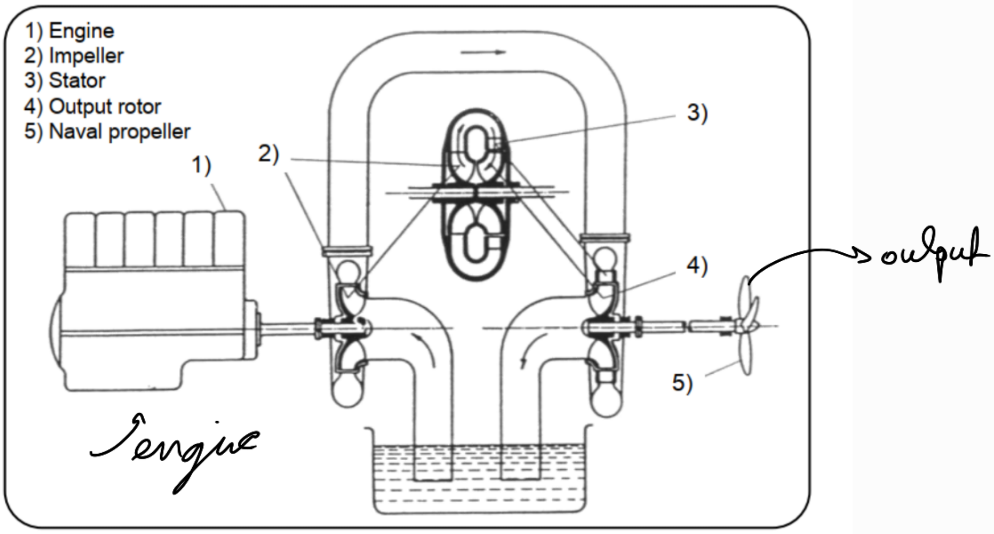
لكي لا يحصل shock الـ engine

$P = T \cdot \Delta W$

transmission torque

Friction losses at slope when accelerating could reach 40 KW

Torque Converter (Hydraulic Transmission)



The torque converter was invented in 1905 by Hermann Föttinger (Föttinger transformer).
It was the objective to create a reduction and reversing gear to link a high-speed steam turbine and a low-speed naval propeller.

The Trilok Converter

The joint venture Trilok (Spannhake, Kluge, Sandner) developed the corresponding Trilok converter.
It is an advancement of the Föttinger converter. The Trilok converter is characterised by fusing two phases, the

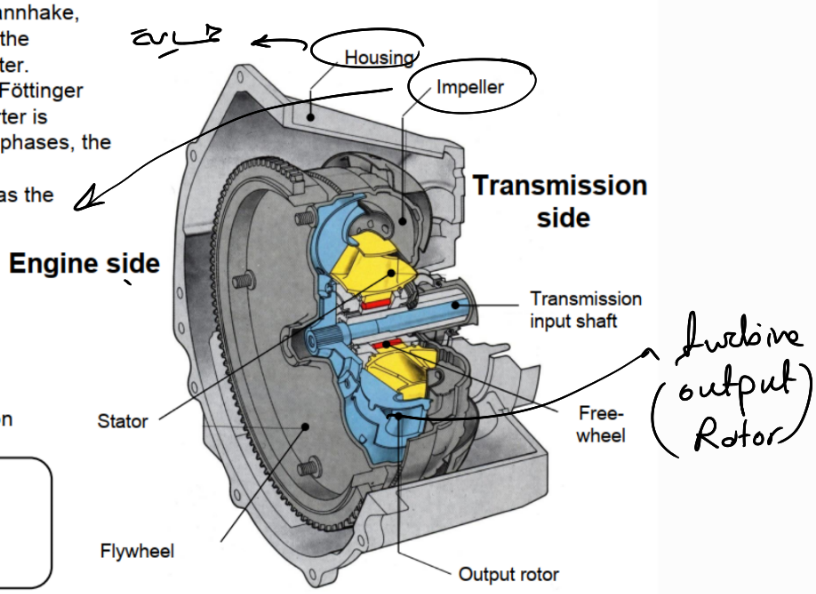
- torque conversion as well as the
- clutch function,

in one design. Thus, it is also called two-phase converter.

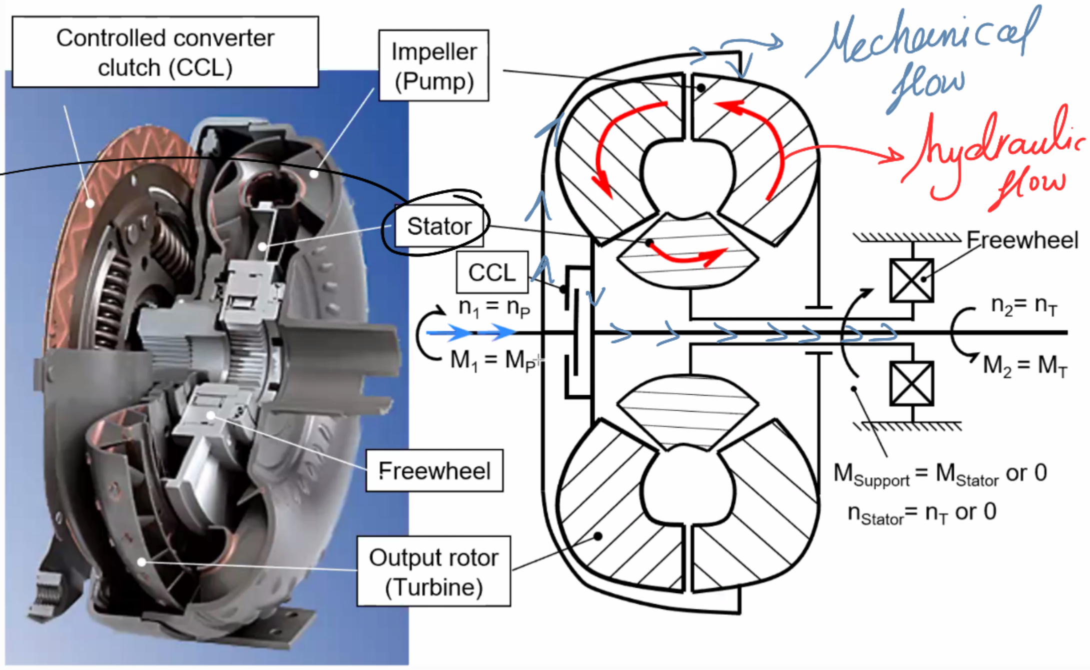
The stator is supported by a freewheel at the transmission housing.

Föttinger converter: torque converter

Trilok converter: speed/torque converter

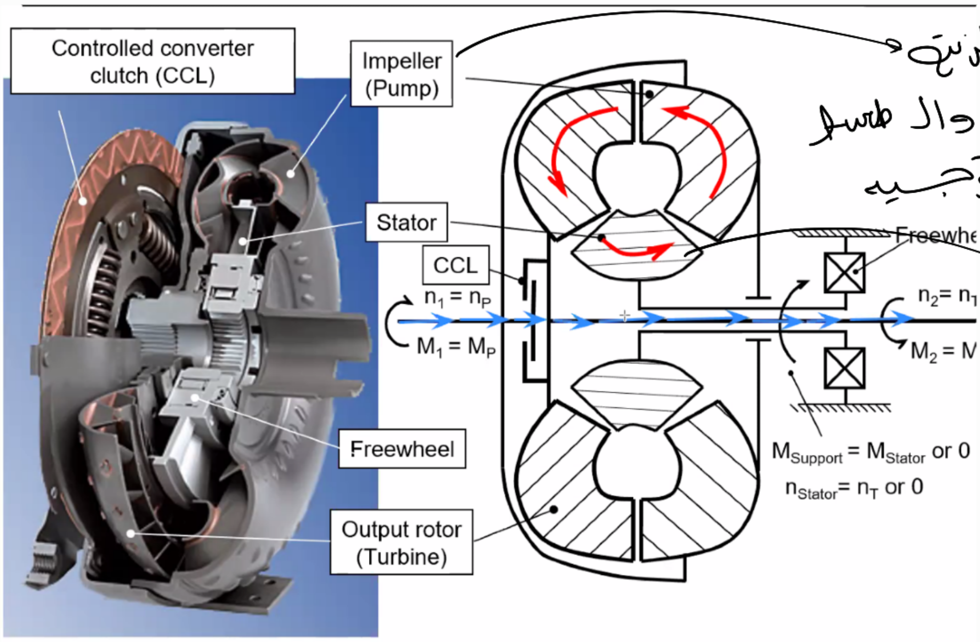


The Trilok Converter



يوجه الزيت من الـ Turbine للـ impeller يمنع خسارة الطاقة

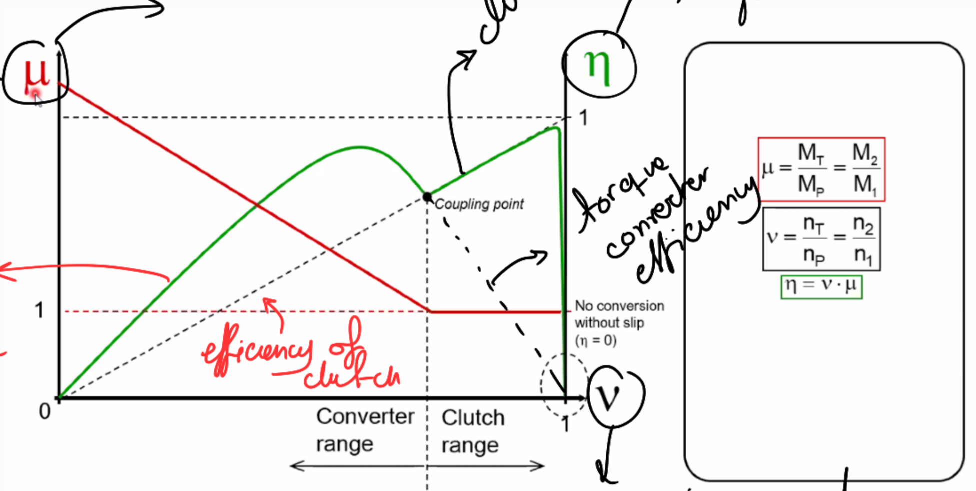
If the clutch is closed →



تدفع الزيت للـ turb والـ turb يعمل توجيه

اعادة توجيه من الـ turb للـ impeller

$n_{impeller} > n_{turbine}$



$$\mu = \frac{M_T}{M_P} = \frac{M_2}{M_1}$$

$$\nu = \frac{n_T}{n_P} = \frac{n_2}{n_1}$$

$$\eta = \nu \cdot \mu$$

μ Torque relation and torque peak (max. approx. 2.5)
ν Speed relation (0 to 1 in traction range, > 1 in thrust range)
η Efficiency

Controlled Converter Clutch (CCL)

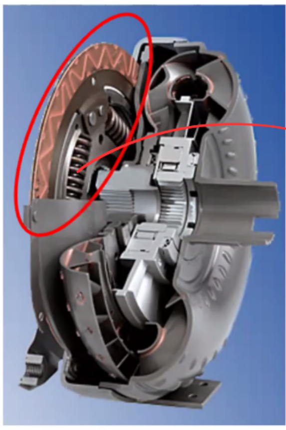
Characteristics of a CCL:

- Engine produces disturbing torsional vibrations which have to be damped
- These torsional vibrations can be damped very well by the converter without CCL, but with negative effects for the efficiency
- CCL provides for an adherence connection between engine and transmission
- Torsional vibrations are damped through CCL regulation:

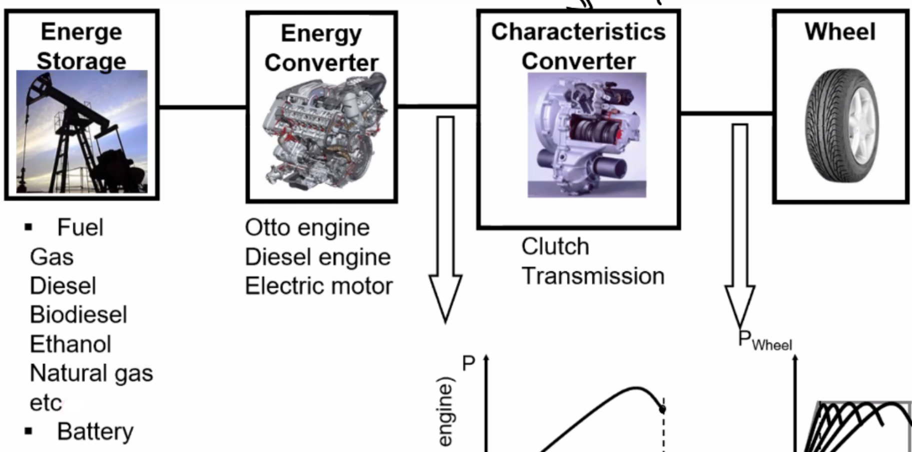
n_{ENG} < approx. 2000 1/min
intense torsional vibrations
CCL operates with a lot of slip

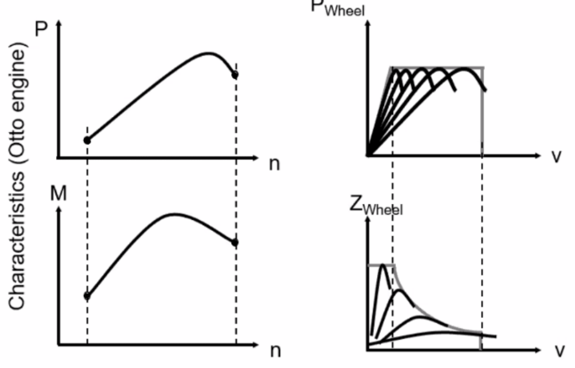
n_{ENG} > approx. 2000 1/min
less torsional vibrations
CCL operates with less slip

CCL = clutch + Torque converter



Transmission is here — speed & torque changing





Main tasks of transmission

- Determine engine speed during light throttle operation
- Determine the max engine speed
- Determine heavy throttle engine operating range
- Improve fuel usage

→ gear changing to reach Best efficiency point

Conflict Area Requirements

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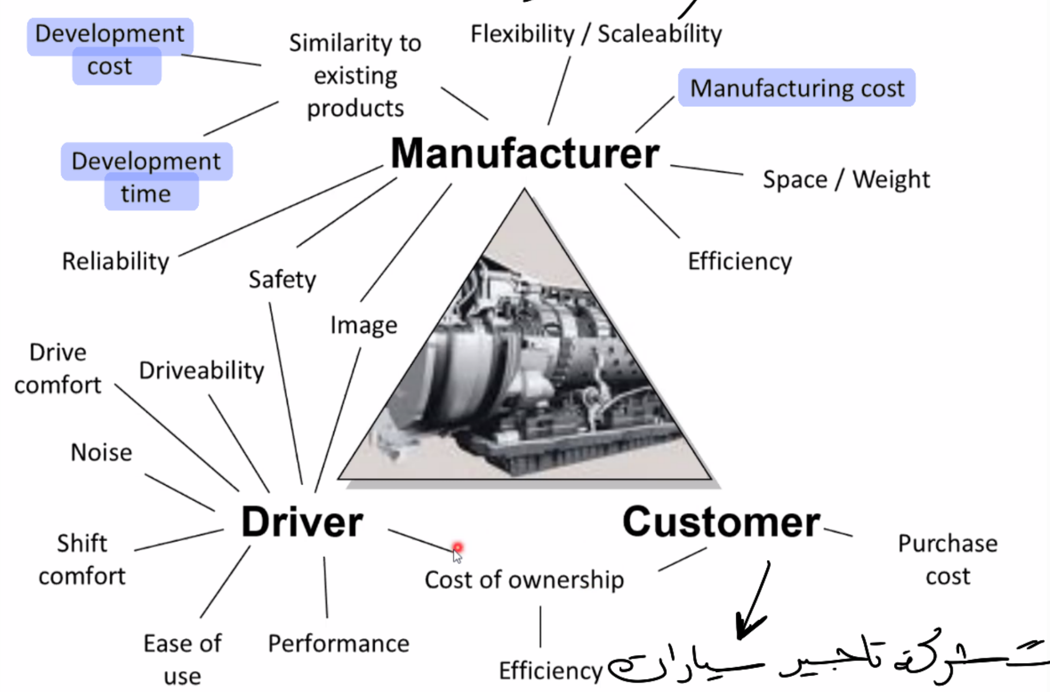


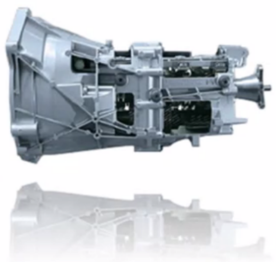
Ratio تغيير — يعني ق

مثلا شركة تأجير سيارات

Degree of automation
- semi-automated ← No clutch Control
- fully automated ← No gear control

Power transmission
- Mechanical
- Hydraulic → Torque converter / Closing & opening the clutch
- Electrical

Type
- Countershaft layout
- Planetary layout
- Single-range transmission
- Multi-range transmission



Interruption of traction
- with → in Manual gear
- without → in Dual clutch

Strategy of ratio adjustment

Stepped transmission
- Constant-mesh transmission
- Double-clutch transmission
- Synchromesh transmission
- Planetary automatic transmission

Continuously variable transmission
- Pulley-based transmissions
- Toroidal (friction wheel) transmission
- Hydrostatic transmission

• Conventional manual transmission (***MT***)	(5 to 6 gears)
• Automated manual transmission (automat. clutch and gear) (***AMT***)	(5 to 7 gears)
• Double Clutch Transmission (***DCT***)	(6 to 7 gears)
• Automatic Transmission (***AT***)	
conventional stepped AT (hydrodynamic converter + planetary transmission)	(3 to 9 gears)
• Continuously Variable Transmission (***CVT***)	(∞)

} Automated / No manual Gear shifting

Transmission Architecture & Case Design

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Powertrain Mounting

Powertrain mounts are used to isolate the vehicle occupants from the vibration of the powertrain.

- In general, the more compliant the powertrain mount, the better isolation it provides.
- However, increased compliance allows greater motion of the powertrain under engine load or due to vehicle and wheel motions. The more the powertrain moves within the engine compartment, the greater the clearance required to keep the transmission from contacting any adjacent components.
- mounts should be located at the node points of the powertain's fundamental mode shape to minimize the magnitude of transmitted vibration.
- As the magnitude of local vibrating motion is small near the node points, relatively stiff mounts can be used to reduce powertrain motion.

Transverse 4 moutings
longitudinal 3 mounting



Rubber

Vibration Damping

Powertrain Stiffness

Ideally, the mass and stiffness of the powertrain structure should be designed to place its natural frequencies above those of both the engine firing pulses and the crankshaft.

Transmission Bearings

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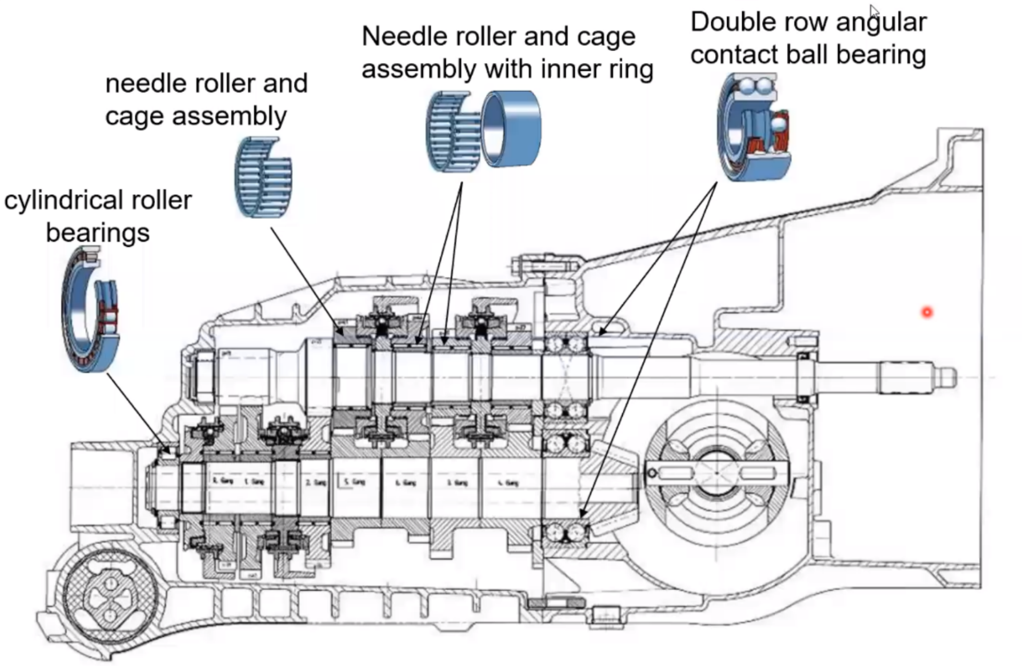
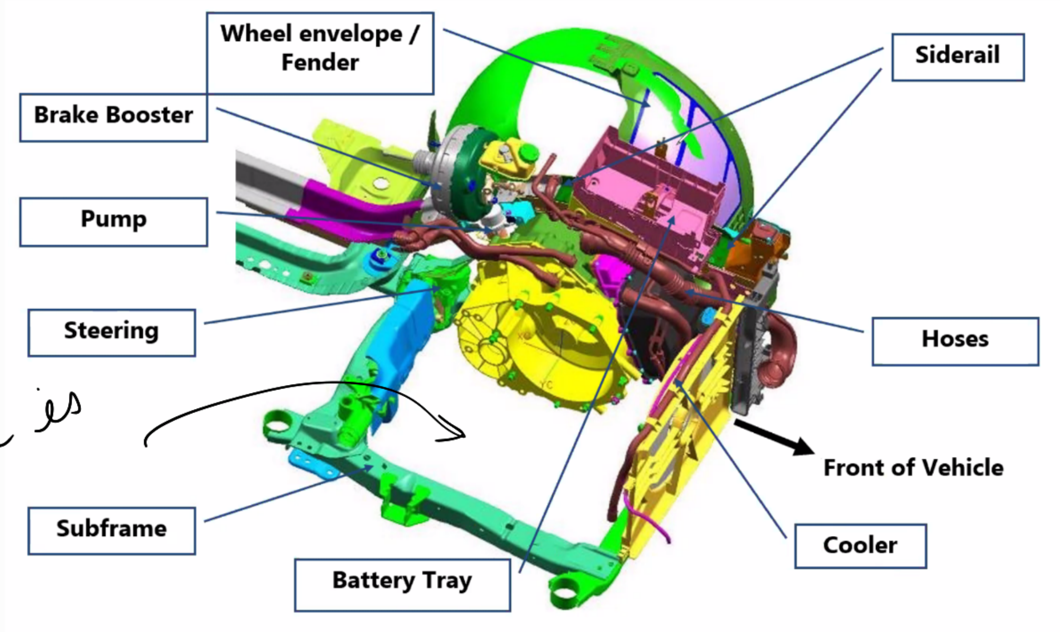




engine is here

Static Clearance

- **20-25 mm nominal position**

Dynamic Clearance

- 10 mm between components when the powertrain moves and/or the suspension travels to full jounce or rebound due to:
  - ⇒ shipping loads
  - ⇒ maximum acceleration, braking, or cornering
  - ⇒ driving over a pothole at high speed
  - ⇒ rocking vehicle free of mud or snow

Thermal Clearance

- 40 mm clearance is generally required between thermally sensitive components and exhaust manifolds or catalytic converters
  - ⇒ 25 mm clearance to a thin heat shield

تركيب فوق ال sensor

عشان لو اجزاء engine ما يصير عندي احتكاك وتآكل

if i used clearance is 25mm down to

Basic Engine Compartment Structural constraints

1 Front
- Electric Fan Motor(s)
- Radiator Frame
- Radiator

2 Rear
- Front Bulkhead
- Steering Rack
- Brake Master Cylinder
- Exhaust Pipe
- Cradle

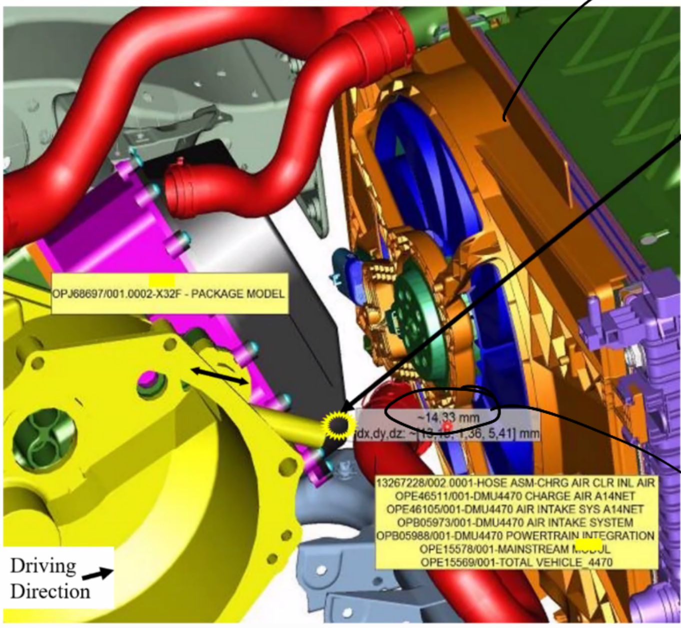
3 Top
- Hood Line
- Brake Master Cylinder
- ABS Module
- Exhaust Pipe
- Engine Block (Cylinder Banks)

4 Bottom
- Ground Clearance
- Sufficient Oil Sump

5 Sides
- Engine
- Mid-Rail
- Cradle
- Shock Towers
- Equal Length Half Shafts
- Radiator Hose Routing
- Battery

radiator

Detected packaging Issue



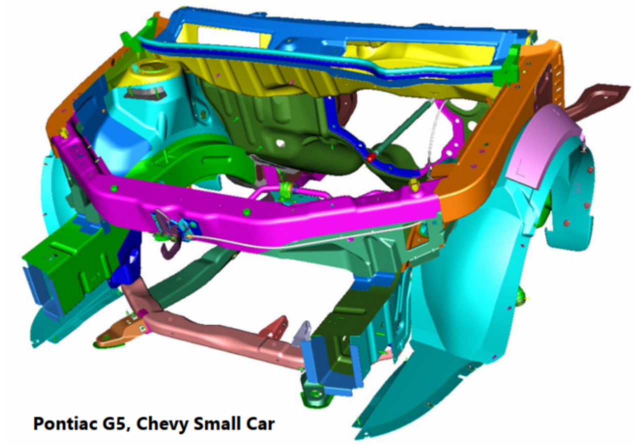
Insufficient distance to air duct
~ 14 mm

Static Clearance

- **20-25 mm nominal position**

clearance < 20-25mm

Packaging constrains – Engine Compartment



Pontiac G5, Chevy Small Car

مواد مختلفة

Drivetrain

MT – Comment on the construction of transmissions

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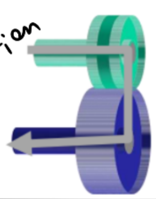
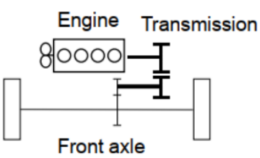
One-step transmission (opposite Direction)

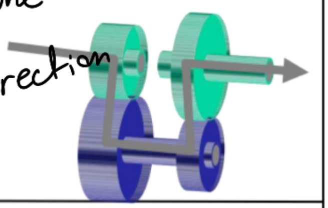


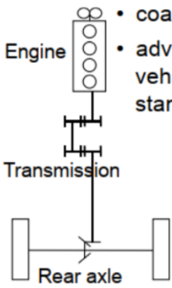
- no coaxial power flow
- advantageous for vehicles with front/transverse drive



↑ Driving direction

Two-step transmission (Same Direction)

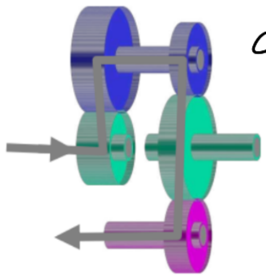




- coaxial power flow
- advantageous for vehicles with standard drive

↑ Driving direction

Multi-step transmission (opposite Direction)



- no coaxial power flow
- short structure
- advantageous as front and rear-mounted groups

symbols view

MT – Comment on the construction of transmissions

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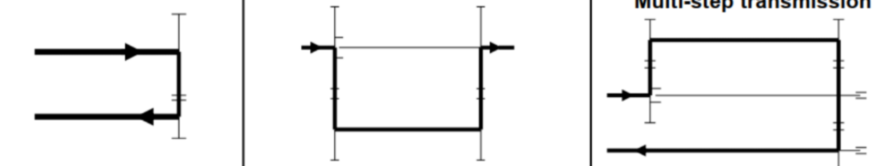
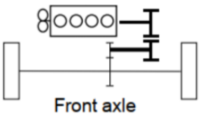
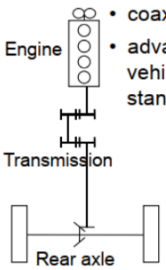
One-step transmission	Two-step transmission	Multi-step transmission



One-step transmission
- no coaxial power flow
- advantageous for vehicles with front/transverse drive



Two-step transmission
- coaxial power flow
- advantageous for vehicles with standard drive



Multi-step transmission
- no coaxial power flow
- short structure
- advantageous as front and rear-mounted group of CVs

↑ Driving direction ↑ Driving direction

MT – Forward and reverse gear

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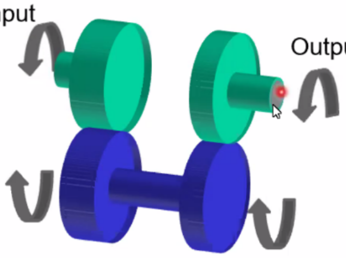
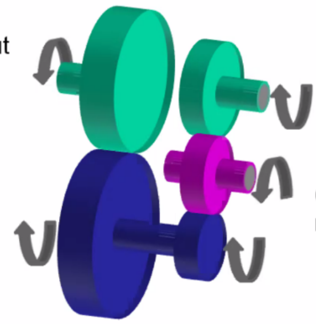
Forward gears



- 2x reversal of direction of rotation

Reverse gears



- 3x reversal of direction of rotation

Stationary, planetary & countershaft transmission

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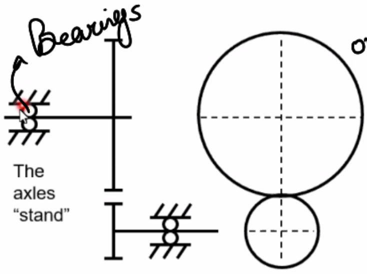
"Stationary" stationary (governor housing) rotation axes of all gears
"Planetary" the axles of the gears circulate

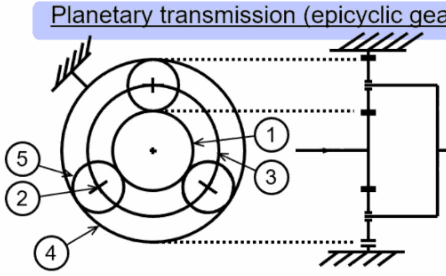
Rotation about fixed Axis

General motion

Stationary transmission



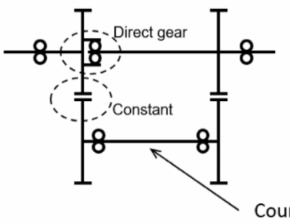
Planetary transmission (epicyclic gear)



1) sun gear 2) axis of the planet gear (circulating) 3) bar 4) internal gear 5) planet gear

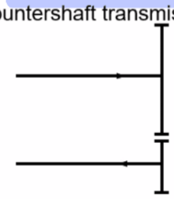
Automatic trans

Countershaft transmission



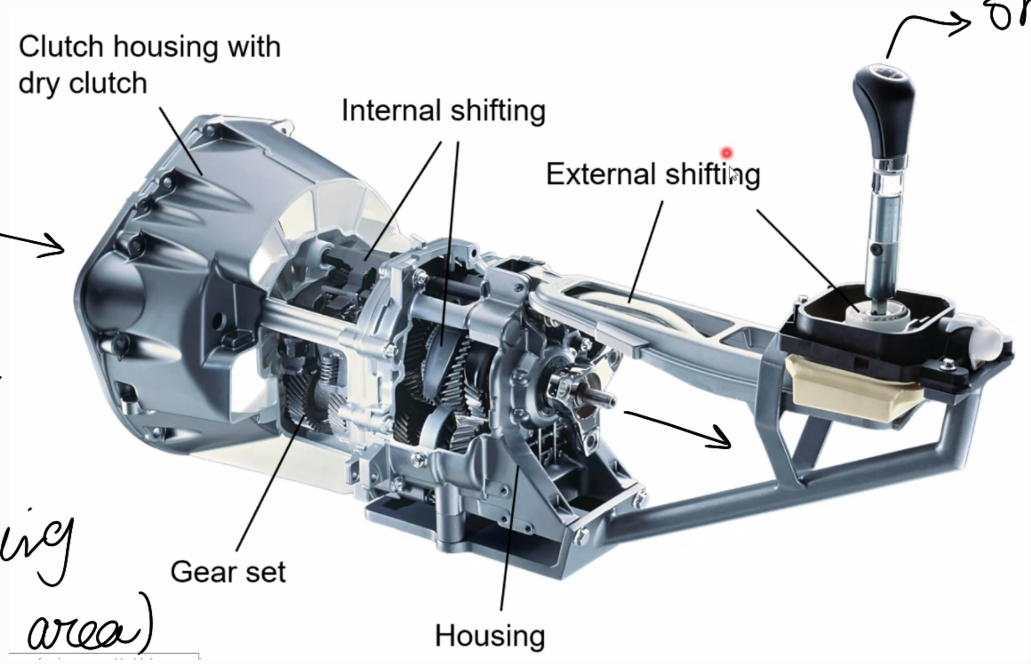
Countershaft transmissions contain:
- only one drive shaft
- only one output shaft
- one countershaft

One-step reduced countershaft transmission



Manual transmission

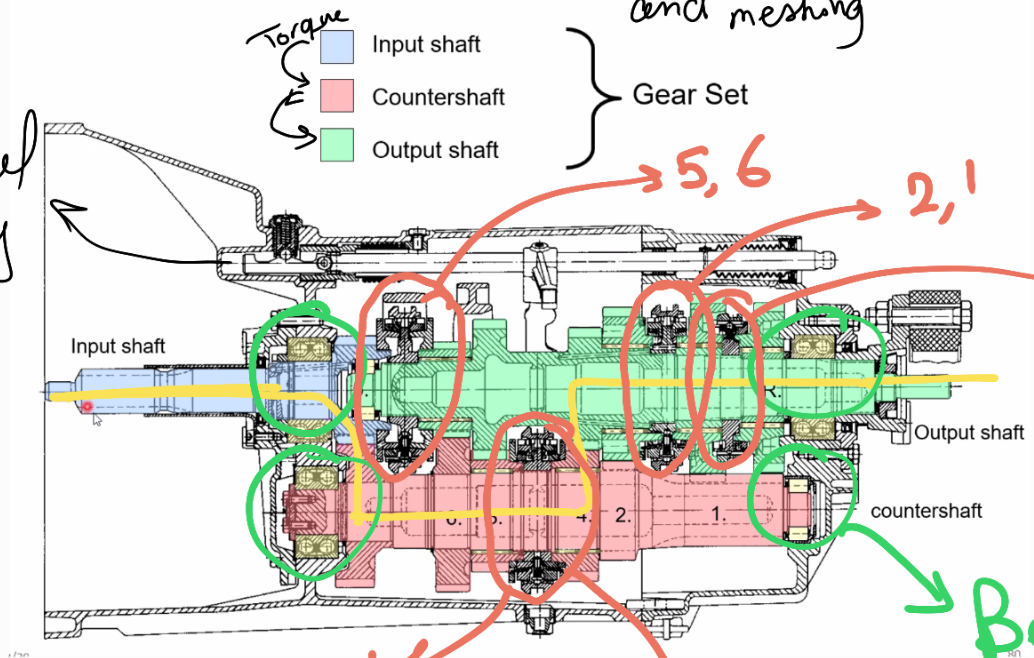
→ shift lever



fins are used for cooling (increase area)

- There are no sensors
- more reboost than automated حركات ميكانيكية
- very high transmission efficiency → Automatic needs power from engine
  losses because of lubrication and meshing

Gear set of a countershaft transmission



External shifting

5, 6

2, 1

R

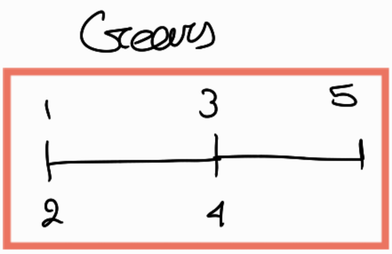
3, 4

Bearings

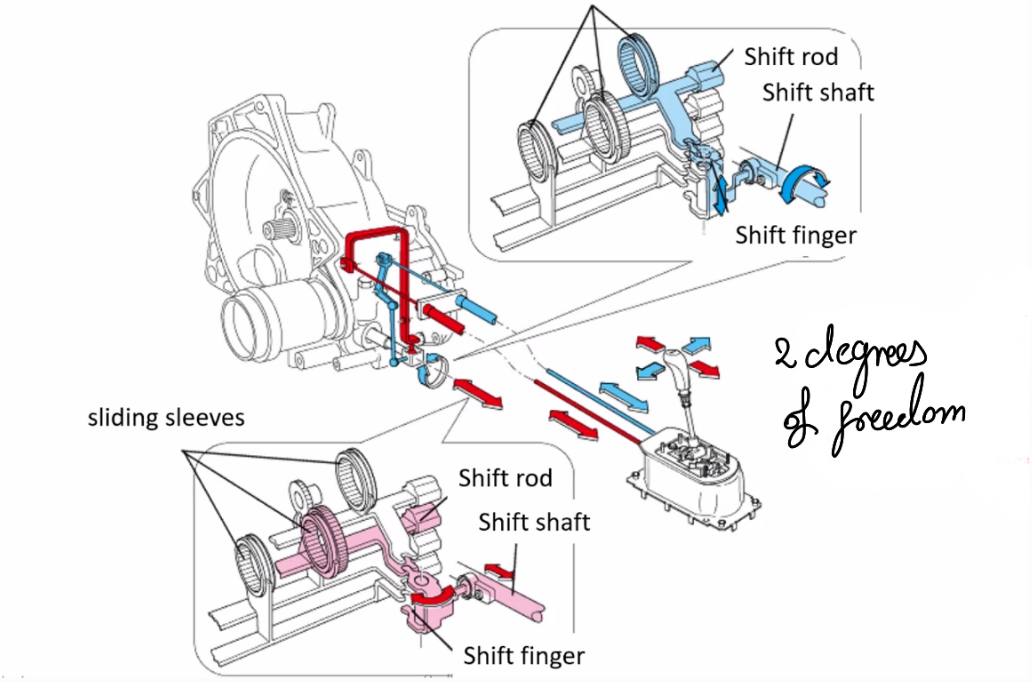
Gear 4 power flow

Synchronization mechanism

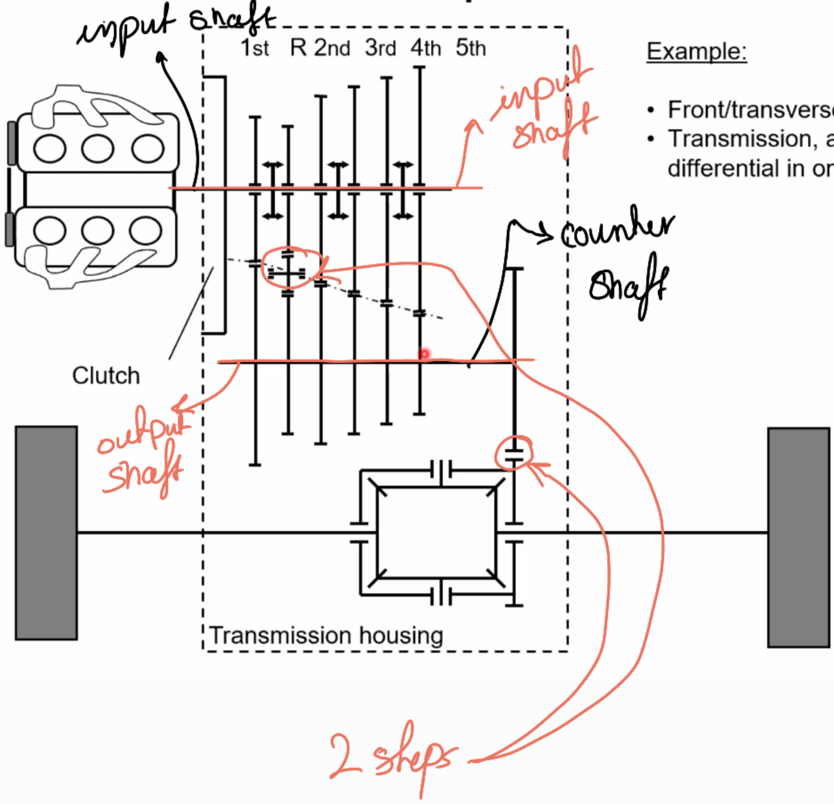
حركة عمودية
+ حركة أفقية



External shifting



front/transverse drive concept



Example:

- Front/transverse concept
- Transmission, axle drive and differential in one housing

MT for front/transverse installation

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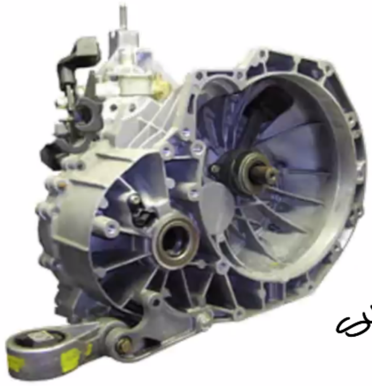

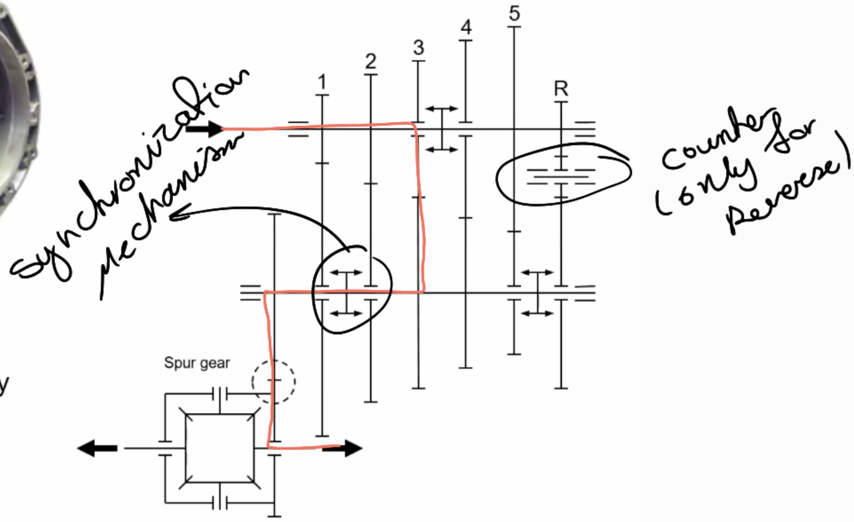

Ford Focus, Mondeo, Galaxy
(MTX 75 / VXT)

- Front-wheel drive; transversal installation
- 130 - 300 Nm

MT for front/longitudinal installation

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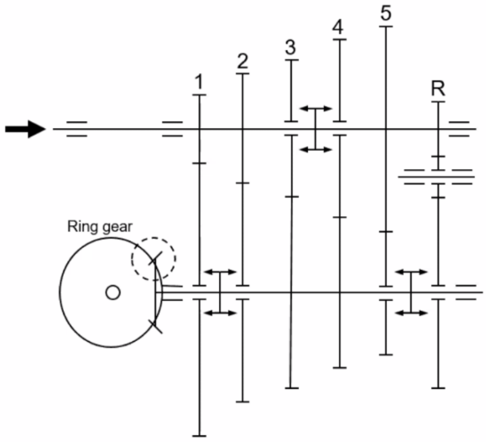
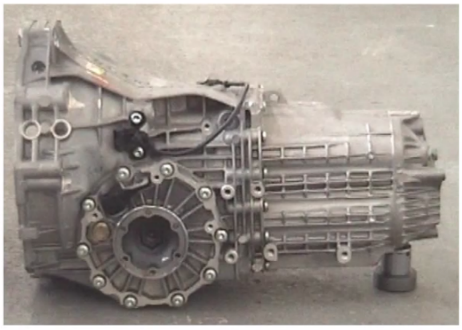




Audi A4, A6, A8 (front-wheel drive)
Front-wheel drive;
longitudinal installation

- 140 - 280 Nm (B80)

Porsche Carrera (rear-wheel drive)

- additional transmission step for reversing direction of rotation

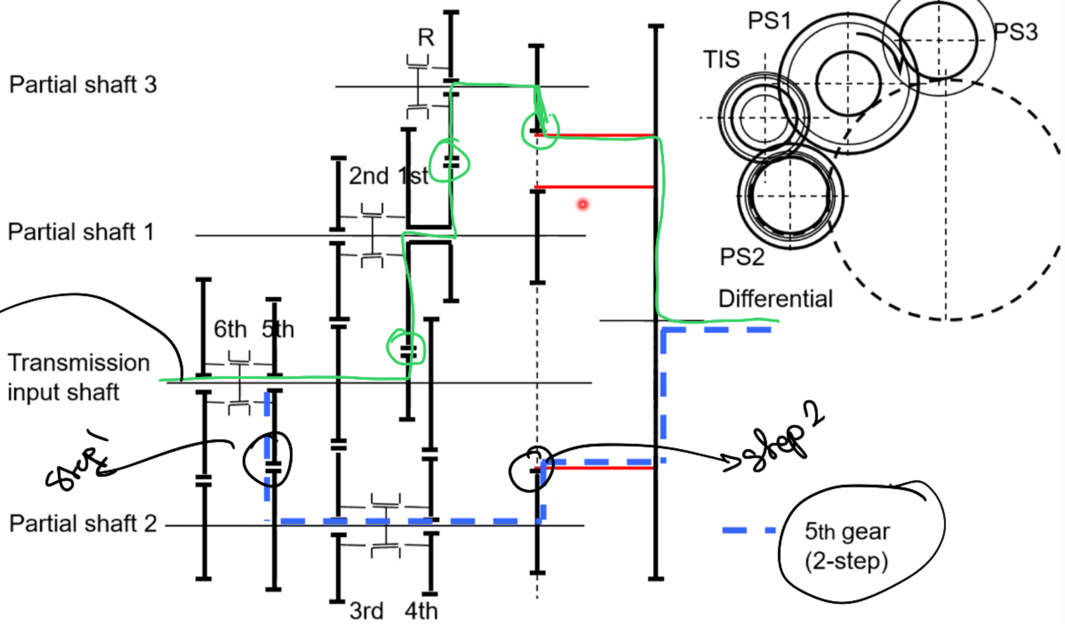
2 step

3step

front / transversal

Before is more efficient

i.e VW MQ500, 6-speed



1	2	3	4	5	6
4	3	2	1.3	1	0.8

Gear over drive

حركة العجال اسرع من حركة الـ engine

Two-step countershaft transmission in a standard drivetrain

جامعة بيرزيت
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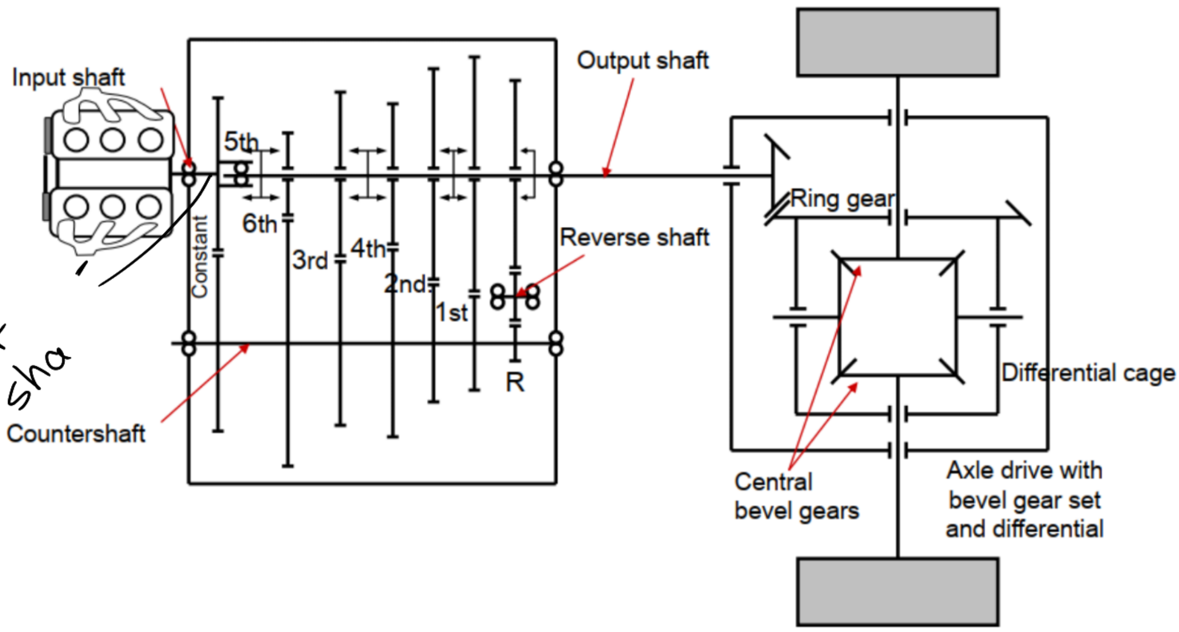
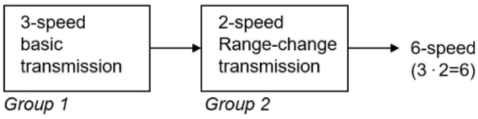
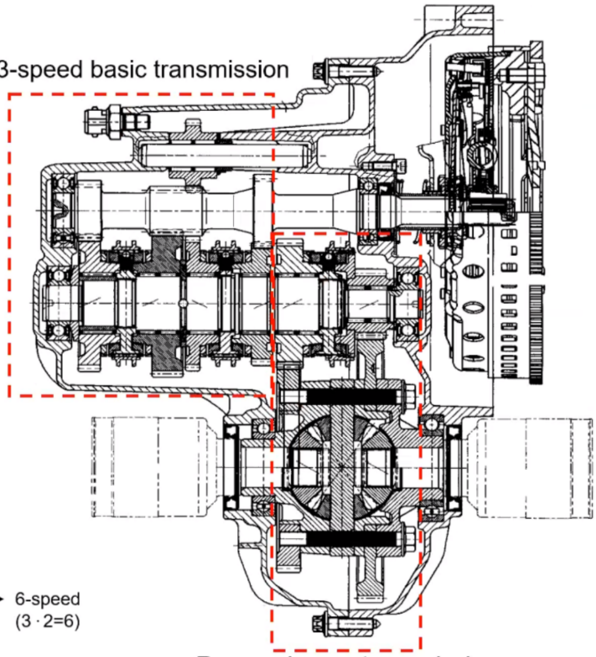


Multi-range-change transmission (Smart)

- 6-speed
- Two-range-change transmissions
- Geometrical gear stepping
- Basic transmission:
  3 shift wheels for forward gears
  1 shift wheel for reverse gears
- Range-change transmission
  (= axle drive)
  2 "shiftable" transmission
  ratios > 1!
- Simple cone synchronisation

Principle design known from lorry sector:





Multi-range-change transmission (Smart)

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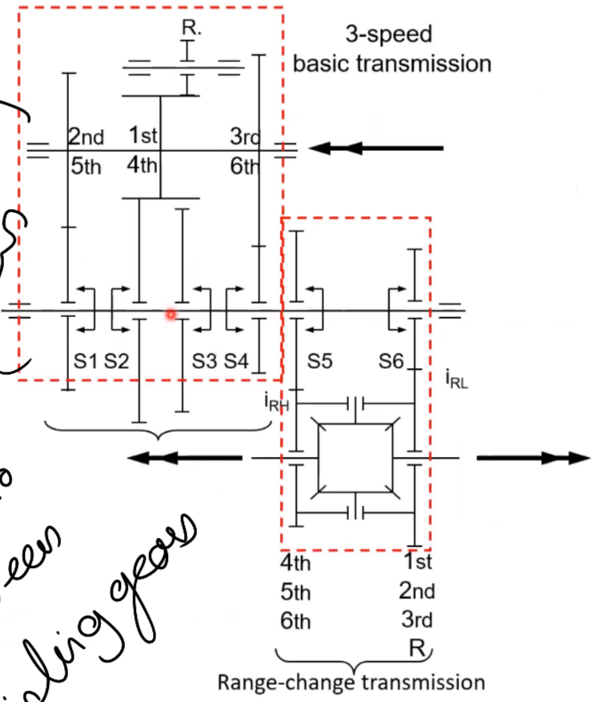


- 6-speed
- Two-range-change transmission
  3-speed main transmission + range-change unit (with i_{RH}, i_{RL} > 1)
- Geometric gear stepping
- 3 shift wheels for forward gears
- 1 shift wheel for reverse gears
- 2 "shiftable" axle drive transmissions
- Simple cone synchronisation
- Al-die casting

	Basic transmission				Range-change	
Gear	S1	S2	S3	S4	S5	S6
1		X				X
2	X					X
3				X		X
4		X			X	
5	X				X	
6				X	X	
R			X			X

Fixed gear
Sliding Gear
مش بس هو اللي بيتحرك
Synchronizatio is Between Two Sliding gears

Synchronization

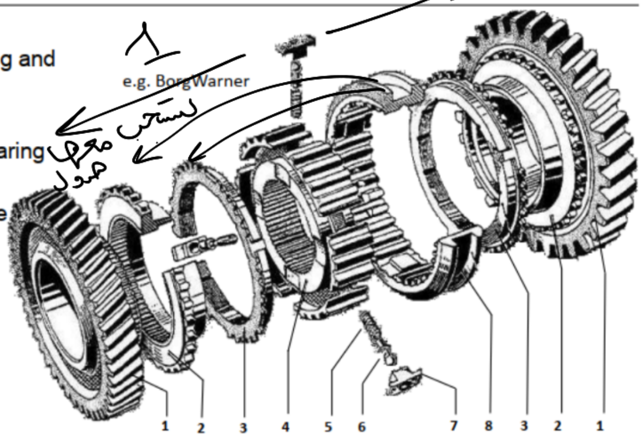
Main functions:

a) Adapting the speed as well as accelerating and decelerating masses (0.1 to 0.3 s)

a) Detecting equal peripheral speed of the components to be synchronised by comparing speeds by means of friction

c) Applying the positive engagement with the new sliding gear *after* adapting the speed

d) Generating positive engagement and power flow



1: Shifting gear / transmission gear

2: Synchronising cone (clutch body)

3: Synchronising ring

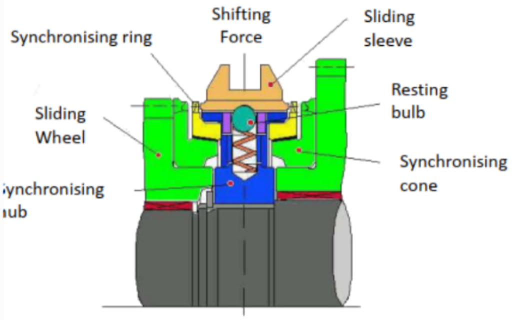
4: Synchronising hub (synchronising body)

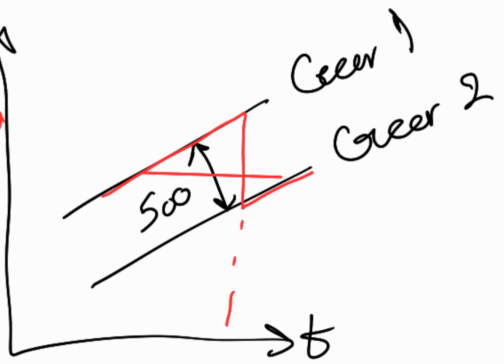
5: Pressure spring

6: Resting bulb

7: Pressure pieces / pre-synchronising unit

8: Sliding sleeve





Synchronization

Jerk

Phase of synchronization

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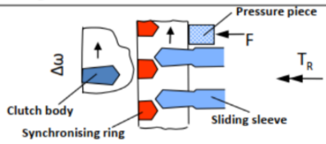
1



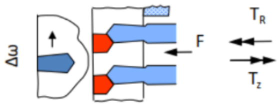
Pre-synchronisation

Synchronising ring is turned to locking position

Before the gearshift process starts, the sliding sleeve is held in the middle position by the locking elements. The gearshift force generates the axial movement of the sliding sleeve, which pushes forward the synchronizer ring against the friction cone gear wheel. The speed difference between the gear wheel and the synchronizer ring causes the rotation of the synchronizer ring.

بين سرعة الـ sliding sleeve و ring

2



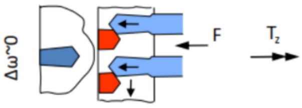
Synchronisation

(1st increase of force, 1st pressure point)

This is the main phase of the speed synchronization. The sliding sleeve is pushed further, which brings the internal splines (teeth) of the sliding sleeve and the teeth of the synchronizer ring into contact. In this phase, the friction torque starts to counteract the inertia torque and the speed difference starts to decrease.

T_R: friction torque between the synchronizer ring and friction cone
T_Z: inertia torque of the input shaft, gears and clutch secondary mass

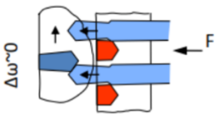
3



Unlocking

The gearshift force is kept on the synchronizer ring through the locking elements and the sliding sleeve. When speed synchronization has been achieved, the friction force is reduced to zero and the synchronizer ring is turn back slightly.

4

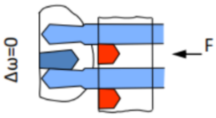


Shifting through and engaging

(2nd pressure point)

The sliding sleeve passes through the teeth of the synchronizer ring and comes into contact with the locking toothing of the gear wheel.

5



Switched-on

The sliding sleeve has completely moved into the locking toothing of the gear wheel. Back tapers at the teeth of the sliding sleeve and the gear wheel locking toothing avoid decoupling under load.

T_R: friction torque between the synchronizer ring and friction cone
T_Z: inertia torque of the input shaft, gears and clutch secondary mass